



Cluster Report
Optics and Photonics
in the Capital Region Berlin Brandenburg



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1.1 Welcoming Address

The German capital region is one of the most innovative regions in Europe and occupies a leading position in many forward-looking technologies. Optics and photonics are two of the key industries in Berlin Brandenburg. As technology drivers, they make an outstanding contribution to the further development of the capital region as a high-tech and industrial location. They are creating added value and securing jobs for the regional market. And there is a close cooperation in these sectors under the umbrella of the Berlin Brandenburg cluster established in 2011 to include both optical and microsystems technologies. The cluster includes a well-integrated network of universities and research institutes as well as a large number of innovative technology companies. Its participants are supported by such professional associations as OpTecBB e.V., the largest network for optical technologies in Germany, which is involved as a direct partner in managing the cluster in the states of Berlin and Brandenburg.

Optics, mostly seen today as a scientific discipline, combines classic optical technologies, such as the manufacture of optical elements and devices like lenses, microscopes and eyewear. Photonics describes the “science of light particles” and has established itself in recent years as a collective term for new optical technologies. Whether lasers or LEDs, fibre-optic networks, displays, and cameras, optical transmitters and receiver chips, or the entire field of optical metrology from sensors to X-ray technologies, all of these are a part of photonics, one of the central technologies of the 21st century. In recognition of the importance of photonics for Berlin Brandenburg, the German name of the optics cluster was changed to the Photonics Cluster in 2017. The policy focus on optics and photonics has given the states of Berlin Brandenburg a unique selling point in the competition among regions. The capital region is ideally equipped to react flexibly to major economic trends such as digitalisation, Industry 4.0, smart cities, and autonomous driving.

Optics and photonics as key technologies are also strong drivers of innovation in many other industries and service sectors – especially when it comes to the implementation of new digital technologies. “Green photonics” is becoming increasingly important: modern lighting applications, especially in combination with microelectronics, offer high energy and resource efficiency that is making an important contribution to a sustainable and environmentally friendly economy. This can be used, for example, to develop solutions in the fields of energy, the environment, health, and

nutrition. In Brandenburg and Berlin, companies are already active in the field of green photonics, creating innovative systems that will help solve some of the challenges facing the world.

The states of Berlin and Brandenburg recognised the potential of optics and photonics as a key technology and the region’s strengths in these fields early on. They integrated the optics cluster into their joint innovation strategy for intelligent regional specialisation in 2011. The goal is to expand and strengthen the region’s leading position on both the German and international innovation landscapes.

This Cluster Report is dedicated to the success story of optics and photonics. It gives an overview of what’s happening on many fronts in these important industries while also highlighting the two states’ tremendous potential in these fields.



Ramona Pop
Senator for Economics, Energy
and Public Enterprises, the State
of Berlin



Prof. Dr.-Ing. Jörg Steinbach
Minister for Economic Affairs and
Energy, the State of Brandenburg

1.2 Editorial

“When it comes to optics and photonics, Berlin Brandenburg is certainly already in second or third place in the world, behind Silicon Valley and the Tokyo region.”

Prof. Dr. rer. nat. Martin Schell

Interview with Photonics Cluster Spokesman, Prof. Martin Schell

Prof. Schell, in October 2017 you became the new chair of the board for OpTecBB e.V. and spokesman for the Berlin Brandenburg Photonics Cluster. How do you assess the work of the cluster in recent years and the current state of the optics industry in Berlin Brandenburg?

The Berlin Brandenburg Photonics Cluster has seen considerable growth in recent years. For that, I would like to thank in particular my predecessor, Prof. Tränkle, for his hard work the past six years. In the early days of the cluster, he managed to give optics and photonics in Berlin significantly improved visibility in the region. This has helped us a lot. Internationally, the industry is now aware of the importance of Berlin Brandenburg as a business location.

Another great success for the region has been the Research Fab Microelectronics Germany established by the Federal Ministry of Education and Research at the beginning of 2017. Investments of 350 million euros for this project went into microelectronics and photonics, whereas 117 million euros have been invested in Berlin Brandenburg.

This sum is largely being used for photonic technologies at the IHP GmbH – Innovations for High Performance Microelectronics, the Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH), the Fraunhofer IZM, and the Fraunhofer HHI.

What do you expect to see over the next five to ten years? Which topics will become more important; what should be tackled and promoted?

The growth in optics and photonics has largely been driven by the use of fibre optic to transmit data on the Internet. In the years to come, many other optics-based technologies will come to the fore, such as the quantum technologies. The optical sensors that are needed in self-driving cars will need to be further developed. Medical sensors with optical

technologies will allow the practice of personalised medicine. All these are topics requiring a lot of research and development and I think that the Berlin Brandenburg Cluster is in a very good position to take the lead.

In your opinion, which aspects of the cluster should carry on and where is there room for improvement?

The Berlin Brandenburg Photonics Cluster is functioning quite well, but there is still room to develop our public relations and web presence. We also need to integrate new topics such as quantum technology and consider them in our work. Otherwise, I am very pleased to be able to build on Prof. Tränkle’s successful work.

Knowledge transfer: using the results of research commercially. How can patents, products, companies, and employees be kept here in the region? Do you have a good example you could share?

The work of the OpTecBB e.V. helps interested researchers make contact with potential employees on the market at a very early stage. These early connections later make it easier to evaluate market opportunities and find partners for commercialisation. In addition, Fraunhofer has founded the Berlin Center for Digital Transformation to support the economic exploitation of research.

A good current example from Berlin is the start-up Sicoya, which is working on the commercialisation of silicon photonics. This project was developed at TU Berlin and has made the leap from research to start-up.

The coming digitalisation of many areas of life is an essential topic for the entire world to address. How do you assess the potential for optical technologies and photonics and what possible projects do you see for the region?

Digitalisation and photonics are not limited to data transmission via fibre optic. 3D sensor technology, for example, digitalises objects for quality control or replication. 3D printing

uses scanning lasers to create objects and is now finding its way into the private sector. The self-driving car will only really be possible by digitalising the environment, for example, with the help of the LiDAR optical radar. Although many people are unaware of this, the fibre-optic cables commonly used for data transmission nowadays can be intercepted by relatively simple means. There are optical ways to prevent or at least detect this. In the distant future, there may be a quantum computer based on photonics that will significantly surpass the power of today's computers.

I think that, with a dense, yet broad research landscape and about 400 SMEs working in these fields, Berlin Brandenburg will be very well positioned, indeed. The future world market leader for one of these topics could easily come from the capital region.

International attractiveness of the region for companies and employees: How attractive is the region and what can be done to make it even more attractive to companies and employees?

I think that Berlin Brandenburg is already second or third in optics and photonics, behind Silicon Valley and the Tokyo region. Our international visibility is already quite good, thanks also to the support of Berlin Partner and joint booths at trade shows. These stands have quite a reputation at the fairs and are popular with visitors. They help to achieve a visibility and attractiveness that we couldn't achieve on our own.

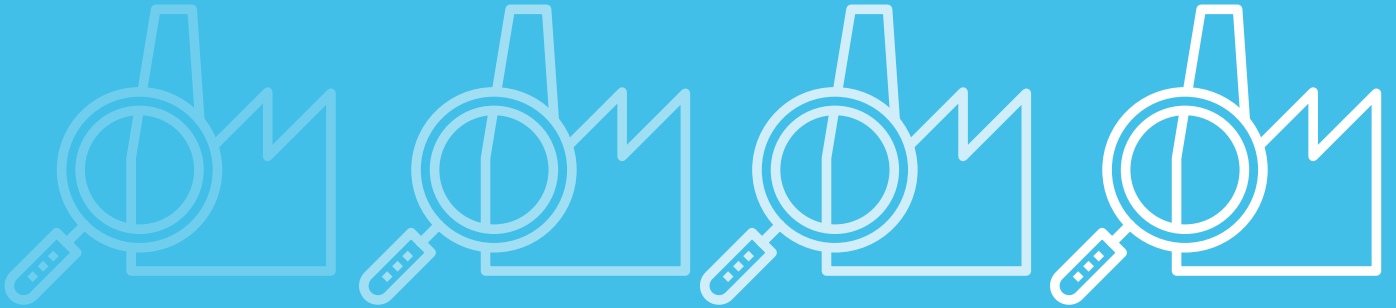
Interview conducted by Markus Wabersky

VITA

After positions at the University of Tokyo, in management consulting (Boston Consulting Group), and in industry (Infineon Fiber Optics), Martin Schell now heads the Fraunhofer HHI in Berlin together with Prof. Wiegand. He is Prof. for Optoelectronic Integration at TU Berlin, a member of the board of the European Photonics Industry Consortium (EPIC), chairman of the board of the industry association OpTecBB e.V., member of the board of stakeholders of the European technology platform Photonics21, and a member of the public policy committee of the Optical Society of America.



Prof. Dr. rer. nat. Martin Schell
© Die Hoffotografen GmbH Berlin



2 Research and Industry



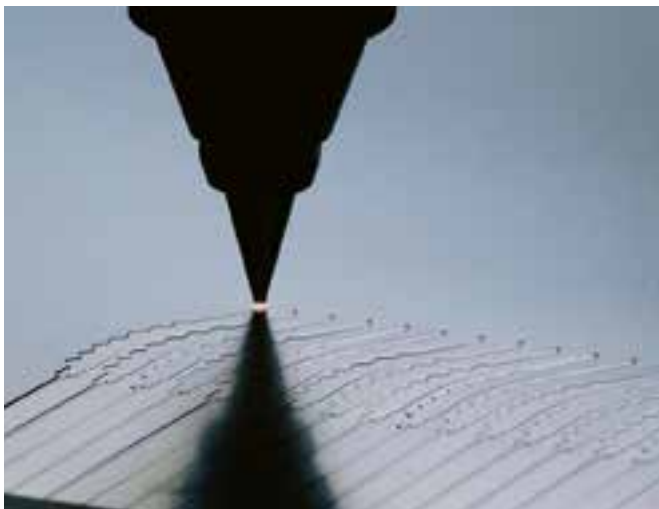
2.1 Laser Technology – Cutting, Welding, and Measuring with Light

“The laser has become a multipurpose tool used in manufacturing and is also a key component in medical, communications, and measurement technology. For more than 50 years, laser technology has been a focus of research and industry in Berlin Brandenburg.”

Thomas Beck | Spokesperson Focus Area Laser Technology, Siemens AG, and Managing Director of Laserverbund Berlin-Brandenburg e. V.



Today, lasers are essential tools that have found their way into many industrial sectors. Thanks to its special properties, laser light today serves as a tool for transmitting information, for highly accurate measurements, for surgical treatments, in automotive engineering, and in the production of computer chips, among many other applications.



The latest laser technology is also used to manufacture eyeglass frames.
© Economic Development Agency Brandenburg (WFBB), S. Drosch

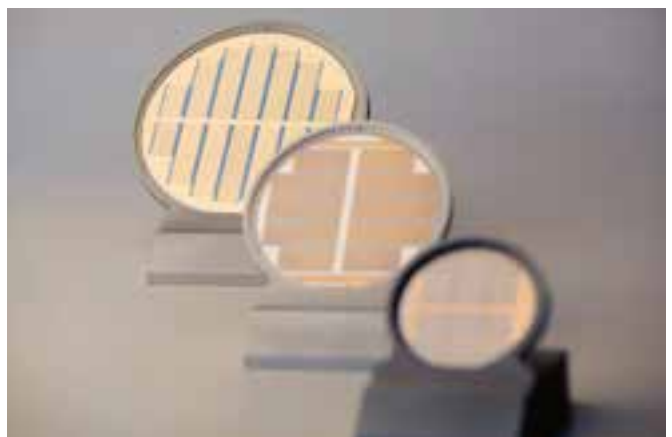
The parameters of laser technology are constantly being improved. Scientists have penetrated into the attosecond range in time resolution. An attosecond is one-quintillionth of a second. With such unimaginably short pulses, fundamental chemical reactions can be monitored with the highest time resolution. In industry, stability and high performance guarantee high throughput. Kilowatt power and more than 99% availability are now commonplace. Cutting and welding in the automotive industry are just some of the applications where the laser has become the standard tool. The diversity of laser technology is also reflected in the Berlin Brandenburg region. Both world-renowned scientific institutes and a number of high-tech companies are based

here covering many aspects of modern laser technology along the value chain from developing semiconductors for new laser materials to processes for using laser deposition welding on large turbine parts.

World-Class Laser Research

The **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH)** is one of the leading institutes in the field of optoelectronics and microwave technology. On the basis of III/V compound semiconductors, the FBH realises high-frequency components and circuits for communication and sensor technology. The institute develops powerful and highly brilliant diode lasers for materials processing, medical technology and precision metrology. One of FBH's strengths lies in the field of high-power laser diodes. For partners and customers in research and industry, FBH develops tailor-made diode lasers for pumping solid state lasers for direct use in materials processing and medicine.

www.fbh-berlin.de



Laser wafers in sizes of 2, 3, and 4 inches
© FBH/schurian.com

Together with the **Quantum Optics and Metrology Working Group** under Prof. Peters at **HU Berlin**, the FBH runs the **Joint Laser Metrology Lab**. The lab's work in laser metrology includes microintegrated electro-optical modules, especially for use in remote locations or in space, interferometers for distance measurements between satellites or quantum-optical sensors such as optical atomic clocks and atomic interferometers.

www.fbh-berlin.com/research/photronics/laser-metrology/joint-lab



Pump module for high-energy short pulse laser systems with approx. 6 kW output power from the fibre

© FBH/P. Immerz



Diode laser on C-Mount

© FBH/schurian.com

Since 2017, the **Leibniz Institute for Crystal Growth (IKZ)** and FBH have been collaborating as part of the Federal Ministry of Education and Research (BMBF) funded **EQuiLa** project (researching and qualifying innovative laser materials and crystals) to establish the **Center for Laser Materials-Crystals (ZLM-K)** at the IKZ. The ZLM-K tests rare-earth- and transition-metal-doped oxidic and fluoride crystals structurally and spectroscopically for their usefulness in operating lasers.

For the execution of simple laser experiments, diode lasers from the project partner FBH will also be used, where the Center for Laser Materials-Semiconductors ZLM-H is established within the **EQuiLa** project. In this way, a world-leading research environment is created in which laser demonstrators can be built using on-site amplifier media and pump sources.

www.ikz-berlin.de/en/research1/center-for-laser-materials



The **Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI)** also conducts top-level laser research at the Science and Technology Park Berlin Adlershof. MBI specialises in ultrashort and ultra-intensive laser pulses. On the one hand, the scientists there are working on new sources for such light pulses, on pulse shaping and pulse characterisation in a broad spectral range from the mid-infrared to the X-ray range. On the other hand, the researchers at the MBI use these possibilities to investigate ultra-fast, nonlinear phenomena in atoms, molecules, clusters and plasmas, as well as on surfaces and in solid bodies. Such combination of modern laser development and measurement technology paired with interdisciplinary applications impart the MBI its unique selling proposition and speciality for external users.

www.mbi-berlin.de



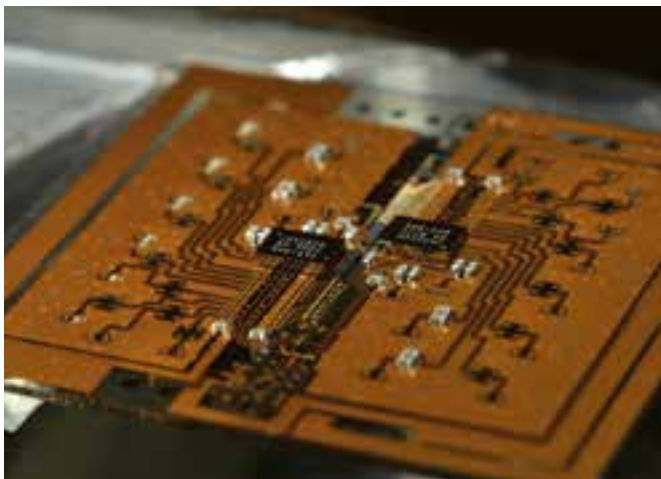
Such laser power packages are urgently needed, among other things, as a technological basis for the European large-scale project **ELI (Extreme Light Infrastructure)**. ELI will become the world's leading laser research infrastructure and is being built at three specialised facilities in the Czech Republic, Hungary, and Romania. This makes it the first **ESFRI (European Strategy Forum on Research Infrastructures)** project to be fully implemented in the new EU countries. The **Deutsche Elektronen-Synchrotron DESY** with its institutes in Hamburg and Zeuthen near Berlin is also a member of ELI.

www.eli-laser.eu



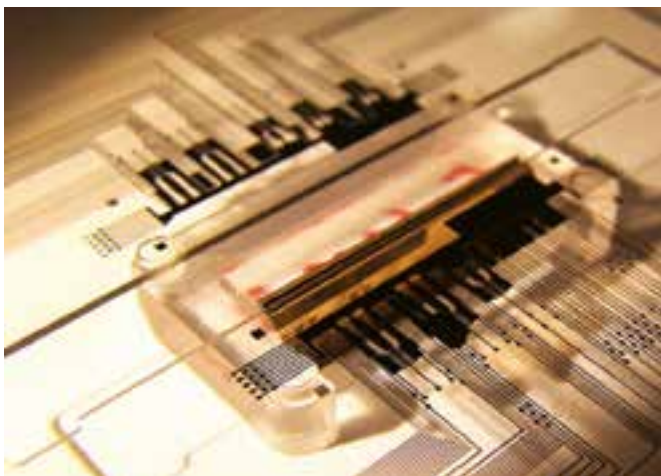
The **Fraunhofer Institute for Reliability and Microintegration IZM** is working on the integration of modern laser technology into industrial applications. Its service range includes consulting, process development, up to technological solutions. The laser technologies developed by IZM comprise special glass fibres, the attachment of lens arrays to laser diode bars with several emitters and using CO₂ lasers to drill holes in glass. Such through-hole plating in glass are key technologies for thermal and electrical connections.

www.izm.fraunhofer.de/en.html



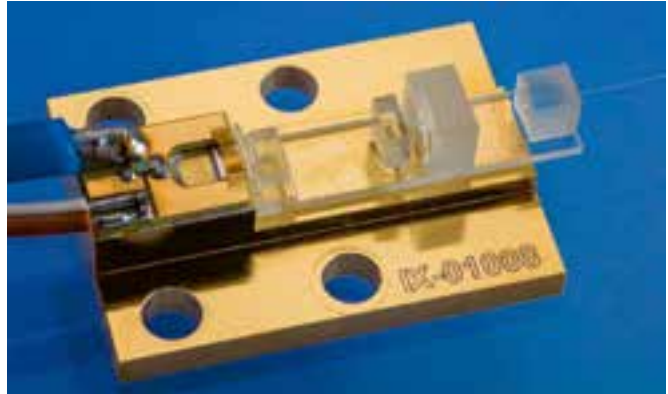
4x25 Gbps/channel on-board transceiver on glass interposer with through-hole plating and integrated lens arrays

© Fraunhofer IZM



Deflecting mirror unit for optical coupling to a glass chip provided with electrical and optical waveguides for EOCB/backplane applications

© Fraunhofer IZM



Fully glass-based micro-optical bench for compact diode laser modules with beam rotation and merging of multiple channels onto one optical fibre
© Fraunhofer IZM

Researchers at the **Institut für Optik und Atomare Physik (IOAP)** at **TU Berlin** are also working on a broad spectrum of topics. Several working groups are doing research on light optics, laser physics, laser molecule spectroscopy, environmental physics, spectroscopy, optical technologies, electron microscopy and holography, as well as X-ray spectroscopy, analysis, and optics. These methods are then applied to special experimental investigations in the fields of atomic, molecule cluster, and solid state physics.

www.ioap.tu-berlin.de



The **Institute of Solid State Physics (IFKP)** at **TU Berlin** is also researching numerous questions related to optics and photonics. Its working groups are investigating micro- and nano-lasers, optoelectronics, and quantum devices, as well as new technologies with nanophotonic components.

https://www.ifkp.tu-berlin.de/menue/institut_fuer_festkoerperphysik/parameter/en/



The **Institute for Optics/Photonics Research at Humboldt University Berlin** has working groups on such topics as nano-optics, optical metrology, attosecond physics, nonlinear quantum optics, and ultra-fast optics. Lasers play a decisive role in almost every aspect of this research.

www.physik.hu-berlin.de/de/op





CO₂ lasers can produce slender and deep weld seams that withstand the highest mechanical loads.

© TRUMPF

Biophysics is a particular strength in the photonics research being conducted in the **Department of Physics at FU Berlin**. Every modern optical method available is used there to decipher the secret of life. In addition, the department has working groups on optoelectronics, near-field optics, and molecular biophysics with photonic materials.

www.physik.fu-berlin.de/en



Several research groups at the **University of Potsdam** are also working in the field of photonics. Their focus areas include such questions as ultra-fast dynamics in condensed matter and modern quantum optics. In addition, there is a joint professorship with the Helmholtz Zentrum Berlin on the methods and instrumentation of research with synchrotron radiation.

www.physik.uni-potsdam.de



The Department of Chemistry in Potsdam is also conducting a lot of research using lasers. Modern laser spectroscopy and optical sensor technology for laboratory, analytics, diagnostics and process control are the core competencies of the **Physical Chemistry Working Group at the University of Potsdam (UPPC)**. The group works in the fields of photo physics and photochemistry, optical sensor technology, biomonitoring, and environmental chemistry and analysis. Together with the **Leibniz Institute for Astrophysics Potsdam (AIP)**, UPPC runs the research and innovation centre **innoFSPEC Potsdam**. The work at innoFSPEC is described in more detail in chapter 2.4 “Optical Analytics”.

www.chem.uni-potsdam.de/groups/pc



Companies with Laser Expertise

One of the international heavyweights on the laser market is the **TRUMPF Group**, which also maintains a laser diode research and development centre in Berlin. The long-established company with tradition has more than 11,000 employees worldwide and is one of the world’s leading suppliers of laser systems of all kinds. With the Berlin site in Adlershof, TRUMPF intends to further expand its technology and market leadership in high-performance diode lasers. For this purpose, the **TRUMPF Laser GmbH** in Adlershof conducts research and development in the high-tech fields of assembly technology, semiconductor physics, and laser physics. A semiconductor laser developed in cooperation with the FBH in Adlershof exceeded the one-kilowatt threshold in 2017.

www.trumpf.com

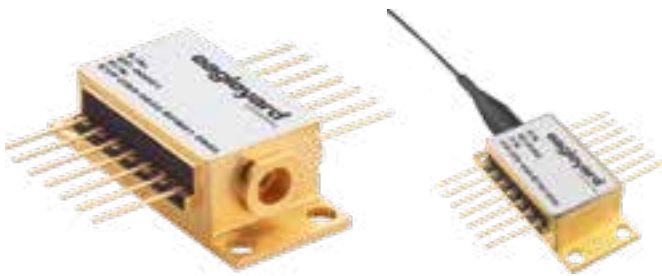




High-power laser diode for extreme, pulsed applications
© eagleyard Photonics GmbH

Adlershof has seen many companies turn research findings into successful business ideas. One example is **eagleyard Photonics GmbH**, which has been developing, manufacturing, and selling high-performance laser diodes for high-end applications worldwide for 15 years. The latest products in the range are new rugged high-performance diodes with peak powers of up to 90 W for pulsed applications, even under extreme temperature conditions and a high brilliance single-mode laser diode with 800 mW output power and integrated beam forming.

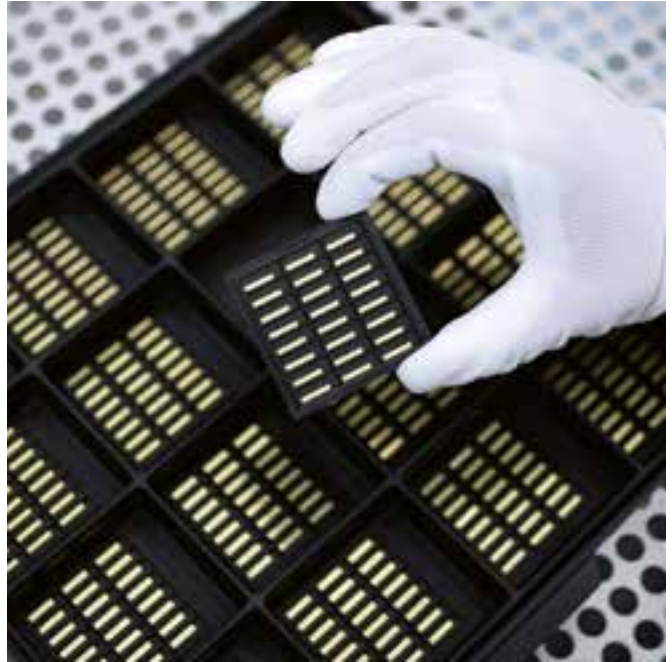
www.toptica-eagleyard.com



14-pin butterfly DFB laser (left: 795 nm, right: 1,064 nm)
© eagleyard Photonics GmbH

Jenoptik AG is an important player in the industry in Berlin. As a result of close cooperation between Jenoptik and the FBH the **Jenoptik Diode Lab GmbH** was founded in 2002. Today it manufactures optoelectronic semiconductor components in Berlin, which Jenoptik later uses in the development and production of high-power diode lasers. Thereby, Jenoptik offers products and applications for laser material processing along the entire value chain, from individual components to complex laser plants. They also manufacture innovative solid-state lasers such as disk and fibre lasers.

www.jenoptik.com



Diode laser bars made by Jenoptik Diode Lab GmbH
© Jenoptik AG/Heiner Mueller-Elsner

Lumics GmbH has also specialised in diodes, mastering all steps in the process from epitaxy to assembly to produce complete laser diode modules. Founded at Stuttgart's Max Planck Institute for Solid State Research, Lumics is now part of the Scansonic Group and a leading manufacturer of high-power diode lasers and laser diodes for medical, industrial, and scientific applications.

www.lumics.de





Laser Diode Controller LDC2000
© Laser Electronics LE GmbH

Laser Electronics LE GmbH also develops and manufactures high-performance laser diode systems. The company specialises in control and cooling technology and offers laser diode controllers, TEC drivers, and laser coolers for material processing and other industrial and medical applications. **PhotonTec Berlin GmbH** specialises in complete modules including optics and fibres for the transmission of laser light. In addition, PhotonTec also offers diode-pumped solid state lasers. The product spectrum ranges from near infrared to ultraviolet and from milliwatts to hundreds of watts of laser power.

www.laser-electronics.de
www.photontec-berlin.com



Brilliance FAB Berlin GmbH was founded in May 2013 as the result of a cooperation between the FBH and the Chinese company Sino Nitride Semiconductor Co., Ltd (SNS). BFB's activities focus on exploiting the semiconductor laser technology developed at FBH for industrial use. At the centre of the development work are lasers for use in automotive lighting, quantum sensors, and Raman spectroscopy.

www.berlin-bfb.de/?lang=en



Specialised in short pulses

Some companies have concentrated on lasers with short pulses. For example, **LTB Lasertechnik Berlin GmbH**, which offers short-pulse lasers in the entire spectral range, high-resolution spectrometers, and laser-based measurement technology. The company offers both nitrogen and dye lasers.

www.ltb-berlin.de/en



Picoquant GmbH works with diode lasers that can deliver ultrashort pulses. The pulse times typically lie in the picosecond range, with repetition rates in the megahertz range. The company also offers fluorescence spectrometers and microscopes. The areas of application range from materials and life sciences to quantum technologies.

www.picoquant.com



A collection of compact PicoQuant laser heads
© PicoQuant GmbH

Advanced Laser Diode Systems A.L.S. GmbH, a subsidiary of Swiss laser technology firm onefive or rather NKT Photonics A/S, focuses on short-pulse lasers. The company is a leading manufacturer of photodetectors and turnkey ultrashort-pulse laser systems with pulse lengths down to the femtosecond range.

www.alsgmbh.com



The Teltow-based company **Adlares GmbH** offers a detection module that can check gas lines for leaks from the air. **Polytec GmbH** maintains a sales and consulting office in Berlin-Adlershof for spectroscopic measuring systems and fibre lasers, optical amplifiers, and component test systems. The Potsdam-based **F&K Physiktechnik GmbH** offers ultrasonic technology for chip production as well as lasers for the alignment of machines and workpieces and optoelectronic measuring systems.

www.adlares.com
www.polytec.com
www.fkphysiktechnik.com





VisUV_AC_Laser module: compact, all-in-one laser module that can generate pulsed laser light with up to three different wavelengths in picoseconds © PicoQuant GmbH

The **Vistac GmbH** in Teltow offers a cane for the visually impaired to scan the surroundings by laser and warn of obstacles. The principle is also used for collision protection sensors.

www.vistac.de



CryLas Crystal Laser Systems GmbH develops, produces, and supplies diode-pumped solid state lasers in the DUV, UV, VIS, and IR ranges for a wide variety of applications in science, research, and industry. How this technology can be used is shown by CryLaS subsidiary **Secopta analytics GmbH**. Secopta develops and produces laser spectroscopic solutions for industrial and security measurement tasks. Using laser-induced breakdown spectroscopy (LIBS) and fast neural networks to evaluate the results, samples can be analysed directly in the process and without special preparation. Applications include the recycling sector for sorting various materials and alloys, process monitoring and quality assurance in the processing industry, and the detection of hazardous substances and pollutants in the health and safety sector.

www.crylas.de
www.secopta.com



Fast and precise: using lasers to process materials

It is impossible to imagine modern production technology without laser-based material processing. Nevertheless, development does not stop, and intensive research continues. Today, the main questions are: Where are lasers a less expensive option than other methods? Where do they enable more performance with less material consumption? And, in general: which new designs are only possible with lasers?

The answers are manifold. The laser already has a strong position in cutting and welding applications, and additive processes such as 3D printing of metals are becoming more common by the day. Due to the great significance of lasers for material processing, it is no wonder that not only technically oriented universities and research institutes are active in this field, but also that many manufacturers in Berlin Brandenburg have also specialised in lasers for these applications.

The **Department for “Beschichtungstechnik” at TU Berlin** is investigating ways to use lasers to join materials that were previously considered to be non-weldable and how this might be applied to the coating or repair of components. The staff at the **Department “Technik” at TH Brandenburg** is also working on joints that were previously not possible, for example, the welding of very thin wires and also those with very different thicknesses. In addition, companies are offered new processes and partnerships in such fields as cutting, soldering, welding, or drilling with lasers.

www.fbt.tu-berlin.de/menue/beschichtungstechnik
<https://technik.th-brandenburg.de/forschung-und-kooperation/fe-schwerpunkte-und-themen/lasertechnik/>



Investigating various laser material processing methods in its **Chair of “Füge- und Schweißtechnik”** will be done at the **Brandenburg University of Technology BTU Cottbus-Senftenberg**. The chair is a part of the Institute for Production Research in the Faculty 3 for Mechanical Engineering, Electrical, and Energy Systems. The focus here is on the cross-industry development of energy- and material-efficient lightweight construction solutions and associated manufacturing technologies. Prof. Vesselin Michailov, who holds the chair, is also Managing Director of **Panta Rhei gGmbH**, a research centre for lightweight construction materials. Since it was founded in 2001, with BTU as its main partner, the centre has primarily been investigating lightweight construction materials based on aluminium, magnesium, titanium, high-temperature titanium aluminide alloys, and high-strength surface-finished steels.

www.b-tu.de/fg-fuegetechnik
www.b-tu.de/pantarhei-cottbus



The staff at **Beuth University of Applied Sciences** is also working on new techniques for laser material processing and medical applications.

www.beuth-hochschule.de



The **Institute for Machine Tools and Factory Operations (IWF)** at **TU Berlin** focuses its research and teaching on the technology and management of industrial factory operations. This includes the development of process technologies and production plants as well as IT modelling. Scientists are working on the “digital factory” on an interdisciplinary basis in six different chairs. One of IWF’s areas of expertise is joining technology, where the main focus is on joining by fusion welding. This includes several projects laying the foundations for applied laser technology.

www.iwf.tu-berlin.de/menue/institut_fuer_werkzeugmaschinen_und_fabrikbetrieb



Together with the **Fraunhofer Institute for Production Systems and Design Technology IPK**, they form the **Production Technology Center PTZ Berlin**, where scientists engage in both theoretical research in production processes and industry-oriented applied research.

Since 1986, the dual TU/Fraunhofer-Gesellschaft institute has operated a large glazed, column-free experimental hall surrounded by a semicircular building with offices, workshops, and laboratories. In the buildings on the banks of the river Spree, the institutes which have been linked by a cooperation agreement since 1979, work on questions related to the research and optimization of industrial production processes.

IPK is closely linked to IWF and joint appointments on issues relating to the industrial implementation of new processes are common. The researchers at the IPK are looking for ways to process brittle-hard and other difficult-to-machine materials as well as surface structuring methods and methods for manufacturing complex geometries. They use laser powder welding, laser beam, and hybrid welding processes in this work.

www.ipk.fraunhofer.de/en



Among other projects, the **University of Applied Sciences HTW Berlin** is working on laser applications in the development of thin-film solar cells and laser material processing.

www.htw-berlin.de



The Federal Institute for Materials Research and Testing **Bundesanstalt für Materialforschung und -prüfung (BAM)** is investigating methods for joining thick-walled components with laser and laser-arc hybrid welding processes reliably and productively. The focus is on joining different grades of steel.

www.bam.de



Laser material processing in use

Many companies are finding ways to apply laser technology. On the one hand, the region is home to several prominent suppliers of laser technology with an international reputation and a broad product range. On the other hand, many metal processing companies are also settling in Berlin Brandenburg to make use of laser technology in order to offer innovative products. A good example of a world-renowned laser supplier in the region is the production facility of **Newport Spectra-Physics GmbH** in Stahnsdorf. The company dates back to the company LAS GmbH. Today the company belongs to the American group MKS Instruments. In the field of photonics, it develops and makes very compact, active Q-switched lasers in the infrared, green and UV wavelength ranges.

www.spectra-physics.com



Europarc Dreilinden in Kleinmachnow is home to **HIGHYAG Lasertechnologie GmbH** (a subsidiary of II-VI Inc.), which is another of the world’s leading brands of laser-based material processing tools. The company offers processing heads for welding, soldering, cutting, coating, and drilling as well as beam transmission systems and adjustments. Adlershof-based **II-VI Directphotonics GmbH** now belongs to the same group. This company develops and manufactures direct diode laser systems for material processing.

www.ii-vi.com





Production Technology Center (PTZ) Berlin, left in the foreground the new Microproduction Technology Application Center (AMP)
© Fraunhofer IPK

The most important segment for **AdIOptica Optical Systems GmbH** is versatile refractive beam shaping and multifocal optics for converting the intensity distribution of a laser beam such as a Gaussian beam into a flat-top profile. This beam forming optics finds applications in numerous industrial and scientific processes. The company name AdIOptica refers to Adlershof, Germany's most modern technology park in Berlin.

www.adloptica.com



Laser-based processing of materials finds many uses in the automotive industry. For example, **Scansonic MI/IPT GmbH** is able to offer a wide range of relevant products. The company develops and supplies systems for laser and arc joining. Scansonic components can be used to weld and solder body and chassis parts made of different materials and to control the hardening of highly stressed components. Like Lumics GmbH, flying-parts GmbH, and **GEFERTEC GmbH**, Scansonic MI/IPT is a part of the Berlin.Industrial. Group under the Berlin-based **Scansonic Holding SE**. The Scansonic Group has thus built up a broad portfolio for laser-based production and measurement technology. Since 2014, the Göttingen-based company Metrolux optische Messtechnik GmbH has also been a part of the Scansonic Group.

www.gefertec.de/en
www.scansonic-group.de/en



Compact Laser Solutions GmbH specialises in ultracompact systems, used for such things as marking and encoding products, but also for material processing in the micro and macro ranges.

www.compactlaser.de/en



Berlin-based **KOMLAS Optische Komponenten und Lasersysteme GmbH** offers pulsed laser welding systems for laser micromachining. The KPL 5000 is maintenance-free and can be supplied with two fibre outputs to allow two spots to be welded at a time. **Canlas Laser Processing GmbH** in Berlin-Adlershof has specialised in using lasers with a high repetition rate and high power for micro-material processing. Canlas's technology has been used to weld semiconductor chips to heat sinks but can also be used to mark medical instruments or engrave data matrix codes on circuit boards.

www.komlas.com
www.canlas.de



Smart Laser Systems GmbH also offers systems for micromachining. For example, the company offers diode-pumped solid state lasers in a compact modular design that are suitable for welding. They can also be used as optical tweezers. Of course, it is also possible to solder by laser. **ATN Automatisierungstechnik Niemeier GmbH** has specialised in systems for automated single-point soldering.

www.sls-berlin.de
www.atn-berlin.de





ALO3: laser processing optics with seam tracking by added wire
© Scansonic Group

Using their own expertise – manufacturers and users in one

Many companies in the region have two mainstays: developing and producing systems for material processing, but also manufacturing components themselves on behalf of customers.

For example, **Photon Laser Engineering GmbH** develops and tests new methods for cutting, welding, soldering, coating, etc. at its Berlin location, especially for use in the production of car bodies and technology, rail, and spacecraft. The results are then implemented in the production facilities of its sister company, **Photon Laser Manufacturing GmbH**, which produces sheet metal parts that are cut, drilled, welded, and soldered using lasers. Both companies are a part of Berlin-based **Photon AG**. The Photon Group's customers include renowned manufacturers of rail vehicles (Stadler Rail, Alstom Transport, Bombardier Transportation), wind turbines (Siemens Energy), and local metal processing companies such as Hennigsdorfer Stahl Engineering GmbH.

www.photonag.com/en



Berlin-based companies **itec Automation & Laser AG** and **Laser-Mikrotechnologie Dr. Kieburg GmbH** also have their hands in multiple aspects of the business. itec not only manufactures laser machines for cutting and welding processes and special machines for complex manufacturing processes, but also does prototype and serial production for customers. Laser-Mikrotechnologie Dr. Kieburg develops and produces systems for laser micromachining, from OEM modules to complete systems. This technology can be used to produce photo templates, metal masks, inscriptions, and pinholes. It can also be used for three-dimensional processing of silicon, ceramics, and metal as well as microstructuring materials and fine-cutting metal foils down to the micrometre range. In addition, the company also accepts outsourcing orders using the same technologies.

www.itec-online.de/en
www.laser-mikrotech.de



Ingenieurbüro Hüyüktepe, Helios Laser-Service is also active in two areas: its employees maintain and repair laser systems, but the company also offers various services with its own technology: fine machining, cutting, welding, drilling, inscribing, marking, and removal of coatings using lasers.

www.helios-laser.com



As part of Poland-based Solaris Group, **DoroTEK Gesellschaft für Systemtechnik GmbH** not only distributes infrared detectors, optical components, and laser modulators from Strausberg, but also provides laser marking and engraving as an outside provider.

www.dorotek.de



Many companies in the capital region act as service providers for various forms of material processing with lasers. One of these is **Laser Micro Präzision LMP GmbH** in Werder. The company offers laser inscriptions down to the micrometer range, e.g. for data matrix encoding of printed circuit boards. They also offer microsurface processing and drilling of holes in the submillimetre range. **escotec Lasertechnik GmbH** in Teltow is a specialist for laser welding, especially for medical technology. Canulas, stainless steel, and titanium foils are typical pieces made by the company.

www.escotec.com/en



Crystalix Enterprises AG specialised in engraving in or on glass using machinery the company has developed in-house. This allows three-dimensional portraits, company logos, and other motifs to be incorporated into glass surfaces. Typical examples are photo displays in the highest resolution or the unobtrusive integration of a QR code.

www.photocrystals.com



LHW GmbH is a specialist in the field of laser hardening of alloyed and high-alloy steels in tool systems. Its customers are in the automotive industry, food and meat processing, mechanical engineering, and forming technology. As a service provider, the company offers the hardening of knife edges, bending and cutting of tools, press molds, rollers, shafts, gears, profile rollers, screws, injection molds, bushings, and bearings.

www.laser-lhw.de



Even completely normal metalworking companies are beginning to take advantage of laser technology and offer innovative products. Typical examples include **LASER-TECHNIK Brandenburg/Havel GmbH** and **Finow Automotive GmbH** in Eberswalde.

www.lasertechnik-brandenburg.de
www.finowautomotive.de



Optical components for laser radiation

The region is home to a wide range of laser manufacturers. And where many lasers are being produced, there will be, of course, companies on hand to supply peripherals. For example, **APE – Angewandte Physik & Elektronik GmbH**, the international market leader for components and systems in ultra-fast laser technology, is located in Berlin. The company's main focus is on systems for ultrashort-pulse diagnostics and wavelength conversion.

www.ape-berlin.de



SLT Sensor- und Lasertechnik GmbH has also specialised in components for the control and monitoring of laser systems. Among other things, the company offers sensors for pulse lasers, display devices for measuring pulse energy, and heads to measure the power and energy of VUV lasers.

www.pyrosensor.de



Laser diode and Peltier drivers as well as modular combinations of these, whether as table-top or rack modules, are being offered by **Ostech e.K.** Integrated diode laser systems and heat sinks are also available.

www.ostech.de/en



The **Berliner Glas Group**, one of the leading European suppliers of optical key components, assemblies, and systems, is located in the capital. The company manufactures lenses, prisms, mesh, and other precision optical components in clean rooms and supplies complete optical, optoelectrical, and optomechanical systems. For companies working with laser technology, Berliner Glas offers custom beam forming systems from the laser source to the workpiece.

www.berlinerglas.com



Holoeye Photonics AG also works with glass. The company offers diffractive optical elements used in 3D metrology as well as in microdisplays and components for modulating amplitude and phase. Berlin-based **Crystal GmbH** sells crystal components, including those used to build YAG:Nd- and YAG:CR lasers. In addition to active and passive laser components, Crystal also prefabricates assemblies upon request. **Ekos GmbH** also develops and designs components for laser optics, including achromatic and light section optics.

www.holoeye.com
www.crystal-gmbh.com/index.en.php
www.ekos-gmbh.de



Fibre optics

FCC FibreCableConnect GmbH covers the full process of manufacturing glass fibre for laser applications from design to prototype and serial production. FCC offers components for the special requirements of laser medicine as well as cables with active cooling for outputs of up to 1 kW.

www.fibrecableconnect.de/en



Leoni Fiber Optics GmbH is another European industry leader with an office in Berlin. It offers optical fibres with custom designs, from cables for industrial fibres to solutions for laser metering. Optical fibres and fibre systems are also the business of **art photonics GmbH**. Its products are used in spectroscopy, analytics, and laser medicine.

www.leoni-fiber-optics.com/en
www.artphotonics.de



PT Photonic Tools GmbH was founded in autumn 2013 to deliver system components and application solutions for industrial short and ultrashort-pulse lasers as well as high-power CW lasers. With the first industrial fibre beam guidance for ultrashort-pulse lasers with microstructured hollow core fibre, Photonic Tools has set a milestone for their easy integration of ultrashort-pulse lasers into industrial applications. The modular laser processing heads and fibre-based beam guidance systems are designed to meet the requirements of laser applications in serial and mass production.

www.photonic-tools.de



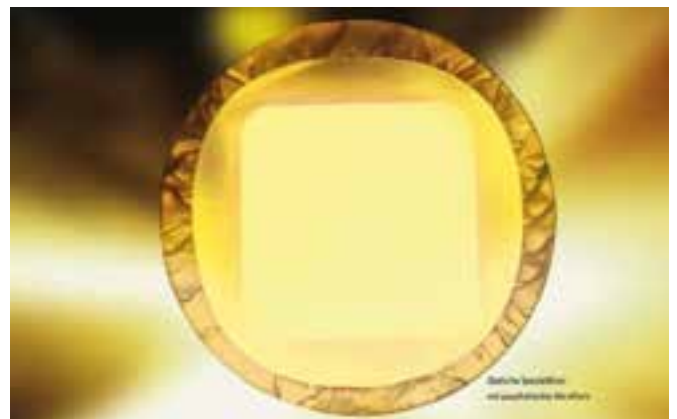
Fisba Photonics GmbH is the German subsidiary of the Swiss company FISBAOPTIK. The company chose to locate in Adlershof because of the high concentration of expertise in the district. With a team of developers, the company carries out basic research, but also performs feasibility studies, experimental investigations, design and development as well as laboratory samples and prototypes. Fisba also offers precision optical components and systems.

www.fisba.com



TRIOPTICS Berlin GmbH has been part of the TRIOPTICS Group since autumn 2010. Founded as a subsidiary of FISBA OPTIK AG of St. Gallen, Switzerland, in spring 1998, TRIOPTICS Berlin has since been active in interferometry and develops hardware and software applications in the field of optical metrology. TRIOPTICS Berlin offers complete interferometer systems, measurement services, and tailor-made solutions for measurement tasks in optical surface measurement.

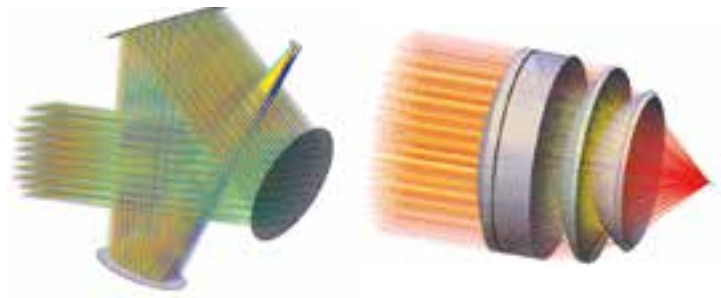
www.trioptics-berlin.com



Special optical fibres with square core shape
 © Leoni Fiber Optics

Overall, there are plenty of providers in the region offering their expertise in the calculation and construction of optical systems. Independent developers like **Raab-Photonik GmbH** assemble and optimise suitable systems, offering measurement, simulation, and testing of optical systems from a single source. In addition, they help their customers on such things as filing patent applications.

www.raab-photonik.com/en



Off-axis telescope with free-form mirror (left) and reflection analysis of a Fizeau interferometer lens (right)
© Baer – Optical Engineering



Compact interferometer for wavefront measurement
© TRIOPTICS Berlin GmbH

Baer – Optical Engineering has similar services on offer. In addition to conventional optical design and the development of optical systems together with peripherals, the office develops algorithms to calibrate optical systems as well as electronic circuits for measurement technology and sensor technology.

www.baer-oe.de/en



JCMwave GmbH develops and distributes software for fast and accurate optical simulations. The applications for the JCMSuite finite element solver are in the field of nano-optics. Systems for photolithography can be calculated as well as solar cells, integrated optical components, active components, waveguides, and plasmonic components. JCMwave was founded in 2001 as a spin-off of the Zuse Institute Berlin (ZIB).

www.jcmwave.com



JP-ProteQ works on the analytical acquisition of production data as a basis for reliable process control without restricting itself to specific technologies or manufacturers. Rather, the task itself is in the foreground. JP-ProteQ thus cooperates with such partners as the University of Potsdam, Raab-Photonik, and Astro- und Feinwerktechnik Adlershof, who contribute their detailed expertise and experience to the respective projects.

www.jp-proteq.com



Laseraplikon GmbH was founded in 2017, emerging from Laser- und Medizin-Technologie Berlin (LMTB). The new company sees itself as a technical and scientific service provider for all aspects relating to laser light. The range of services offered by Laseraplikon GmbH includes the organisation and implementation of laser courses to meet the latest legal requirements, scientific editing for publications with a special focus on medical and technical laser applications, as well as laser inscription, labelling, and marking of workpieces, tools and components, and custom measurement and testing equipment.

www.laseraplikon.de



Networks for Laser Technology

In recent years, a variety of networks related to laser technology have formed in the region to facilitate access for companies and research institutions to such resources as knowledge or capital, both locally and internationally. Chapter 4.2 “Networks” gives a look at these organisations. Particularly noteworthy is **Laserverbund Berlin-Brandenburg e.V.** which hosts regular meetings for users and manufacturers of industrial laser technology. Many user meetings include visits to companies and institutes of interest, with the goal of promoting further exchange with leaders in the industry.

www.laserverbund.de



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2.2 Lighting Technology – a Changing Industry

“In the last ten years, there has been a revolution in lighting due to the change in technology from gas discharge lamps to semiconductor light sources. A particular strength of the local manufacturers are the high quality and design of their products.”

Prof. Dr.-Ing. Stephan Völker | Spokesperson Focus Area Lighting Technology, TU Berlin



Berlin Brandenburg have a long tradition in lighting technology: both the essential scientific foundations and key product lines were developed here. To this day, not only light generation, but also photometry, lighting technology, and the metrological fundamentals for light measurement have been driven forward by local institutes and companies. Overall, lighting technology in Germany is an industry of the future promising dynamic growth and a considerable export share. There are also close links to building technology, lighting of public spaces, environmental technology and energy efficiency, using solar power, and various health aspects.

The importance of lighting technology today is evident from the sales figures: the German lighting industry has recorded steady growth over the past few years and in 2016 achieved a total turnover of almost 7 billion euros (statista.com). However, due to increasing automation and a global shift in production, the number of employees in the industry across Germany has declined slightly over the years.

About 70 Berlin Brandenburg companies are active in lighting technology. This makes lighting one of the most important drivers of the region’s economy, a position that must be maintained and expanded in the future.

The key innovation in the field of lighting technology in the

Bebelplatz, Berlin

© Festival of Lights International Productions GmbH/Nelofee



past decade have been semiconductor-based light sources. LEDs (light-emitting diodes) not only have an excellent energy efficiency and performance. They can also be controlled electronically and enable the design of novel, intelligent lighting systems.



Measuring site for LEDs
© Epigap Optronik GmbH

OLEDs, light sources based on organic semiconductors, play an increasingly important role. These organic light-emitting diodes are thin-film components and can be produced more cost-effectively than normal LEDs, but, for now, their lifespan is currently shorter. Since they do not require monocrystalline materials, however, they can also be used in flexible screens or as electronic paper.

Lighting technology has also taken on a cultural and artistic significance for the German capital. This can be experienced directly at the city’s lighting festivals each October: “**Berlin leuchtet**” and the “**Festival of Lights**”, when lighting artists spectacularly stage many of the city’s buildings with exceptional light shows and projections. The events attract large

crowds who come out to enjoy seeing the city and its historical landmarks in a whole new light.

www.berlinleuchtet.com/en/
www.festival-of-lights.de/en



Research, Measurement, Testing

The future looks bright for the Berlin Brandenburg region thanks not least to the **Chair of Lighting Technology at TU Berlin**, which is training the next generation of innovators for the numerous regional companies in the sector. Lighting technology has been taught at TU Berlin for well over a century. With his inaugural lecture on “electrical light and lighting systems” in the winter semester of 1882/83, Prof. Hermann Wilhelm Vogel held the world’s first chair in lighting technology. The research now focuses on new concepts for exterior and interior lighting as well as daylighting. It is also investigating such physiological questions as the non-visual effects of light and the possibilities of vertical farming.



Entrance to the TU Berlin, Chair of Lighting Technology
 © TU Berlin

Both theoretical and applied research take place in the field of lighting technology in cooperation with numerous companies and institutions both within and outside Germany. Given the transition of urban lighting to new light sources and the growing issue of light pollution, research on the development of intelligent lighting concepts for public areas is also underway.



The LED runway enables the testing and investigation of various urban lighting scenarios.

© TU Berlin

The most important research and demonstration instrument is the **LED runway**, which the Chair of Lighting Technology at TU Berlin built together with the German Museum of Technology Berlin and the Berliner Immobilienmanagement GmbH. Industry participates by providing a wide variety of luminaires and lighting control systems.

Over a total length of 1,500 m (almost a mile), numerous LED light points were installed on several test tracks on the grounds of the German Museum of Technology. The targeted control of the light sources is used to demonstrate and investigate the importance of light quality, road safety, energy efficiency, and their dependence on mast height, mast spacing, buildings, light distribution, and light colour. This is groundbreaking work for the future of urban lighting and not just in Berlin.

www.li.tu-berlin.de/menue/home/parameter/en
www.led-laufsteg.de



The aspects of colour temperature, glare, and the photobiological effect of light sources are also becoming increasingly important. In this context, the TU Berlin’s Lighting Technology chair also conducts testing for external customers. This includes the measurement and evaluation of general lighting as well as the characterisation of special lighting or radiation solutions using standard-compliant measurement methods. The Chair of Lighting Technology at TU Berlin is also a partner of the **Professional Lighting Design Convention**, the leading conference on lighting design in architecture.

www.pld-c.com



The **University of the Arts (UdK)** is also working on new forms of lighting, with the primary focus on light as a design element. The **Industrial Design/Technology Chair** at UdK under the leadership of Prof. Holger Neumann is investigating all aspects of light experimentally. Seminar topics include light and design, basic principles of luminaire design and lighting technology, as well as luminaire design taking into account new technologies such as LEDs and OLEDs as light sources. Aspects of product development, construction and manufacturing as well as subsequent serial production are integrated into the technically oriented product design process.

www.design.udk-berlin.de/Prof_Holger_Neumann



Industry with history and a bright future

Berlin's lighting industry can also look back at a long history: Siemens, AEG and later OSRAM all produced light sources here.

OSRAM was founded in Berlin in 1919 and has been one of the largest regional optics and photonics employers ever since.

Today the Berlin plant focuses on automotive applications, for example, a glare-free matrix car headlight with 1,024 individually controllable pixels developed in a BMBF-funded project by partners such as OSRAM Specialty Lighting and Fraunhofer IZM. One of OSRAM's latest projects is the development of innovative, actively luminous LED light modules being integrated into textiles. See the chapter regarding Smart Textiles on page 28.

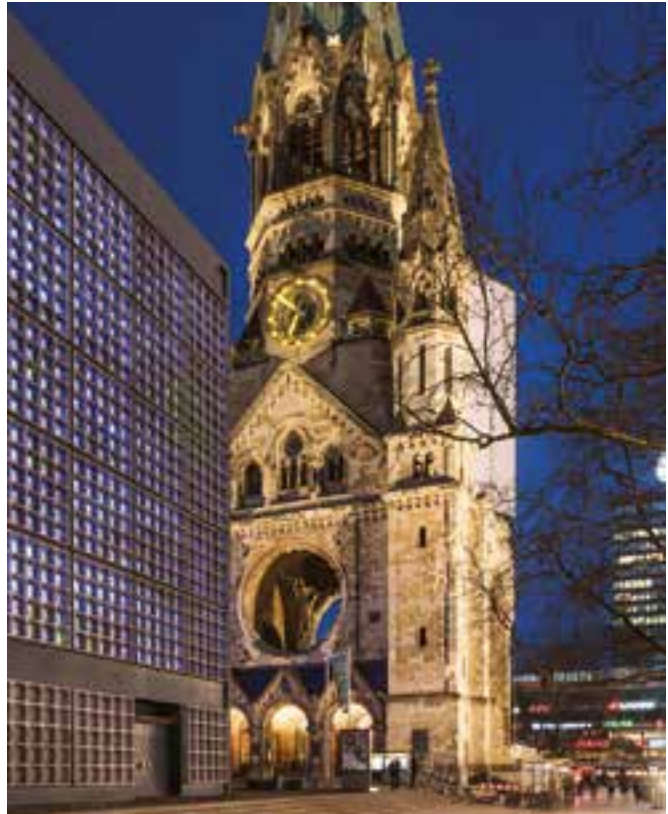
www.osram.com



Lighting public spaces

Berlin was a pioneer in both general electrification and electrical lighting. So, it is hardly surprising that renowned designers and manufacturers of luminaires and lighting systems are among the region's leaders in lighting technology. One of the city's globally active lighting manufacturers is **Selux AG**, known as Semperlux AG until 2012.

The company's products range from faithful reproductions of historical models to extravagant forms and designs for exterior and interior lighting. With over 500 employees worldwide, the company produces luminaires in Berlin and nearby Zachow in Havelland as well as concepts and designs for



A new lighting concept puts the Emperor Wilhelm Memorial Church in good light © Linus Lintner

public spaces and company buildings. The latest innovations include LED street lights with wireless Internet and integrated charging stations for electric vehicles.

Selux products are found in the German Chancellor's offices as well as in the Harley Davidson Museum in Milwaukee. One of the strengths of Selux are its accurate replicas of historic lighting pieces. Selux has installed the Hardenberg candelabras on Kurfürstendamm, the Witzleben candelabras in Kreuzberg and around Charlottenburg Palace. Since 1998, Schupmann candelabras once again shine in front of the Brandenburg Gate and on Berlin's magnificent boulevard "Unter den Linden". By the way, the company's name also comes from Berlin history: Selux was founded in 1948 as Semperlux and initially produced batteries to help counter the power cuts during the Berlin blockade. "Semperlux" means "always light".

www.selux.com/int



Sill Leuchten GmbH is another player in a similar field that has been active for more than 60 years. Founded as Franz Sill GmbH Lichttechnische Spezialfabrik, the company has been a part of Hoffmeister Leuchten GmbH since 2013. The company's luminaires and spotlight systems are used to illuminate such Berlin icons as the Brandenburg Gate and

the Victory Column as well as the plenary hall of the Council of Europe in Strasbourg and the Nelson Mandela Bridge in Johannesburg.

State-of-the-art reflector technologies and intelligent thermal management ensure safe, yet long-lasting lighting solutions. In Berlin, Sill Leuchten produces a wide range of lighting products, including high-performance spotlights and floodlights, LED spotlights, indoor spotlights, recessed floor spotlights, and industrial lighting.

www.sill-lighting.com



Lighting with style

The growing influx of creative minds moving to Berlin is also reflected in the lighting industry. In recent years, Berlin has developed into one of the world's great design capitals. Many creative, industrial, and lighting designers are also active in the field of lighting design and have made Berlin a centre of these activities.

Berlin-based **Kardorff Ingenieure Lichtplanung GmbH** is one of the leading European offices for technical and creative lighting design. It develops lighting concepts for museums, shopping centres, bars, office buildings and other public places.

Kardorff, for example, created the lighting concepts for Dubai Sports City, the Beijing Automobile Museum, and VW's Gläserne Manufaktur in Dresden, as well as for the Brandenburg Gate. In 2017, a 3D model generated with the help of drones served as the basis for a lighting concept for the tower of the Emperor Wilhelm Memorial Church.

For Lufthansa's long-haul aircraft (Airbus A350 and Boeing 747/8), Kardorff implemented cabin lighting that takes chronobiological aspects into account. Daylight concepts optimise the quality of residential construction and reduce energy consumption in office buildings. The team at Kardorff Ingenieure Lichtplanung was awarded the German Lighting Design Prize in the category Office and Administration 2017 for their lighting design work during the comprehensive modernisation of the Renzo Piano Building in Berlin-Mitte.

www.kardorff.de/en



The interior lighting in an Airbus A350 provides relaxation as the day progresses.

© Dominik Mentzos/Lufthansa AG

Studio Dinnebier is also specialised in the design of and with light: the company creates lighting plans and designs luminaires. From the speed skating rink and the Turkish embassy in Berlin to the Palace of Peace and Reconciliation in Astana, Kazakhstan, Studio Dinnebier has implemented projects in collaboration with several internationally renowned architects. The list of references includes Daniel Libeskind, Norman Foster, Tabanlıoğlu Architects, and Sunder-Plassmann Architects.

www.lichtlicht.de



Kardorff and Dinnebier are just two of many renowned names in the Berlin Brandenburg lighting industry. **Lichtvision Design GmbH** has designed lighting concepts for the Bauhaus Museum in Dessau as well as for Gottdorf Palace, the Zurich Police & Justice Centre, and the Hao Yi Centre in Hengqin, China. For its lighting concept in the control room of the PCK oil refinery in Schwedt, the company was awarded first place in the lighting design category at the 2017 Brandenburg Design Awards.

www.lichtvision.com



Among the projects of **Licht Kunst Licht** are the Baden-Württemberg buildings of the state parliament and the Ministry of the Interior in Stuttgart, the Berlin department store KADEWE, and the German Ivory Museum in Erbach. **L-PLAN LIGHTING DESIGN** won the German Lighting Design Prize in 2017 for its lighting concept in the Hotel Adlon. They are just as involved in modern large-scale projects such as the Doha Convention Center in Qatar as they are in cultural buildings: the company planned the lighting for the Christuskirche and Torhaus in Lüdenscheid.

www.lichtkunstlicht.com/en
<https://l-plan.de/en/>



One of the initiators of the Berlin lighting festivals “Berlin leuchtet” and the “Festival of Lights” is Andreas Boehlke, board member of Berlin leuchtet e.V. and managing director of **Hans Boehlke Elektroinstallationen GmbH**, a company that can look back at 70 years of tradition. In addition to special event lighting, such as the execution of the Christmas lighting in Berlin, the company has also developed 3D and 4D video mappings and facade projections, fixed installations, and shop lighting.

www.boehlke-beleuchtung.de



Limax Bühnen- und Studiobeleuchtung GmbH in Erkner manufactures professional stage lighting equipment precisely tailored to the customer’s requirements. The luminaires of **SUMOLIGHT** also deliver massive luminous intensities, particularly suitable for studio recording and film productions.

www.limax-erkner.de
www.sumolight.com



The **Leoni Business Unit Fiber Optics** has developed an optical fiber on its own that emits light in all directions: The AmbientFiber. The core of the optical fiber is fused silica, which works to prevent any discoloration effects or undesirable reactions to incident sunlight. Applications can be found in the automotive industry, in interior and emergency lighting or for illumination in architecture and infrastructure.

www.leoni-fiber-optics.com/en



Luminous motorbike clothing for enhanced safety on the road
 © OSRAM

OSRAM’s smart textiles unit in Berlin develops a defining innovation to illuminate clothing and accessories such as helmets, back-packs and school bags using LED lights. OSRAM’s LED modules are available in a variety of colors and configurations and they can be washed* with the garment providing active illumination.

www.osram.com



ThePowerHouse GmbH is an innovation agency for fashion tech, wearable technology, and smart textiles. The parent company **ElektroCouture** combines fashion and technology and develops wearables using smart fabrics and light.

<https://thepowerhouse.group/>
<https://elektrocouture.com/>



New radial emitting illuminating fibers with maximum freedom in product design – AmbientFiber®
 © Leoni Fiber Optics

Start-ups in Berlin Brandenburg

In recent years, Berlin has made a name for itself as a start-up hub and has seen a number of new companies in the fields of lighting technology and lighting design. **volatiles lighting GmbH** is working on developing the first intelligent lighting surfaces for residential spaces. At the heart of the



Potsdam-based oSol:e GmbH develops and designs solar lights for the .STOOL brand.
© oSol:e GmbH

system are square modules about the size of a deck of cards that are assembled to form individual lighting surfaces and play both static and dynamic lighting scenes. The colours, patterns, and brightness can be changed by touch as well as by the smartphone app. The lighting surfaces communicate with their environment via interfaces to the Smart Home and automatically adjust the lighting as required. The technology remains invisible to the user at all times.

www.volatiles.lighting/en



LittleSun GmbH founded by Olafur Eliasson and Frederik Ottesen is a global project with a social business model. The goal is to bring clean and affordable light to the 1.1 billion people in the world who live without a constant power supply. The company's first product, the LED solar light Little Sun, is sold worldwide. By selling its products in regions with reliable power supplies, the lights can also be offered at lower, locally affordable prices wherever there is no connection to the power grid. They thus represent a clean alternative to toxic and expensive light sources based on fossil fuels, such as kerosene lamps.

www.littlesun.com



Lighting up paper is what the Berlin start-up **INURU GmbH** does. Thanks to new printing processes, ultra-thin, environmentally friendly, and flexible OLED coatings can be applied to papers.

www.inuru.com



Individual neon lights, on the other hand, are the trademark of the **Sygnis GmbH**. Customers can choose from various in-stock options or can create their own neon font.

www.sygnis.com



The start-up **Siut GmbH** brings light into concrete using fibre-optic. It is currently working with Deutsche Bahn to create digital edges for rail platforms. But architects are also very interested in the new design possibilities of fibre-optic concrete.

www.siut.eu



Intelligent solutions for lighting with solar energy are the specialty of **oSol:e GmbH** in Potsdam. These include lighting for home use as well as solar modules for trucks, which supply cooling or on-board electronics with electricity. **Artrolux GmbH** offers complex lighting systems for architects, industry, and research. Thanks to intelligent control and dimming, even complex lighting situations can be realised.

<http://osole.net/>
www.artrolux.de





LEDs offer a variety of possibilities
© Epigap Optronic GmbH

LEDs dominate luminaire manufacturing

Modern lighting technology is no longer conceivable without light-emitting diodes. LEDs combine high durability with energy efficiency, a long – service life, and a wide range of spectral diversity.

Epigap Optronic GmbH in Berlin produces LEDs, LED chips, and photodiodes for all types of industrial applications both as standard products and as custom designs. Epigap offers high-end LED chips for the entire spectrum. The company specialises in the production of smaller to medium quantities that meet high quality standards. In recent years, Epigap has further sharpened its profile towards customer-specific solutions in the field of LED chips, LEDs, and photodiodes and serves the industrial sensor technology, medical technology, and security technology markets. Epigap is currently strengthening its competence in the field of optoelectronic measurement technology.

The company is also in partnership with **Jenoptik Polymer Systems**, which also manufactures optical components in Berlin, including optoelectronic chips, light-emitting diodes, photodiodes, and spotlights.

www.epigap-optronic.de/en
www.jenoptik.com/optoelectronics



Lumi-Con has dedicated itself to finding ways to dim LED lights. It develops and produces its own dimmers, control units, and the corresponding highly efficient LED lights and lamps for private and commercial use. **TQ Technology** de-

velops systems for automotive, medical, and other special lighting applications. Using the latest CAD systems and simulation software, the company carries out concept or feasibility studies for LED- and laser-based projects.

www.lumi-con.de/index_eng.html
www.tqtechnology.com



The young Berlin enterprise **FutureLED GmbH** specialises in specialty light sources for industrial, medical, and agricultural applications. The company develops and manufactures LED light sources and radiation modules that operate with wavelengths ranging from 280 nm to 1,600 nm, i.e. not only the visible, but also the ultraviolet and infrared ranges. The “Sunlike” system, for example, is an LED platform from which light can be emitted in various wavelengths between 350 nm and 1,100 nm. This allows the full spectrum of daylight to be replicated with the highest possible accuracy. In addition to other applications, the company is also working on measuring the performance of solar-powered systems.

www.futureled.de



OSA Opto Light GmbH also produces specialised LED chips, modules, and lamps both as standard and as custom products. The spectrum ranges from the ultraviolet to the infrared range.

www.osa-opto.com



Easy Lights GmbH, based in Dallgow-Döberitz, provides ergonomic lighting solutions for the workplace. Intelligent sensor controls ensure optimal illumination for a fatigue-free work.

www.easy-lights.eu/_en



Mawa Design Licht- und Wohnideen GmbH in Michendorf develops and produces innovative luminaires and lighting systems. Using the latest CNC and robot technology, the company also implements individual and complex projects. The designers of the lighting design office **leuchtstoff*** in Cottbus also focus on devising new lighting concepts. Their systems include components that the company develops together with companies from the region.

www.mawa-design.de/en
www.leuchtstoff.de



LIGHT-TOOL sees itself as a complete service provider for all aspects of LED lighting. For architects, builders, event organisers, and industry, the company manufactures individual luminaires including the required operating devices and controls.

www.light-tool.de



Measuring laboratory for lighting technology
 © TU Berlin

Measurement Technology: at the Pulse of Light

For many industrial applications, an exact knowledge of the different physical parameters of the light sources is necessary. There are several companies and institutes in the Berlin Brandenburg region that are dedicated to the development of measurement technology or the performance of technical light measurements.

Instrument Systems GmbH, one of the leading manufacturers and suppliers of light measurement technology in Europe, has its own subsidiary **Optronik** in Berlin. The company offers the entire spectrum of light, radiation, and colour measurement technology and can supply complete light measurement laboratories, especially for the automotive and transport sectors.

www.optronik.de/en



The OUT e.V. has an optical laboratory for measuring luminous flux, colour temperature, and radiation characteristics.

© Berlin Partner for Business and Technology – Monique Wüstenhagen

PRC Krochmann is also active in the field of light measurement technology. Indeed, the company's name is an acronym for photometry, radiometry, and colorimetry. PRC Krochmann supplies research institutions and industrial producers as well as planners and operators of large lighting installations. The product range covers all areas in which light, radiation, and colour are measured.

www.prc-krochmann.com



Other suppliers of light measurement technology based in Berlin include **LMT Lichtmesstechnik GmbH Berlin** and **Czibula & Grundmann GmbH**. These two also supply the complete range of technology and software for professional light measurements as well as for applications in measurement and control technology.

www.lmt-berlin.de
www.photo-meter.com



Optotransmitter-Umweltschutz-Technologie e.V. (OUT e.V.) is a research and development service provider focusing on lighting technology and offers optical measurements on flat layers and surfaces as a technical service. These include wavelength-dependent transmission, absorption, and reflection measurements from 0.2 μm (UV) to 1.25 mm (terahertz) as well as the determination of optical constants. In addition, OUT e.V. offers a wide range of photometric measurements on all relevant physical parameters of LEDs and small radiation sources.

<http://www.out-ev.de/en/home-2/>



OLIGO surface controls GmbH in Lenzen (Elbe) is well known for its visual and digital systems for high-precision surface inspection and for its colour matching systems which detect colour differences on individual parts and finished products. Leading global companies in different sectors such as automotive, plastics, ceramics, and paper are using this technology which allows unevenness and small defects to be repaired at any time in the production process.

www.surface-controls.de



ColVisTec AG, founded in 2009 in Berlin-Adlershof, develops, produces and distributes process monitoring systems with fine-resolution spectrophotometers for inline colour measurement. The technology allows direct, continuous measurements of materials in liquid, paste, powder, or molten form at any time during the manufacturing process and at operating temperatures of up to 400 °C (750 °F) and 345 bar. Thus, inline colour measurement is directly possible on an extruder. Applications for inline technology include extruders used in plastics processing, paint and coatings manufacturing, the food industry, and in processes involving chemical reactions.

www.colvistec.de



From theory to application

Several institutes are addressing complex problems associated with the further development of LED technology. In Berlin, for example, the **Fraunhofer Institute for Reliability and Microintegration IZM** is researching an abundance of individual projects. They are trying to improve the heat dissipation of individual and packaged LEDs, as well as increase their performance, service life, and efficiency. They are working on new standards for their construction, connection, and assembly and are trying to make production processes as efficient as possible. The IZM is also working on innovative optoelectronic applications as well as plasmonic and 3D photonic systems.

www.izm.fraunhofer.de/en.html



Together with the Berlin-based **Holoeye Photonics AG**, the Fraunhofer IZM is working on the development of LCOS

(Liquid Crystal on Silicon) cells for the UV and SWIR bands as part of the PALM project (Photonic Applications for Spatial Light Modulators). PALM is a ProFIT project and co-financed by EU funds. Holoeye Photonics is a specialist for diffractive optical elements and microdisplays.

www.holoeye.com



Covert Science GmbH is a Berlin-based start-up that develops LED-based flexible and textile-based opto-electronic solutions. Founded in 2018, the company offers solutions in the areas of flexible power electronics, optical encapsulation processes, and non-imaging optics as well as electronics systems on non-standard substrates including textiles and thermoplastics. Covert Science partners extensively with research institutions such as the Fraunhofer IZM.

www.covert.science



The scientists at the **Fraunhofer Institute for Applied Polymer Research IAP** in Potsdam-Golm are working on the fundamentals of lighting technology. The researchers are looking for new polymer materials and basic processes that can be used for the LEDs and OLEDs of the future. The spectrum ranges from the development of materials with semiconducting characteristics to chromium-bearing, phototropic, and luminous polymers for processing into OLEDs. Various printing processes are used on a pilot system to produce organic solar cells and OLEDs at low cost. The Fraunhofer IAP has joined forces with Germany's leading mechanical engineering companies in this field to form the German OLED Technology Alliance (GOTA).

www.iap.fraunhofer.de/en/fraunhofer-iap.html



One of the leading institutes in the field of optoelectronics and microwave technology is the **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoehstfrequenztechnik (FBH)**. Researchers at FBH are also developing new nitride-based laser diodes and UV light-emitting diodes, especially for the UV-B and UV-C spectral range. The LEDs are suitable, for example, for the use as surface treatments or to illuminate plants.



UV-B module for plant irradiation with various LEDs: UV (310 nm), blue (451 nm), red (660 nm). The LEDs can be adjusted separately to provide the optimal light to grow healthy plant substances (close-up: LED)
© FBH/P. Immerz

The **Joint Lab GaN Optoelectronics** of FBH and TU Berlin is developing innovative light emitters based on group III nitrides. The material system AlN-GaN-InN covers an extraordinarily large wavelength range, covering the entire visible spectral range as well as far ultraviolet and near infrared.

www.fbh-berlin.com/research/photonics/gan-optoelectronics



The FBH-led **Advanced UV for Life Consortium** is an alliance of companies and research institutions dedicated to the development and application of UV LEDs with the aim of advancing the technical development, availability, and use of UV LEDs on a broad scale. Central concerns are the replacement of the still dominant mercury-based lighting systems with UV LEDs and opening up of new applications, for example in water disinfection and sterilisation, medicine, sensor technology, plant cultivation, and printing technology.

www.advanced-uv.de/en



The **UVphotonics NT GmbH** is the corresponding spin-off of the Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FHB) in Berlin and the Institute for Solid State Physics at TU Berlin. UVphotonics develops and distributes highly efficient and reliable ultraviolet light-emitting

diodes (UV-LEDs) as single chips and as fully assembled devices. The product portfolio covers the wavelength ranges UV-B (280 nm to 320 nm) and UV-C (< 280 nm). In addition to customer-specific UV-LED solutions, UVphotonics also offers services and consulting for the integration of innovative LED systems into the products of its industrial customers

www.uvphotonics.de



Short Distances and Good Networking

The wide range of activities related to lighting technologies in the region are well organised and networked. Lighting technology is one of the six identified focus areas in the Berlin Brandenburg Photonics Cluster. The regional industry association **OpTecBB e.V.** in collaboration with the Berlin Brandenburg section of **German Lighting Technology Society (Deutsche Lichttechnische Gesellschaft – LiTG)** has led the way in developing this focus area for the cluster with its spokesperson Prof. Stephan Völker of the Chair of Lighting Technology, TU Berlin. Together, exchanges of experience and workshops will be organised in which, for example, innovative lighting concepts using LED technology are discussed. Research institutions such as OUT e.V., Fraunhofer IZM, and Fraunhofer IAP and companies such as FutureLED and Selux organise and support seminars and expert discussions that are well received by all stakeholders. This healthy spirit of cooperation is one of the region's greatest strengths. Thanks to the diversity in local expertise, geographically concentrated like this nowhere else, Berlin can still call itself the "City of Light".

<https://optecbb.de/en/>
www.litg.de



Contact: Prof. Dr.-Ing. Stephan Völker

Spokesperson Focus Area Lighting Technology



Phone: +49 (0)30 31422277

E-mail: stephan.voelker@tu-berlin.de

2.3 Photonics and Quantum Technology for Communications and Sensors – High-Tech for Fast Data Transmission

“Higher performance, miniaturisation, physical advantages through system integration of optoelectronics and microoptics, as well as photonically integrated circuits (PIC) in data and telecommunications, medical technology, industrial sensor technology, and biosciences – this is the main focus in the field of optical technologies in communications and sensors. A broad spectrum of expertise, first-class research infrastructure, short distances, and long-lasting networking are important factors for the attractiveness of Berlin Brandenburg. The intensive exchange between science and business has been living a long tradition with regular meetings of the focus group, during project developments, and visits to companies belonging to our focus area.”

Dr.-Ing. Henning Schröder | Spokesperson Focus Area Photonics and Quantum Technology for Communications and Sensors, Fraunhofer IZM



Digitalisation, Industry 4.0, 5G mobile communications, cloud computing, augmented reality, and new media. All these buzzwords have one thing in common. They are social trends that are driving the need for fast data transmission. Before industrialisation, it was the rivers that offered a network of natural traffic routes and supplied the first settlements and later cities. With industrialisation, rail and road networks were added. Today, it is fast data connections that are the prerequisite for the economic success of a region.

The amount of data that is created, duplicated, and transmitted worldwide is expected to be around 40 zettabytes by 2020 and this figure has doubled every 18 months for many years. One zettabyte is 40 sextillion bytes, equal to the data held by 250 billion DVDs.

The only technology that can move this once unimaginable amount of data around the world is based on light transmitted in fibreglass. This fibre-optic technology can be used to move, detect, direct, collect, and amplify data.

Research and development in Berlin Brandenburg are focusing on the necessary components and technologies: fast laser sources, light modulation, integration into closed systems, and everything needed to interface with a digital world. A good introduction to the activities can also be found on YouTube:

www.youtube.com/watch?v=XN7UeTh95JM



There is still a need to increase the transmission capacity and reduce latencies and error rates. However, given the widespread use of optical transmission paths, the goalposts keep getting moved. The systems should become more energy-efficient, more powerful, and more robust, because neither the energy consumption nor the costs should increase despite the massive growth in data transmission.

Berlin Brandenburg are in a very good position when it comes to optical data transmission. The region is home to leaders on the world market, internationally important research institutions, and highly innovative start-ups. The density of companies and institutions working in this field is only surpassed by the Silicon Valley.

A diverse range of optical sensor technology is being worked on and extends into all fields of application. Miniaturization and system integration play an essential role for sensors in medical technology, autonomous driving, and Industry 4.0. An essential goal is to combine the requirements of precision and reliability in photonics with the possibilities of microsystem technology and the assembly and connection technologies of electronic systems.

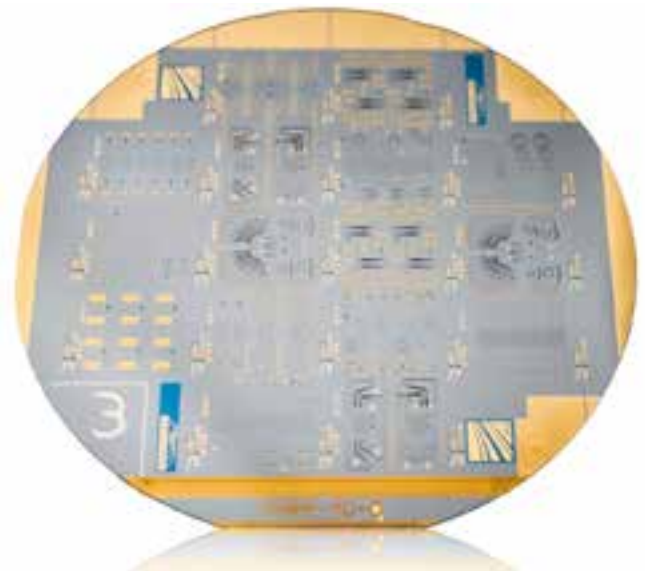
Diode Lasers and Photodiodes from Berlin hold International Records

Every second bit on the Internet is transferred by hardware from Berlin! In 2014, the Fraunhofer HHI spin-off **u2t Photonics AG** was acquired by Finisar, the world's market leader for optical components. One reason for this was the coherent receiver by u2t Photonics that enjoyed

a high market penetration. This receiver is used for the long-range transmission of optical signals in suboceanic fibre-optic lines, so that one out of every two bits that crosses the Atlantic Ocean touches one of the u2t Photonics receiver modules. The **Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI** is a leader in the development of the photodetector chips for the coherent receiver modules and their transfer to manufacturing.

The separation of design and manufacturing processes opens up new fields of application: a decisive breakthrough in the development of new applications for photonic integrated circuits (PICs) was achieved with a new indium phosphide integration platform. The aim of the platform is to make low-cost prototyping possible. Indium phosphide is used to make semiconductors for lasers, detectors, and other components in telecommunication wavelengths from 1,200 to 1,800 nm. Customers from all over the world create their own designs which they could never produce themselves. HHI handles the production separately from the design process. It processes orders from different customers on a single wafer and manufactures them very efficiently. The advantages created by these efficiencies are shared with the client.

www.hhi.fraunhofer.de/en



Multi-project wafer processed using a modular system
© Fraunhofer HHI

However, such strategies are not only applied to indium phosphide. In Berlin, directly modulated vertically emitting laser diodes (VCSELs) are manufactured which, with transmission rates of up to 161 gigabits per second per channel, were among the fastest in the world when launched.

On this basis, **V-I-Systems GmbH** offers complete VCSEL modules for feeding in signals, high-speed photodetectors for reception, and individual chips. The company is also able to model chips and entire modules in 3D and precisely represent their thermal, electrical, and optical properties.

www.v-i-systems.com

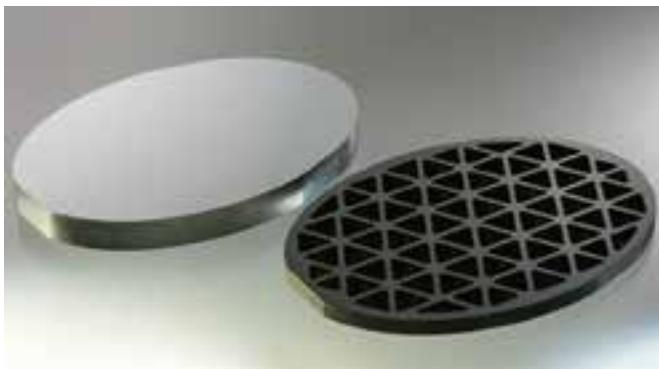


On-wafer chip characterisation at Fraunhofer HHI
© Berlin Partner for Business and Technology – Monique Wüstenhagen

Laser Technology in Space

Optical communications technology offers clear advantages beyond reliable broadband Internet. In recent years, it has also made the leap into space. For example, laser-free beam optics are used to communicate both between satellites in space and from the satellite to earth. The market leader is Tesat Spacecom in Backnang. The photodetectors in the Laser Communication Terminals (LCTs) sold by Tesat Spacecom were developed and manufactured at Fraunhofer HHI. In the meantime, eight satellites in orbit have been equipped with the LCTs and ensure communication between the satellites in the ESA's Copernicus project.

One example is the ESA earth observation satellite “Sentinel-1A”. Equipped with a laser communication terminal containing laser diode benches from Berlin’s **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH)** and several optical components and systems from the **Berliner Glas Group**, the satellite can transmit data over long distances using lasers, a first in the communication of earth observation satellites.



Closed lightweight structures for mirrors in space
© Berliner Glas Group

The German communications satellite “Heinrich Hertz” is scheduled to go into orbit in 2021. More than 40 German companies and organisations are involved in this showcase project. The satellite is expected to operate for 15 years at about 36,000 km (22,370 miles) above the earth’s surface. Given the rough conditions in space, quality work is a must. A special antenna for communication with the earth is being built by the Berlin company **First Sensor AG** in cooperation with the Aachen University of Applied Sciences (RWTH) and IMST GmbH in Kamp-Lintfort. First Sensor is one of the world’s leading suppliers in the field of sensor technology, especially for industrial, medical, and mobility applications. The company’s avalanche photodiodes, for example, are used as optical sensors in autonomous industrial drones. The company has more than 850 employees at its six German locations and worldwide.

www.first-sensor.com/en



DiGOS Potsdam GmbH has been founded as a spin-off of the GeoResearchCenter (GFZ). As a system integrator for geodetic and geophysical observation systems by developing complete turnkey systems, their working domains are manifold with a focus on turnkey Satellite Laser Ranging stations (SLR), seismic measurement stations



Semiconductor manufacturing requires experience and precision.
© First Sensor AG

(DATA-CUBE³), autonomous multi-sensor systems, real-time communication and streaming solutions (CCUBE). DiGOS develops hard- and software on its own as well as together with longtime scientific partners such as the Eu-

www.digos.eu



ropean Space Agency (ESA). The innovative SLR stations designed and developed by DiGOS are flexibly extensible for future applications like space debris tracking and laser communication.

The laser diodes from **eagleyard Photonics GmbH** have also found their way into space. The Adlershof-based subsidiary of TOPTICA Photonics AG develops and manufactures laser diodes for a wide range of applications including analytics, automotive technology, and industrial applications as well as aerospace.

For quantum technology applications they offer single frequency lasers with a line width down to below 1 MHz.

www.toptica-eagleyard.com



Quantum Technology: from Theory to Application

Quantum technologies open new horizons in the field of communication and computer technology. This includes the absolutely secure encryption of information by entangled photons, but also quantum simulations, quantum



Single photon source for quantum experiments
© AG Benson, HU Berlin

computing and quantum sensors. Thanks to the good interplay between basic and applied research in the capital region, a broad ecosystem of innovative research groups of the major research institutes and of young quantum technology companies has formed in recent years. All major institutes involved in laser technology and metrology are now also involved in the field of quantum technology.

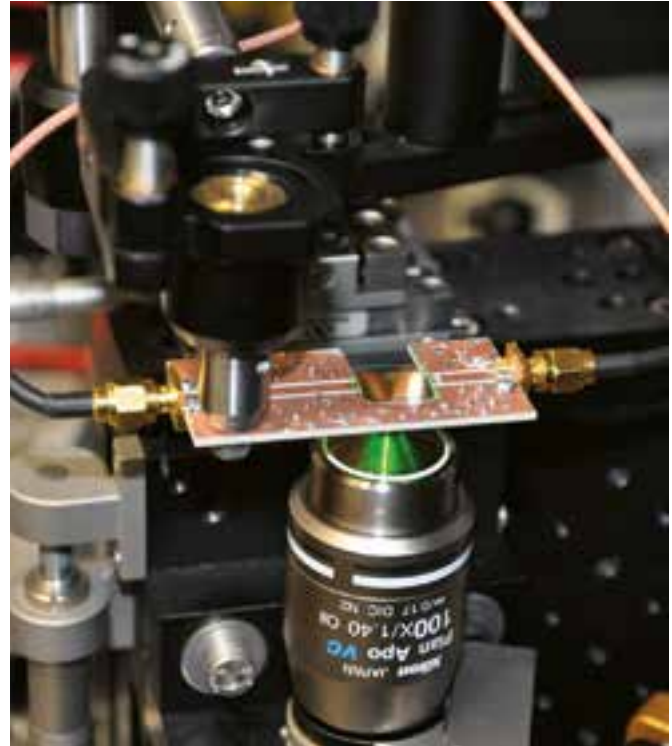
This expertise is also reflected in the InnoQT innovation network, which connects the regional players and is open to new partners. This network links university and non-university research with industry partners, from start-ups and medium-sized companies to large, established firms.

<https://www.fbh-berlin.de/en/research/quantum-technology/quantum-technologies-berlin>



The working group of Jens Eisert at the **Dahlem Center for Complex Quantum Systems** of the **Freie Universität Berlin** analyzes the theoretical problems of realistic quantum computers. The researchers pose questions about what kinds of quantum communication protocols can be conceived and how to develop a vision of the quantum internet. A recurrent theme is the issue how one can certify the correct functioning of components. Even if this kind of research is being pursued with theoretical methods, the work is often linked to quantum optical experiments.

<https://www.physik.fu-berlin.de/einrichtungen/ag/ag-eisert/index.html>



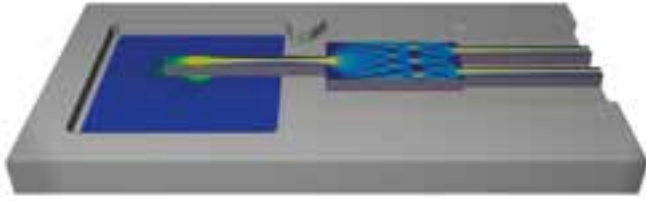
Experiment for measuring the quantum Zeno effect
© AG Benson, HU Berlin

The **Nanooptik AG** led by Prof. Oliver Benson at **Humboldt University Berlin** investigates the theory of light-matter interaction. The researchers analyze fundamental questions with new methods, such as quantum emitters in solids that generate single photons or exchange such photons with each other. Optical methods make it possible to verify the theories of quantum physics with tremendous precision. Particularly important phenomena are entanglement, wave-particle dualism, and other quantum paradoxes such as the quantum Zeno effect.

The group also works on new quantum technologies, such as single quantum light sources on scanning probes for high-resolution spectroscopy and microscopy. They also develop photon sources and algorithms for a quantum cryptography. Together with local partners at universities, research institutions and industry, these new approaches are already being implemented in test tracks and demonstrators. They also perform quantum-enhanced optical precision measurements and develop ultra-stable optical systems to test fundamental physics, even in space.

www.physik.hu-berlin.de/en/nano





Element consisting of an integrated quantum optical chip
© TU Berlin/AG Optoelektronik

At the **Institute for Solid State Physics of Technical University Berlin**, Prof. Stephan Reitzenstein's **research group in optoelectronics and quantum devices** develops nanophotonic devices based on semiconductor heterostructures. The infrastructure of the Center of Nanophotonics at the TU Berlin is available for their nanofabrication. One focus of the work is the study and targeted application of light-matter interactions in quantum optical regimes, which provide novel functionalities in quantum devices. One example are single photon sources for quantum cryptography. For this purpose, individual semiconductor quantum dots are integrated into nanophotonic structures and optimised for their emission properties using in situ electron beam lithography, a unique technology specially developed by the working group. Further work aims at quantum networks and at integrated quantum photonics and ultimate micro- and nanolasers with disappearing laser thresholds. The latter are not only very interesting from the perspective of theoretical physics but can also be used as nanophotonic hardware components in the field of neuromorphic computing.

www.ifkp.tu-berlin.de/menue/arbeitsgruppen/ag_reitzenstein



The **DLR-Institute of Optical Sensor Systems** develops active and passive optical sensor systems for spaceborne and airborne applications as well as for robotic systems. Quantum technologies are vital for the institute's mission. The research activities cover novel quantum materials, sensors and detectors with quantum-limited sensitivity. Quantum technologies of particular interest are quantum light sources and quantum memories, as well as on applications of such devices in quantum communication and computing.

www.dlr.de/os/en



The **FBH** is very active in the field of modern quantum components. Together with Humboldt University Berlin, they are working on state-of-the-art laser technologies. In 2017, its technology was used in the first success in generating a special state of matter called a Bose Einstein condensate aboard a sounding rocket. These and other quantum technologies are used to research quantum optical sensors and other components for secure communication, quantum simulation and computing, quantum-assisted imaging, and spectroscopy. Coherent radiation sources are important for quantum optical applications and as well robustness and reliability for space technologies. For this purpose, FBH uses its competences in the fields of semiconductor, microwave and diode laser technology. This also includes hybrid photonic modules, integrated quantum sensors or nanostructured diamond systems. Such components as well as nonlinear optical quantum devices are relevant for quantum networks.

www.fbh-berlin.com



The **Fraunhofer HHI** has comprehensive experience and expertise in designing, developing and prototyping photonic components and systems towards quantum communication and sensing. Their foundries offer rapid and flexible development and fabrication of photonic integrated circuits (PICs) and components. With the innovative PolyBoard platform, they offer hybrid integration of low loss free-space sections and bulk materials, such as Faraday rotators and nonlinear crystals for quantum applications, into PICs via micro-optical benches. For R&D purposes they offer a quantum testbed facility comprising optical free-space and fiber links.

www.hhi.fraunhofer.de/en



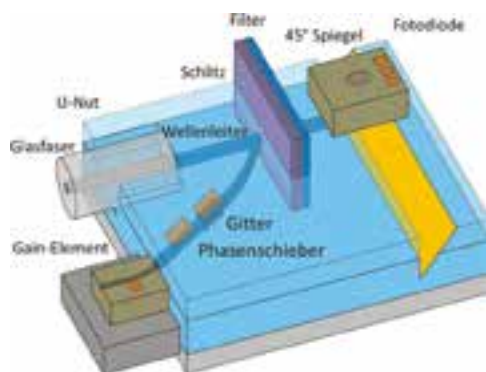
The experts at **Fraunhofer Institute for Reliability and Microintegration IZM** are using their expertise in photonic system integration and miniaturization to find new solutions for the quantum age. This includes the integration of optical waveguides, design-based processing of tailored refractive index profiles, generation of strong evanescent fields in the immediate vicinity of quantum emitters, the trapping of neutral atoms in such evanescent fields or the coupling of optical fibers using innovative interconnection techniques. These technologies are also used for the production of future all-glass quantum chips.

www.izm.fraunhofer.de/en.html



Spin qubits in semiconductor materials are promising candidates as basic elements for quantum computers. For this reason, researchers at **Leibniz Institute for Crystal Growth (IKZ)** grow isotopically enriched thin-strained silicon layers between SiGe barriers by molecular beam epitaxy. Such a layer forms a quantum well for a two-dimensional electron gas. Top gates on such semiconductor structures electrostatically form the quantum dots which are hosting single electrons for spin manipulation.

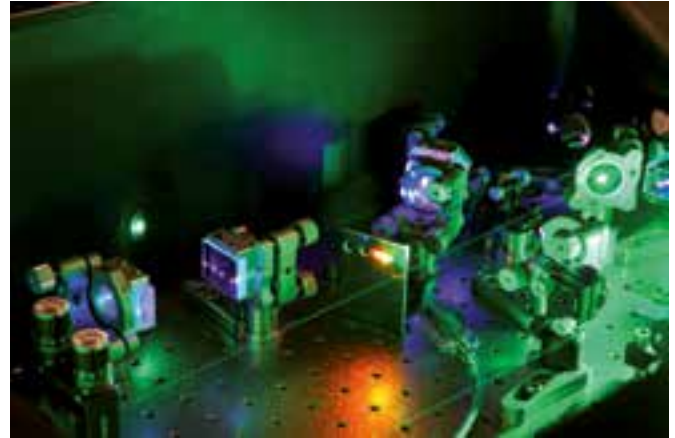
www.ikz-berlin.de/en/



Platform for polyphotonics
© Fraunhofer HHI

The **Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI)** conducts basic research in laser-matter interaction. Taming the unusual propagation scenarios of light in novel photonic devices offers unprecedented opportunities where optical quantum effects can be exploited. In the next years, the femtosecond-laser microprocessing group together with the group for theoretical optics & photonics will focus on making such chips reprogrammable, holding the promise to provide versatile optical circuits for classical and quantum-based applications.

www.mbi-berlin.de



Light source (optical parametric amplifier) used to manufacture networks of waveguides in glasses.

© MBI

The quantum technology activities at **Paul-Drude-Institut für Festkörperelektronik (PDI)** are based on expertise in semiconductor nanostructure epitaxy as well as in phononics, quantum photonics, quantum transport and the manipulation of single atoms. Highlights combining these aspects of quantum technology include their hybrid opto-mechanical single-photon sources and spin processors. These rely on surface acoustic waves that transport spin-polarized electronic excitations and inject them into two-state centers, where they recombine and emit single photons. The researchers are also working on quantum circuits on a chip. This leads to quantum structures on semiconductor surfaces on an atomic scale and allows complete control of their properties. The goal is to implement such structures in quantum information technology in the future.

www.pdi-berlin.de



The **Physikalisch-Technische Bundesanstalt (PTB)** works on several fields of quantum technology, with a focus on quantum sensing and metrology. It supports the transfer of quantum technology from science to applications in industry and academia. The new **Quantum Technology Competence Center** coordinates these activities. At PTB's site in Berlin the activities focus on quantum magnetometry and cryogenic sensors, for instance highly sensitive SQUIDs and optical magnetometry for me-

tology, fundamental research, medical applications and beyond. It also provides an exceptionally well controlled environment for sensing smallest magnetic fields. This infrastructure is accessible to external partners.

www.qtz.ptb.de/en



The **Zuse Institute Berlin (ZIB)** is an interdisciplinary research institute for applied mathematics and high-performance computing. The Computational Nano Optics group investigates and applies numerical methods for the simulation of light-matter interactions in nanoscale devices. A highly topical field of application is optical quantum technology: modeling and simulation are used for the interpretation of experimental results as well as for the effective design of future technologies, such as quantum communication devices and quantum computers.

www.zib.de/cno



In Brandenburg, research groups from the **Institute of Physics and Astronomy** at the **University of Potsdam**, the **Max Planck Institute for Gravitational Physics (Albert Einstein Institute)** and the **GFZ German Research Centre for Geophysics Potsdam** are working on quantum technology topics.

www.physik.uni-potsdam.de/index.php?&c=562447_5e6d1147b474&m=menu,self
www.gfz-potsdam.de/en/home
www.aei.mpg.de



Berlin researchers also make important contributions to exciting space projects. For example, they are not only working on optical atomic clocks that make more precise satellite navigation possible. As part of the BECCAL experiment, they are also helping to realize a highly sensitive Bose-Einstein condensate on board the International Space Station.

As a startup in secure communication, **GoQuantum c/o Factory Works GmbH** develops connectivity devices for post-quantum communication. The algorithms used are not affected by quantum computers which can break



FC1500-Quantum complete laser system for a Strontium lattice experiment including sub-Hz laser and frequency comb
 © Menlo Systems GmbH

standard encryption. This technology also uses quantum random number generators for extra-secure keys and permits customer-specific security implementations for 5G and IoT networks.

www.goquantum.tech



JCMwave GmbH develops software for fast and accurate optical simulations. For use in quantum technologies the software comprises special features such as the simulation of quantum dot light sources, the determination of the Purcell effect, or the calculation of resonator field modes.

www.jcmwave.com



Menlo Systems GmbH provides complete laser systems for cold atom experiments that can be used in different applications. Such setups are necessary parts of optical clocks, quantum simulations or quantum computing ex-

periments based on cold atoms or ions. The company also has experience in optical frequency combs, cavity-stabilized lasers, femtosecond lasers and terahertz systems.

www.menlosystems.com



For some years already, **M Squared Laser Limited** has been at the heart of the international quantum supply chain. Its experts develop components, sub-systems and sensors for commercial quantum applications. The company provides the world's purest light to enable scientific progress and power industry. Its lasers and cutting-edge photonics systems are working to realise the potential of the coming quantum age, deliver advances in healthcare and provide the scientific understanding to help halt climate change. M Squared also specialises in the development of extremely stable and robust lasers with expertise spanning CW to fs, and DUV to THz wavelengths.

www.m2lasers.com



The lasers of **Picoquant GmbH** also find application in quantum technology. These include Hanbury-Brown-Twiss set-ups to study single photon sources, quantum communication and quantum key distribution (QKD), Bell state measurements, or experiments on quantum gates for future quantum computers.

www.picoquant.com



QUARTIQ GmbH is a pioneer in the development of open hardware and software solutions for quantum technology applications. It supplies research and metrology institutes worldwide with custom designs and also provides development and integration in collaborative industrial research projects, such as transportable and robust optical atomic clocks. The firm also works on algorithms and components for high-performance measurement and control tasks.

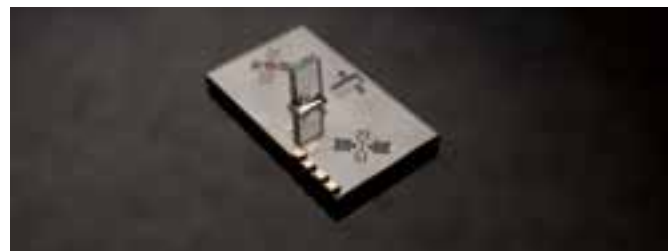
www.quartiq.de



New Modulation Methods increase Transmission Capacity in Fibre-Optic Networks

Even with optical data networks, size doesn't always matter. At Fraunhofer HHI, existing data connections between continents are analysed and simulated in the laboratory. Whereas, in the past, the light was only switched on and off quickly and one bit was transmitted with each pulse, today four bits and more are transmitted in the same time using phase and amplitude modulation. This often requires a compromise between transmission speed and cost. There is worldwide interest in Fraunhofer HHI's robust, fast methods, but the installation of a new intercontinental submarine cable could easily cost more than a billion euros.

However, companies and institutes are also working on making quantum technologies useful on earth. In the field of communication, there is particular interest in quantum cryptography. Concepts are being worked on to enable efficient repeaters.

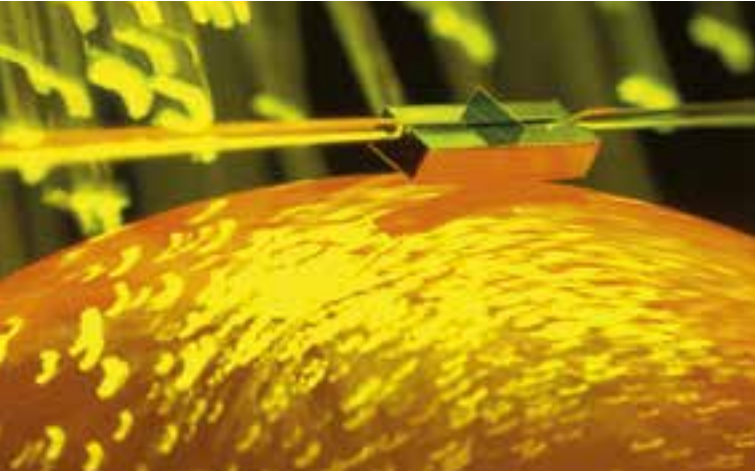


Photonic integrated PolyBoard chip
© Fraunhofer HHI

Important pioneering work in the field of modern fibre optics is carried out by the **PolyPhotonics Berlin** technology network. Eleven companies and three research institutes have joined forces in this regional competence network to develop polymer-based optical components. A hybrid-optical modular technology platform serves as the flexible basis for different assemblies. The central chip with optical waveguides made of polymer material can accommodate other passive elements such as glass fibres, thin-film filters, and micro-optics as well as active components such as photo diodes and laser chips. The various project partners contribute their respective expertise so that the platform can be used in telecom and data communications applications as well as in analytics and sensor technology.

www.polyphotonics-berlin.de





Polyboard 1x1 structure with lilix® reflector
© FOC – fibre optical components GmbH

ADVA Optical Networking SE also has offices in Berlin. The telecommunications company has seen strong growth in recent years and is on the DCI (data centre interconnect) market one of the leading providers in the “Metro ICP/CNP” (Internet content provider/carrier neutral provider) and “Enterprise” categories. The ADVA FSP 3000 CloudConnect is a solution for fast data transfer that requires less floor space and energy than comparable technologies.

www.advaoptical.com



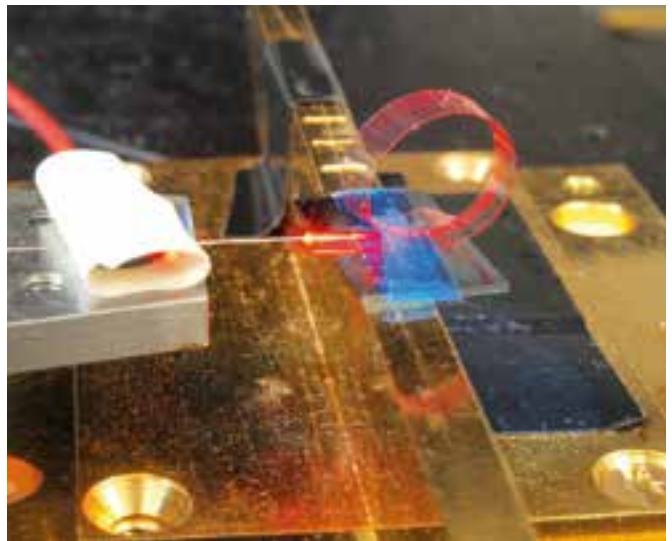
Fibre Optics continues to be innovative

Optical fibres are not only transmission elements for digital, analogue, or spectral information; they can also become sensor elements themselves. They can also be used as probes or applicators for surgery or photodynamic therapy. Further information can be found in chapters 2.1 “Laser Technology”, 2.4 “Optical Analytics”, 2.5 “Biophotonics and Ophthalmic Optics” and 2.6 “Microelectronics and Microsystems Technology”.

On its website, **CORNING Inc.** claims that after the Stone, Bronze, and Iron Ages, the Glass Age has begun. And the global corporation certainly plays an important role here. In Berlin, **Corning Optical Communications GmbH & Co. KG** has offices in Mitte and Adlershof. The Mitte branch manages the company’s complete fibre-optic and copper product solutions for telecommunications and data

networks in Europe, Africa, and the Middle East. At Adlershof, the company operates a research and development centre for innovative products in telecommunications technology.

www.corning.com/emea/en.html



Optical flexline
© Fraunhofer HHI

The Fraunhofer HHI spin-off u2t Photonics AG was recently acquired by the global player **Finisar Germany GmbH**. Finisar, headquartered in California, is a major provider of fibre-optic systems and data communications. The outstanding indium phosphide technology of u2t Photonics’ 100G high-speed receivers and photodetectors has proven to be an important investment for Finisar. The Berlin site continues to play a critical role in the development of advanced components targeting 100/200G and 400/600G applications, achieving up to 64 GBd data rates and providing fluid continental and intercontinental data traffic through underground and submarine cables.

<https://ii-vi.com/optical-communications-products/>



The region is also home to companies that manufacture glass fibres and waveguides. One example is **FOC – fibre optical components GmbH**, whose fibre coupling and splicing technology is used worldwide. FOC develops and produces passive optical components for use in data transmission, telecommunications, industrial control, sen-

sor technology, laser and medical technology. **FCC Fibre-CableConnect GmbH**, on the other hand, specialises in fibre-optic cables for transmitting laser beams. The cables transport up to 1 kW laser power and are used in both industrial and medical applications. In addition, FCC has fibre bundles, probes for spectroscopy, and optical fibre couplers in its portfolio.

www.foc-fo.de/1/company/
www.fibreconnect.de/en



Measurement Technology

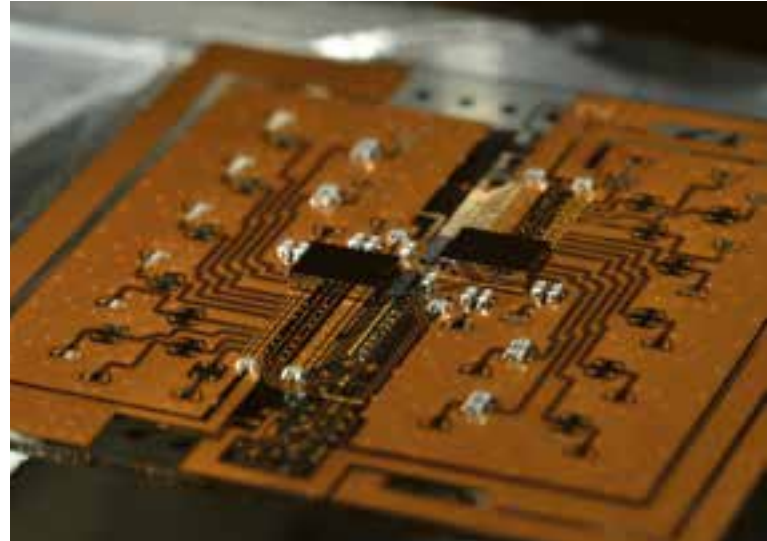
Founded in 1983, **SHF Communication Technologies AG** develops, manufactures, and sells components and measuring instruments for high-speed data transmission. These components and measuring instruments are frequently used in the communications industry, especially by telecommunications companies, network equipment manufacturers, and research institutes. SHF's products primarily help increase the data transmission capacity of optical networks. Due to its special expertise in the field of high-speed data transmission, SHF has become one of the world's leading manufacturers in this area. The growing demand for fast optoelectronic components and measurement devices is served by the following product segments: bit pattern generators and error analysers for data rates of up to 100 Gbps, optical transmitters and receivers for data rates up to 128 Gbps, driver amplifiers for optical modulators, and passive components for high-frequency technology.

www.shf-communication.com



Tektronix GmbH is another specialist for measurement technology, sensor technology, and high-speed communication in Berlin. The company develops and manufactures testing and measurement solutions for complex tasks, including health, communications, mobility, and space flight. It has offices in 21 countries and offers a broad portfolio of services which include performance and energy efficiency as well as 3D sensor technology, semiconductor development, and wired communication.

<https://uk.tek.com>



Optical transceiver based on a 2.5D glass interposer with optoelectronic components and microlenses

© Fraunhofer IZM

Photonic System Integration turns Components into Complex Systems

Optical data transmission and sensor technology are more than just transmitters and receivers. In addition to electronic components, light sources (edge-emitting lasers, VCSEL, or LEDs), and detectors, but also passive elements such as lenses, optical fibres, filters, and polarisers are integrated into optoelectronic and photonic modules with transmitters and receivers, modulators, amplifiers, and switches. Such modules are much more complex than purely electronic modules and are therefore still usually set up and adjusted manually.

One example of this is the manufacture of very high-quality micro-resonators from optical glass fibres. There is currently some very promising work underway in this field at the **Fraunhofer Institute for Reliability and Microintegration IZM**, which, in addition to production, also focuses on the packaging of these highly sensitive components. Many activities at Fraunhofer IZM (such as the PhoxLab) are described in detail in chapter 2.6 "Microsystems Technology" of this Report.

Fraunhofer IZM develops standardised methods and processes for assembly and connection technology that are suitable for automation and drastically reduce manufacturing costs. For example, electro-optical interposers

and printed circuit boards are based on display glass into which optical waveguides have been embedded. These are used in data centres and also for sensory integration platforms.

www.izm.fraunhofer.de/en.html



Optical transceiver module for data centre connections
© Sicoya GmbH

Energy consumption and high data rates are some of the biggest challenges that come with the steady growth of data traffic. Berlin-based **Sicoya GmbH** is offering a solution in the form of low-cost, energy-efficient, and scalable optical transceiver chips. The technology company has won numerous prizes, including the “Berlin-Brandenburg Innovation Award”, the “Start-up Energy Transition Award”, and the “Deep Tech Award”.

The company, which was spun off from TU Berlin in 2015, can look back at ten years of successful research and development work in the field of silicon photonics. This disruptive technology is making it possible for the next generation of data centres to have optical connections that will excel not only through less energy consumption, but also through lower costs and high scalability. Sicoya’s special solution lies in the co-integration of ultra-fast electronic Bi-CMOS circuits for drivers and amplifiers with photonic elements on the same chip. This integration leap directly translates into higher energy efficiency for the electronics and the use of light from the laser source, resulting in outstanding performance in terms of energy consumption, reliability, and signal integrity. The chips are distributed worldwide as OEM products or packaged with optical interfaces as transceiver modules.

Last year, the start-up was able to acquire Series B financing from various well-known international investors.

These resources have made the ramp-up to producing several thousand transceiver modules each month possible, thus realising Sicoya’s vision of faster and more energy-efficient data transfers.

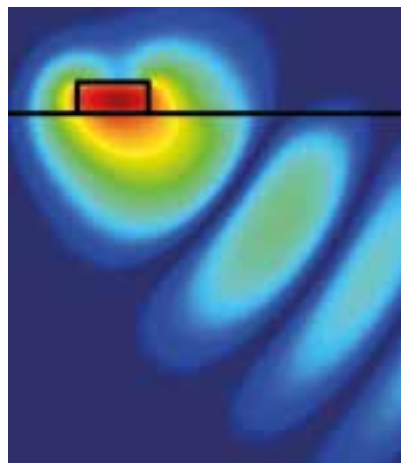
www.sicoya.com



Highly complex assembly of micro-mirrors
© AEMtec GmbH

Numerous companies in industry are also involved in integrated microoptics. The **AEMtec GmbH** in Berlin-Adlershof, for example, specialises in the development, qualification, industrialisation, and production of microelectronic and optoelectronic modules and complete systems. Using high-end technologies such as UBM, solder balling, stud bumping, chip on board, flip chip, and opto-packaging, highly complex electronic assemblies (optical assemblies, micro-optics, imaging arrays, VCSEL assemblies, sensor systems, optical MEMs, hybrid electronic assemblies) are manufactured with micrometre-accuracy precision.

www.aemtec.com/en



H-field of a curved waveguide, calculated with VPImodeDesigner
© VPIphotonics GmbH

A champion in the field of simulation and calculation of optoelectronic systems is **VPIphotonics GmbH**, headquartered in Berlin. It offers professional simulation software for the design of active and passive components, fibre-optic applications, optical communication systems, and cost-optimised network planning. In addition, its team of experts consults, addresses customer-specific design and configuration requirements, and provides training on appropriate modelling techniques and advanced software features.

www.vpiphotonics.com



From the theoretical model of an opto-semiconductor made by a solid state physicist to engineering support for production, and from optical chips to assembly and connection technology to complete optical systems, Berlin Brandenburg offer the entire spectrum of optical data transmission and sensor technology. A viable network has been created in the region that can meet almost all the challenges for finding a solution.

Contact: Dr.-Ing. Henning Schröder

Spokesperson Focus Area Photonics and Quantum
Technology for Communications and Sensors



Phone: +49 (0)30 46403-277

E-mail: henning.schroeder@izm.fraunhofer.de

2.4 Optical Analytics – Analytical Tools for a Wide Range of Applications in Photonics

We humans perceive a lot of the world with our eyes and it's not very different for technology: optical methods play a dominant role in recording a wide variety of data. With the increasing digitalisation of many production processes as part of Industry 4.0, sensor technology is taking on an even more important role than before. Optical sensors are usually contactless, fast, and provide electrical signals that are easy to process. The variety of optical sensors and measuring methods is correspondingly large.

While our eye only perceives a small part of the electromagnetic spectrum, there are optical sensors for a wide range of wavelengths: from X-rays to ultraviolet and visible ranges to infrared and even terahertz radiation. The fields of application in measurement and analysis technology are as varied as the possible wavelengths. They range from microscopes in the laboratory to security technology at the airport and large-scale scientific equipment such as BESSY II in Berlin-Adlershof.

X-rays, for example, can penetrate most materials and are used in medicine as well as in material analysis and non-destructive testing of components. At the same time, their high spatial resolution makes it possible to look at the nanoworld.

Excitation with ultraviolet radiation leads to self-fluorescence in most biological materials. From the spectroscopic analysis of this self-fluorescence, conclusions can be drawn about the composition of the biological material.

The applications of visible light are extremely diverse. The results are usually accessible to the naked eye. But thanks to highly developed sensors, measuring instruments can also perform tasks such as monitoring production processes and free people from such exhausting work. Optical sensors help with counting, simple and complex length measurements, and colour measurements, to name just a few examples.

The application of infrared radiation often uses the effect that this radiation is not visible to our eyes and is not harmful within wide limits. When autonomous vehicles eventually take over our roads, they will detect their surroundings with IR sensors. Infrared radiation can also provide important information about our environment, such as the heat loss from buildings. An infrared camera can be used, for example, to investigate the insulating effect of a facade.

A new field for optical analysis is the development of sources and sensors for terahertz radiation. Some people may have already seen such devices at airport security, where they are supposed to replace the conventional X-ray devices.

“The importance and possibilities of optical analytics will continue to grow. Only the improvement and further development of analytical methods ensure the technological advancement as you can only produce what you can measure and characterize at the required precision level. Hence, the exploitation of research results and developments is very important. Not only start-ups should play a role here, but also the cooperation with existing companies that are already established on the market with many years of experience.”

Dr. Michael Kolbe | Spokesperson Focus Area Optical Analytics,
Physikalisch-Technische Bundesanstalt (PTB)





EMIL, the Energy Materials In-Situ Laboratory, has direct access to the radiation from BESSY II.

© HZB/Ingo Knies

UV and X-Ray Technologies

UV and X-ray technologies extend the application of optical analytics to even the tiniest spatial and temporal dimensions. They make nanostructures visible, as well as ultra-fast processes. In this way, they enable significant progress to be made in such important areas as medical technology and nanotechnologies.

X-ray analysis has a long tradition in the Berlin Brandenburg region. Some of the first X-ray tubes with which Wilhelm Conrad Röntgen began to experiment after 1895 were manufactured in Berlin by Reinhold Burger.

Today, Berlin and Brandenburg have unique potential in this field and an outstanding position internationally. The region covers the entire value chain, from basic research to product development in innovative companies.

X-ray analysis for medical technology and material analysis

In the development of X-ray analytics, many methods are now being transferred from research to industry. In concrete terms, this can be seen in the transfer of processes and systems from the synchrotron to normal laboratory environments.

The focus is on imaging techniques such as tomography, X-ray microscopy, but also on holography and coherent diffraction. This evolution is being driven by medical technology and questions related to material science. The region is home to unique expertise in both fields. One example is the technology that was used to examine the deep layers of the Dead Sea scrolls found at Qumran without destroying them. A 3D micro X-ray fluorescence analysis developed by scientists at TU Berlin was used for this project. The needs for future technologies are shaping the work being done by researchers and developers in the region. These include X-ray tubes; X-ray optics and X-ray capillary optics, especially HOPG (highly oriented pyrolytic graphite) optics, as well as Bragg Fresnel lenses and more powerful X-ray semiconductor detectors, laser-based X-ray sources for the soft and medium X-ray range,

especially for pulses in the femtosecond to nanosecond ranges, as well as methods of chemical speciation independent of synchrotrons and large-scale equipment.

Research institutions and companies in Berlin Brandenburg will not run out of work any time soon. Each research step in material analysis also brings about different technologies. Especially when it comes to dissolving small and very small structures. Because UV and X-ray light is the light of micro- and nanotechnologies and thus one of their most important tools.

Research opportunities unlike anywhere else

The Berlin Brandenburg region offers an excellent research infrastructure with close ties to industry. The **Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)** is one such institution. The HZB operates in unique laboratories and large-scale facilities for research on energy materials in Berlin-Wannsee and Berlin-Adlershof. These include solar cells of the next generation and beyond, future IT materials (spintronics), and also catalytically active material systems that use sunlight to split water and produce solar fuels (artificial photosynthesis).

The **Berlin electron storage ring BESSY II** in Berlin-Adlershof provides brilliant synchrotron light pulses on almost 50 beam tubes for research, especially in the soft X-ray range. External guests from research and industry can also apply for measurement time at BESSY II. HZB teams of experts are constantly developing the instrumentation and working on new X-ray optical components (**HZB Department for Nanometre Optics and Technology**).

www.helmholtz-berlin.de/industrie/angebote_en.html



The **Energy Materials In-Situ Laboratory EMIL** is directly connected to BESSY II. It is home to Sissy, the energy material research laboratory of the HZB and CAT, the catalysis laboratory for sustainable energy supply of the Fritz Haber Institute of the Max Planck Society, and the PINK beamline for X-ray emission studies, which is operated by the Max Planck Institute for Chemical Energy Conversion.

www.helmholtz-berlin.de/forschung/quellen/corelabs/emil/index_en.html



The **Nanometre Optics and Technology Department at HZB** was formed in 2010 from the former BESSY Optics Group and the Microtechnology User Centre (AZM). It combines the internationally recognised expertise of HZB in the design, manufacture, and measurement of optics for short wavelengths.

www.helmholtz-berlin.de/forschung/oe/fg/nanometeroptik/index_de.html



Large single crystals are produced in this optical zone melting furnace.
© M. Setzpfandt/HZB

The **CoreLab for Quantum Materials** provides a range of methods and instruments for the synthesis and investigation of new quantum systems for energy and information technology. The instrumentation has many applications, including many other substance classes and questions. The CoreLab makes the instruments available to all HZB scientists, external researchers, and commercial users.

www.helmholtz-berlin.de/forschung/quellen/corelabs/quantum-materials/index_en.html



The **Ultra-fast Dynamics in Condensed Matter at the University of Potsdam Working Group** is affiliated with HZB. The focus of research here is on the electronic properties of materials, which are expressed properties such as ferroelectricity, optical absorption, and the coherent mixture of electromagnetic waves. The University of Potsdam is also home to the **Laboratory for Electron Microprobe Analysis**

er (EMPA). This allows the non-destructive examination of the chemical composition of minerals and glasses in the micrometre range. X-rays can be used to produce concentration maps of individual elements.

www.udkm.physik.uni-potsdam.de/research-interests
www.geo.uni-potsdam.de/electron-microprobe-analyser.html



DESY Zeuthen, a branch of the Deutsches Elektronen-Synchrotron in Hamburg, is located in the southeastern outskirts of Berlin. The scientists at the site are not only involved in numerous international astrophysical projects. Zeuthen is also where important components for the main DESY site are developed. The new X-ray light source European XFEL in Hamburg offers unique research conditions for the analysis of physical, chemical, and biological processes in highest spatial and temporal resolution.

www.desy.de/index_eng.html

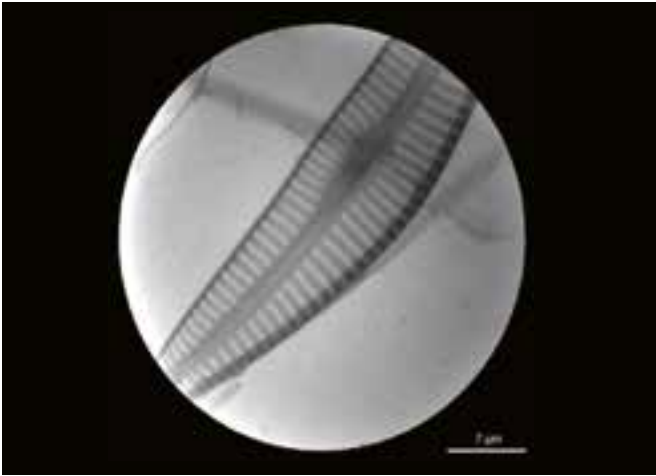


The **Analytical X-Ray Physics Working Group at TU Berlin** in Charlottenburg (Prof. Birgit Kanngießner) is investigating and developing methods of X-ray spectroscopy for applications in the life sciences and in materials science. This will allow, for example, chemical compounds and oxidation states to be determined using X-ray emissions (XES) and absorption methods (XAFS). The main aim of the research is to bring established methods from the synchrotron into a normal laboratory and thus make them accessible for a broader use.

Another focus of the Kanngießner working group is X-ray microscopy. The short wavelength of X-ray radiation can achieve particularly high resolutions. In cooperation with the Remagen University of Applied Sciences, a system with a spatial resolution of less than 30 nm has been set up at the Hamburg synchrotron PETRA III. The system enables spectroscopic and tomographic measurements. In addition to material science research, a joint project with the Charité is also investigating in vitro biomedical samples at the cellular level.

www.xp.tu-berlin.de/ag_kanngiessner





Diatom as seen with the X-ray microscope LTXM (Laboratory Transmission X-ray Microscope) at TU Berlin © TU Berlin

At the **Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI)**, a major focus is on the investigation of particularly short pulses. The shortest pulses currently accessible in experiments are in the attosecond range. This is much shorter than a single vibration of visible light. Accordingly, such pulses can only be generated at much shorter wavelengths, typically by high-order harmonic generation (HHG). The researchers at the MBI are using such pulses in the EUV and X-ray ranges to investigate the structure- and time-dependent dynamics of electrons in atoms, molecules, and solids. Various spectroscopic methods up to X-ray holography are therefore being researched.

www.mbi-berlin.de



Together with TU Berlin, MBI operates the **Berlin Laboratory for Innovative X-ray Technologies (BLiX)**. The equipment includes the BLiX X-ray microscope with a highly brilliant laser plasma source. This allows time-resolved and single-shot (NEXAFS) measurements in a range of up to 1 keV.

The BLiX is located at the endowed chair for analytical X-ray physics held by Prof. Birgit Kanngießler. The aim of the development work is to bring established methods from the synchrotron into a normal laboratory. The potential applications range from geology and environmental sciences to biomedicine. With such innovative labs, TU Berlin is seeking to create institutions in which university and non-university research institutes can collaborate with companies on innova-

tive products. As part of MBI, a member of the Leibniz Association, the BLiX also functions as a Leibniz application laboratory.

www.blix.tu-berlin.de/en/index.html



Bridging the gap between synchrotron-based X-ray analytics and R&D demand of both, industry and academia, **Xploraytion GmbH** offers comprehensive consulting services and facilitates access to advanced X-ray analysis techniques. Their support mainly focusses on spatially and time-resolved material analysis and elemental distributions in the life - and material sciences.

www.xploraytion.com



An important focus of optical analytics in Berlin are the city's laboratories for research, testing, and standards, above all the National Metrology Institute of Germany **Physikalisch-Technische Bundesanstalt (PTB)** and the Federal Institute for Materials Research and Testing **Bundesanstalt für Materialforschung und -prüfung (BAM)**.

The two PTB departments in Berlin-Charlottenburg address issues related to thermometry, radiometry, medical physics, mathematics, and information technology for metrology. At Berlin-Adlershof, PTB operates the MLS (Metrology Light Source) electron storage ring for calibrations from the infrared (THz) to extreme ultraviolet (EUV) and also uses the BESSY II electron storage ring.

www.ptb.de/cms/en/about-us-careers/about-us/sites-in-berlin.html



BAM has its own department for radiological processes, which develops, applies, validates, and certifies radiological procedures with X-, gamma-, and terahertz (THz) rays. To this end, BAM is developing new two- and three-dimensional digital measuring and testing methods (computer laminography, tomosynthesis, and computer tomography) for industrial and security applications.

The **Department of Micro Non-Destructive Testing (ZFP)** is developing and evaluating non-destructive testing methods for the detection of structures and defects in



PTB in Berlin Charlottenburg: the Imperial Metrology Institute was founded here in 1887 under Hermann von Helmholtz.
© Physikalisch-Technische Bundesanstalt

the micrometre range and smaller. This is achieved with high-resolution X-ray imaging methods and quantitative 3D characterisation of the material microstructure. BAM offers special expertise in computer tomography and X-ray scattering which complement the city's industrial and academic landscape. In addition, material characterisation is the keyword for the development of competencies and apparatus such as tensile or high-temperature tests in CT and refraction devices.

www.bam.de/Navigation/EN/About-us/Organisation/Organisation-Chart/President/Department-8/Division-85/division85.html



The Berlin-Adlershof **Institute of Applied Photonics (IAP) e. V.** is a non-profit, private industrial research institution working on projects in theoretical and applied research in X-ray physics and technology. Every two years it organises the **Process-Oriented X-ray Analysis (PRORA)**.

<https://iap-adlershof.de>



The industry: market leaders and experts

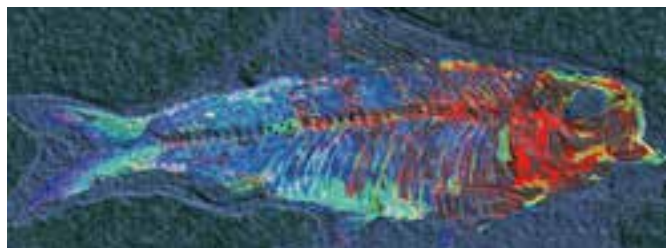
Over the years, the outstanding scientific infrastructure in Berlin and Brandenburg has favoured the founding and settlement of many companies. Some were able to develop

into world market leaders in their segment in a very short time and have since then expanded this position or were able to develop further after being taken over by international corporations.

X-ray analytics

X-ray fluorescence analysis (XRF) is a well-established method for measuring the concentration of individual elements in biological samples. For example, **Bruker Nano GmbH** offers a range of XRF devices which allow the quick metabolism testing of biological samples without having to prepare large samples. They provide valuable information on environmental influences. In addition, they are also used in building material analyses, geological investigations, and in forensics and archaeometry. In addition to X-ray analysis systems and components for element and structure analysis, Bruker Nano offers analysis systems for electron microscopes. These include energy dispersive X-ray spectrometers (EDS), wavelength dispersive X-ray spectrometers (WDS), electron backscatter diffraction systems (EBSD, Kikuchi diffraction), and micro X-ray sources for micro XRF at the SEM, as well as mobile and table-top micro XRF fluorescence (micro XRF) and total reflection XRF fluorescence spectrometers (TRFA).

www.bruker.com/nano-analytics



Multi-element map of a fish fossil taken with the M4 TORNADO micro-RFA system by Bruker
© Bruker Nano GmbH

BESTEC GmbH has settled down in the direct vicinity of Bruker Nano at Berlin-Adlershof. BESTEC GmbH develops and manufactures optical systems for the soft and hard X-ray range which are used for synchrotron radiation sources, free-electron lasers, and laser plasma sources. These include monochromators, mirror and slit systems on the illumination side, as well as spectrometers, reflectometers, and ellipsometers in the field of experimental systems.



High-resolution spectrometer and integrated sample system for the investigation of inelastic scattering processes on solid surfaces © BESTEC GmbH

www.bestec-berlin.de



The Berlin location of **Helmut Fischer GmbH** (formerly **IfG Institute for Scientific Instruments GmbH**) produces a wide range of X-ray capillary optics and micro- and nano-structured glass products at its Berlin-Adlershof location. It also offers X-ray sources (iMOXS) for such uses as X-ray diffractometry and X-ray fluorescence analysis, the latter being an additional component that can be installed on scanning electron microscopes. The X-ray fluorescence analysis is also used in measuring heads for monitoring processes such as the production of photovoltaic elements.

www.helmut-fischer.de/en/germany



Element analyses at pressures far above the ultra-high vacuum are performed by systems produced by **Specs GmbH**. This makes it possible to examine liquids, tissue, plastics, or biomaterials in a turnkey facility with high throughput. From the insertion of the sample to the result it takes less than ten minutes. Specs also develops and produces systems for electron spectroscopy (XPS), electron microscopy at low energies (LEEM/PEEM), near-ambient pressure (NAP) XPS, and SPM (scanning probe microscopy) for the investigation of non-solid or degassing substances and in situ investigations of chemical surface reactions.

www.specs.de



Medical technology continues to be a major field of application for X-ray systems. Potsdam-based company **TuR – Röntgentechnik GmbH** offers various conventional and digital X-ray solutions for the use in X-ray therapy and diagnostics as well as solutions for special requirements. They also make special X-ray machines for veterinary medicine.

www.tur-x-ray.com



Analytics for Environmental and Life Sciences

How clean is our water? What ozone levels can we expect this summer? Which contaminated sites have to be taken into account when redeveloping industrial wasteland? In order to answer such questions, environmental analysis deals with the qualitative and quantitative investigation of substances in the environment.

Here, too, closely networked structures have emerged in Berlin and Brandenburg. Large, medium-sized, and small research institutes work closely together with a large number of mainly SMEs.

In the **Department of Analytical Chemistry, Reference Materials** of the Federal Institute for Materials Research and Testing **Bundesanstalt für Materialforschung und -prüfung (BAM)**, several units are addressing various aspects of environmental analysis. These include, for example, inorganic and organic trace analysis, environmental analysis, and chemical and optical sensors. The department also has special expertise in the analysis of inorganic trace element, element species, and isotopes, in particular of high-purity substances as well as environmentally relevant, biological, and medical materials. Moreover, the department is specialised in the development of suitable analysis processes and equipment.

In the field of biophotonics, BAM is working on the development, application, and validation of optical-spectroscopic measuring methods for a wide range of liquid and solid samples, with a focus on static, time-resolved and spatially resolved fluorometry. The tasks include the characterisation of organic dyes, semiconductor quantum dots, and conversion materials; quantitative and absolute fluorescence measurements; as well as material and bioanalytical applications such as optical assays; and the development and provision of reference materials for optical spectroscopic analysis methods.

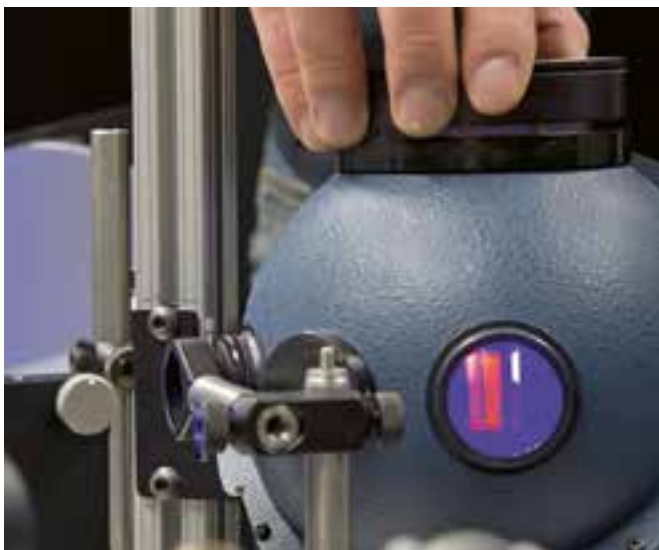
For more than 130 years, **G. Lufft Mess- und Regeltechnik GmbH**, headquartered in Fellbach, Germany, has been developing and producing professional components and systems for climate and environmental measurement technology. Following the takeover of the cloud altimeter product range from Jenoptik subsidiary ESW GmbH in April 2014, the newly established Optical Sensors business unit of G. Lufft has settled in Berlin-Adlershof. G. Lufft products and equipment are to be found wherever atmospheric pressure, temperature, relative humidity and other environmental factors require to be measured or recorded. These applications include industrial climate measurement technology, environmental technology, climatology, agricultural meteorology, and traffic engineering.

The Berlin division is primarily involved in the sale and further development of cloud altimeters and the family of laser-based snow depth sensors.

www.lufft.com



Oxygen levels can be measured without contact using lasers in a process called absorption spectroscopy. A part of Munich-based TOPTICA Photonics AG, **eagleyard Photonics GmbH** in Berlin-Adlershof offers DFB lasers that meet the strongest oxygen absorption lines. Due to their significantly higher output power compared to other lasers such as VCSEL, they are also ideally suited for industrial use under



Possible reference materials are tested in the integrating sphere by being irradiated with a light source.

© BAM

difficult measurement conditions. The excellent wavelength stability of DFB lasers eliminates the need for regular recalibration and can significantly reduce maintenance costs.

www.toptica-eagleyard.com



Colibri Photonics GmbH is an innovator for high-quality, non-invasive micro- and nanoprobe for optical measurement of oxygen levels. The customer-specific high-performance oxygen sensors are designed for use in human and plant physiology, as well as in biology and environmental analysis. Colibri Photonics' primary customer base is in the life sciences working with micro and nanovolumes, such as manufacturers of lab-on-a-chip systems for cell-based testing, neurologists, oncologists, plant physiologists, and developers of bioreactors for three-dimensional tissue engineering.

www.colibri-photonics.com



Since 2013, **Stöbich technology GmbH** has been developing and marketing innovative products in the fields of battery safety and fibre-optic sensor technology. It bundles the expertise of various companies to develop innovative products, organises joint development projects, takes over project management responsibility, and the manufacture of the resulting products. Issues the company tackles include battery management, optical gas sensors, fibre-optic sensors, and intelligent materials made from tissue structures in cooperation with the Battery and Sensors Test Centre and HHI FS in Goslar.

www.stoebich-technology.de



Sensors for food quality and safety

At the **Leibniz Institute for Agricultural Engineering and Bioeconomy e. V. (ATB)**, analytical protocols are developed based on optical sensors data. Using such methods as flow cytometry, fluorescence, and UV spectroscopy, ATB is developing rapid tests for the identification of microorganisms. Plants data obtained in-situ with thermal imaging, hyperspectral analysis, chlorophyll fluorescence kinetic analysis, absorption spectroscopy in the VIS and NIR range, are employed as input variables in physiological and agronomic models aimed at the sustainable intensification of the fresh-food production.

www.atb-potsdam.de/en



In addition to the research institutes, several companies in the region are also very involved in environmental analysis. Müncheberg-based **Umwelt-Geräte-Technik GmbH** offers an entire range of measuring instruments with which water, wind, and weather conditions or plant growth can be measured. Founder Manfred Seyfarth received a special Future Prize Brandenburg in 2017 for his commitment to ecology.

www.ugt-online.de/en



Photonic Insights GmbH designs and builds embedded systems that combine affordable and precise optical sensors for cutting-edge spectroscopy and edge-computed machine learning in the form of handheld devices to support testing without laboratory preparation. Their sensor solutions are specialised for agricultural and eco hydrological use cases.

www.photonicinsights.com



Photonic Insights Tea Scanner a tea analyser that is currently being used by a joint venture spin-off Spectrify.AI in Sri Lanka.
© Photonic Insights 2020

Comde-Derenda GmbH also specialises in innovative sensor technology and environmental measuring technology. The company based in Stahnsdorf has particular expertise in the manufacture of devices for monitoring air quality, such as sensor solutions for measuring dust and gas concentrations.

www.comde-derenda.com/en



A portable Raman laser system for field use was developed at FBH, seen here in an orchard.

© FBH/A. Müller

Sensors for a wide range of applications are also offered by **deka Sensor + Technologie Entwicklungs- und Vertriebsgesellschaft GmbH**. These include light sensors in the infrared, optical and ultraviolet ranges to complete measurement systems that monitor physical parameters such as temperature, pressure, humidity, and wind speed that are used in everything from weather stations to industrial settings.

www.deka-s-t.com



Umweltanalytische Produkte GmbH offers sensor technology for data acquisition in soil physics, meteorology, plant physiology, and hydrology. These devices allow investigations of the water and nutrient balance, biological test series, and the investigation and monitoring of contaminated sites.

www.upgmbh.com



While some companies are considering relocating their activities to Asia, there is also movement in the opposite option: the Indian company **Everest Instruments Pvt. Ltd.** established Everest Scientific Europe, a development centre in Berlin-Adlershof at the beginning of 2016. The parent

company in India specialises in monitoring the quality of milk and other foodstuffs.

www.everestinstruments.in



With the mobile phone microscope from Oculyze, for example, it is possible to count cells automatically.
© Oculyze GmbH

Oculyze GmbH in Wildau has developed an automated, digitalised, and mobile microscopy platform. The Oculyze microscope consists of a detachable optical module (~400x), a smartphone, and an Android application with integrated connection to the company server where the image recognition takes place.

The optical module is plugged onto the smartphone and the enlarged image is displayed on the screen via app. The system was first used to analyse yeast levels in the brewing process. The mobility of the platform promises many other applications for the device.

www.oculyze.de



Extensive information on research and industry in the field of microscopy can also be found in chapter 2.5 “Biophotonics and Ophthalmic Optics”.

Optical remote sensing

The **Remote Sensing of Waterways Working Group of DLR's Earth Observation Center (EOC)** has offices in Berlin-Adlershof. The working group is working on using optical methods to measure the elements found in waterways from afar.

While non-imaging sensors are used for this purpose on board ships or in the water itself, imaging spectrometers are used on aircraft and satellites to provide a separate image of the landscape for each spectral channel. Remote sensing is the only technology that can observe the high spatial and temporal dynamics of water bodies.

The imaging spectrometer MOS-IRS developed at DLR and on board the IRS-P3 satellite from 1996 to 2005 was the first instrument of its kind. It was primarily developed to lay the foundations and prove the viability of satellite-based quantitative remote sensing. The imaging spectrometer MERIS on board ESA's environmental satellite ENVISAT marked the transition to the regular provision of data for environmental monitoring by official users and to the monitoring of European environmental guidelines within the framework of the GMES programme.

www.dlr.de/eoc/en



The **Remote Sensing and Geoinformatics Working Group** at the **Helmholtz Centre Potsdam German Research Centre for Geosciences – GFZ** deals with radar and optical methods for the analysis of such geo-hazards as earthquakes, mass movements, glacier dynamics, permafrost, and anthropogenic surface deformations. The aim of the research is to develop automated procedures for monitoring and sharing radar and optical data to determine hazardous locations.

www.gfz-potsdam.de/en/section/remote-sensing-and-geoinformatics/overview



The increasing climate change has led to a number of research activities in Berlin and Brandenburg. For example, the **Research Institute for Post-Mining Landscapes (FIB)** conducts spectroscopic measurements to monitor the evaporation and water demand of different landscapes. For such tasks they use drones or images from satellites such as

LANDSAT or SENTINEL. Experts from the **Leibniz Center for Agricultural Landscape Research ZALF** also collected comprehensive know how in the interpretation of satellite data for agricultural purposes. The **Technical University Berlin** hosts a **chair of Geoinformation in Environmental Planning**. There, they measure, model and evaluate spatio-temporal landscape structures and biophysical phenomena on the local to regional scale using remote sensing and geoinformatics methods.

www.fib-finsterwalde.de/?lang=en
www.zalf.de/en
www.geoinformation.tu-berlin.de/menue/das_fachgebiet/parameter/en



Plasma spectroscopy

The **Leibniz-Institut für Analytische Wissenschaften – ISAS e. V.** is a non-university research institution based in Dortmund with a branch in Berlin-Adlershof. ISAS is developing different spectrographic methods and systems for applications in material and biomedical analytics. ISAS is working closely with companies in Berlin-Adlershof which will often also subsequently market the systems. Together with **LTB Lasertechnik Berlin GmbH**, ISAS has established an application laboratory for Raman microscopy in the VIS-UV-DUV spectral range, using the Echelle spectrometer concept developed by ISAS.

In cooperation with **SENTECH Instrument GmbH**, ISAS develops ellipsometers for thin-film analysis. These are used for tasks in the fields of biomedicine and optoelectronics.

www.isas.de/en



Arc Precision GmbH in Wildau has modular plasma sources for the highest industrial demands in its portfolio. These can be used to refine surfaces with ultra-hard coatings. The company also specialises in analysing the surfaces of coatings.

www.arcprecision.com



Process analysis of disperse materials

The research and innovation centre **innoFSPEC Potsdam** (“innovative fibre-optic spectroscopy and sensor technology”) was founded in 2008 as a joint project of the **Leibniz Institute for Astrophysics Potsdam (AIP)** and the **Univer-**

sity of Potsdam’s Physical Chemistry Department with the aim of generating innovations through intelligent application of fibre optics. **innoFSPEC Potsdam** is developing a unique fibre-optic method for the absolute quantification of optical absorption and scattering properties of highly light scattering, opaque materials. Among other things, this will enable a high-performance particle size determination in highly concentrated dispersions as inline-process analytics. In close cooperation with research and industry partners, the technology is used in the fields of food and polymer chemistry, nanotechnology, and biomedicine. Prof. Hans-Gerd Löhmannsröben, Dr. Roland Hass, and Dr. Oliver Reich founded the spin-off **PDW Analytics GmbH** from the University of Potsdam to use their research for commercial purposes.

www.innofspec.de
www.pdw-analytics.de



L.U.M. GmbH is one of the world’s leading manufacturers of instruments for direct and rapid stability analysis and particle characterisation of dispersions. With the help of the extremely powerful measuring technology, material separation processes can be analysed quickly, efficiently, and reliably, and dispersions can be comprehensively characterised. L.U.M.’s innovative analytical instruments are standard equipment in the laboratories of large chemical, food, cosmetics, and pharmaceutical companies. In addition to analytical measuring instruments, L.U.M. GmbH also offers analytical services and contract research in these same fields. L.U.M. GmbH is certified according to DIN EN ISO 9001:2000 and EN 46001.

www.lum-gmbh.com



SOPAT GmbH is a specialist for the analysis of particulate systems. The SOPAT system (Smart On-line Particle Analysis Technology) is a combination of photo-optical measurement technology and image processing software. It is used for in situ analysis of particle sizes in real time. In contrast to offline methods, this analysis takes place directly in the reactor, for the first time making it possible to control processes based on particle size. The technology allows easy measurement of drop size distribution before, during, or after a reaction, as it can be easily added to pipelines, columns, or reactors via standard flanges.

www.sopat.de



Flow measurement without media contact has been perfected by **FLEXIM GmbH**. The system works with liquids or gases and at extreme temperatures, strongly fluctuating flow rates, and pipes of any size. Refractometry, the measurement of the light refraction, has proven itself in the laboratory countless times as an analytical method for determining the concentration, density, and purity of liquids. FLEXIM shifts refractometry from the laboratory to the production process in order to take advantage of the measuring principle for inline measurements as well: speed, accuracy, reliability and the independence of gas inclusions, colour, and turbidity.

www.flexim.com/en



Constantly improving product quality while using less and less resources: this requires detailed knowledge of the production processes. **JP-ProteQ** is active in the development of measuring instruments, analysers, sensors, and automation solutions. To this end, the company adapts any manufacturer's process analysers to solve special analytical tasks as well as develops and implements metrological concepts.

www.jp-proteq.com



Thin-Film Analytics

The precision control of thin film processes is particularly relevant due to its high innovation potential and the development of new inorganic, organic, and hybrid material structures. It can be found in key diagnostics for nanotechnologies, semiconductor technologies, and materials science. It enables the accelerated development of innovative complex material systems. The technological challenges are many. These include, for example, the further development of optics (FIR to XR), light sources (miniaturisation), detectors (sensitivity, dynamics), and algorithms for data evaluation, image processing/pattern recognition, as well as the miniaturisation and optimisation of more cost-effective systems for specific material-technological applications. Component developers and manufacturers along the entire innovation and value chain are active in the region. In addition, strong research with complementary technologies is available at

large-scale facilities (synchrotron) and a strong potential user community is active in materials science.

Reflectometry on large samples

The product portfolio of **BESTEC GmbH** includes measuring systems for photon-in/photon-out technologies in the energy range from UV to soft X-ray radiation, used, for example, in spectroscopy, reflectometry, ellipsometry, and Raman spectroscopy. They are used to characterise multilayer mirrors in the optics industry and for theoretical research on synchrotron radiation sources and free-electron lasers.

www.bestec-berlin.de



Reflectometer system for large samples (sample diameter up to 1,500 mm, total load up to 800 kg) with integrated source and monochromator beam tube for the wavelength range 6 nm to 20 nm

© BESTEC GmbH

Spectroscopic ellipsometry

SENTECH Instruments, located in the Berlin-Adlershof Technology Park, specialises in thin films. The company offers plasma process technology for the structuring and deposition of thin layers and nanostructures. It offers a wide range of reflectometers as well as laser and spectroscopic ellipsometers for the characterisation of very thin layers.

SENTECH ellipsometers can now determine all elements of the Mueller calculus and thus extend the range of applications to anisotropic, depolarising, and structured samples. This innovation also enables the precise determination of refractive index, absorption, and film thickness by applying the Step Scan Analyzer (SSA) principle.

www.sentech.de





SENresearch spectroscopic ellipsometer
© SENTECH Instruments GmbH

In situ spectroscopy

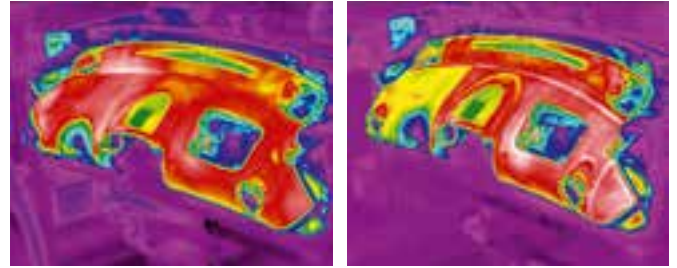
The development of in situ spectroscopy, especially vibrational spectroscopy, for the investigation of functional organic surfaces and hybrid layers is the main goal of the **In-Situ Spectroscopy Group at the Leibniz-Institut für Analytische Wissenschaften – ISAS e. V.** in Berlin-Adlershof. In particular, the group is developing methods for optical models, evaluation methods, and experimental set-ups for in situ investigation of layers and surfaces in liquid environments (reflection anisotropy, ellipsometry, Raman and infrared spectroscopy, IR microscopy, IR mapping ellipsometry at BESSY II). Combined laboratory and synchrotron measurements concentrate on the properties of functional layers and the adsorption of molecules on such surfaces, for example functional polymer brushes or specific linker films for bio- or solar cell applications. They are also developing measurement concepts for faster analyses with higher sensitivity and higher lateral resolution.

www.isas.de/en/institute/departments/interface-analytics/in-situ-spectroscopy



Imaging spectroscopy of optical layers

Thin layers are used in optics to determine the reflection and transmission behaviour of surfaces and optical components for UV, VIS, and IR radiation in a targeted manner. Typical applications are the manufacture of reflecting elements (e.g. mirrors) or the anti-reflective coating on many optical surfaces (e.g. eyeglass lenses, objectives, prisms, displays, plates, and OLEDs). The main materials used are metals with high absorption or reflectivity and dielectric materials with high transparency.



Thermographic recording of a vehicle cockpit component with identified defect (left) and after optimisation (right)

© GTT Willi Steinko GmbH

The NIR hyperspectral imaging camera “uniSPECx.xHSI” from **LLA Instruments GmbH** can measure the spectral characteristics of the reflection and transmission level of optical components in the wavelength range between 350 nm and 2,200 nm with spatial resolution. A typical application is automated full-surface material testing of spectacles or filter glasses with dielectric coatings directly after the evaporation process in the UV, VIS, and NIR spectral range. However, a great deal of attention is being paid to another application of LLA cameras: they can be used to classify plastic waste very quickly. For example, they can recognise PVC to allow for automatic sorting.

www.lla-instruments.com



Infrared thermography

Today, non-contact temperature measurement with an infrared sensor is state of the art in almost every industrial sector or research laboratory. Berlin-based **Optris GmbH** develops, produces, and sells handheld laser thermometers, stationary pyrometers, and infrared cameras made in Germany. The measuring instruments are not only used in innovative fields such as 3D thermography, laser technology, and additive manufacturing, but also in classic processes such as in the steel and plastics industries. In the injection moulding process in the plastics industry, for example, 60 to 70 % of all moulding defects responsible for inadequate quality and overly long cycle times are caused by improper control of the mould temperatures. High-resolution infrared cameras allow thermal faults to be detected inline as they occur. In this case, images of the moulded parts are created in each cycle and analysed using a reference image. An alarm is sounded if deviations are identified.

www.optris.com





EpiTT in situ sensor to analyse growth during MOCVD and MBE processes
© LayTec AG

Measurement technology for thin film processes

Founded in 1999 as a spin-off of TU Berlin, **LayTec AG** has a leading position in process-integrated optical measurement technology for thin-film processes. The company's measurement systems are used in various areas such as optoelectronics, electronics, photovoltaics, optics, photonics, and the semiconductor industry as well as in the manufacture of flat panel displays, memory chips, etc. They monitor the growth processes of crystal layers, for example, in metalorganic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE). The company uses and combines optical measurement techniques such as reflection, emissivity-corrected pyrometry, laser deflectometry, reflection anisotropy spectroscopy, and scattered light and photoluminescence measurements to monitor the fabrication of nanodimensioned thin film structures. Optical methods are used to check the temperature, dimensions, quality, and surface finish of each sample. This is done either in situ directly during the process or inline between the individual coating steps of multilayer structures, shortening the development cycles and increasing the process yield.

www.laytec.de



Certified testing of coating systems and surfaces

The **Surface Modification and Measurement Technology Department** of the Federal Institute for Materials Research and Testing **Bundesanstalt für Materialforschung und -prüfung (BAM)** investigates thin layers and functional surfaces such as hard coatings (e.g. wear protection), optical coating systems (e.g. UV protection), and metallic coatings

(e.g. corrosion protection or electromagnetic shielding). Many accredited test methods (DIN EN ISO/IEC 17025) are available for investigating the mechanical, optical, microstructural, and chemical characteristics of surface and layer parameters as well as general surface and layer properties such as surface topography and energy, layer thickness, and adhesion.

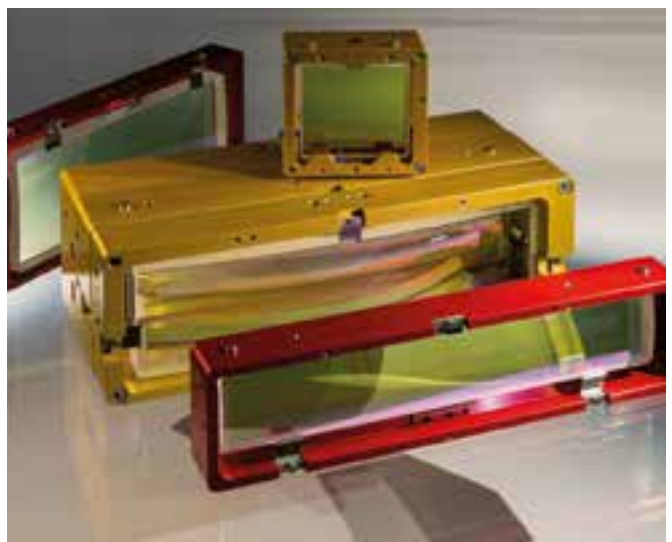
www.bam.de/Navigation/EN/About-us/Organisation/Organisation-Chart/President/Department-6/Division-67/division67.html



Nanotribology and nanostructuring of surfaces

Analytical methods for tribology, mechanics, electrics, and optics on the submicrometre scale are the specialty of **BAM's Department of Nanotribology and Nanostructuring of Surfaces**. Among other topics, the department is researching the structure-property relationships of complex polymer systems. Understanding the mechanisms of failure and damage in composites, inner and outer surfaces, and how polymer solids interface with organic, inorganic, and metallic solids is another focus of the department.

www.bam.de/Navigation/EN/About-us/Organisation/Organisation-Chart/President/Department-6/Division-66/division66.html



Framed optics for high-precision laser beam guidance in tension-optimised holders
© Berliner Glas Group

Optical coatings

The **Berliner Glas Group** offers coatings for a wide range of substrates and for wavelengths from VUV to the IR range. Many years of experience with various types of coatings enable the development team to find the best possible solutions from coating design to serial production. Customer-specific development and coating tasks include: anti-reflective (AR) and mirror (HR) layers, polarising and non-polarising beam splitters, various filters (transmittance, edge, and laser protection filters), absorption layers, various mechanical wear protection layers (also DLC), as well as bondable and solderable layers.

www.berlinerglas.com

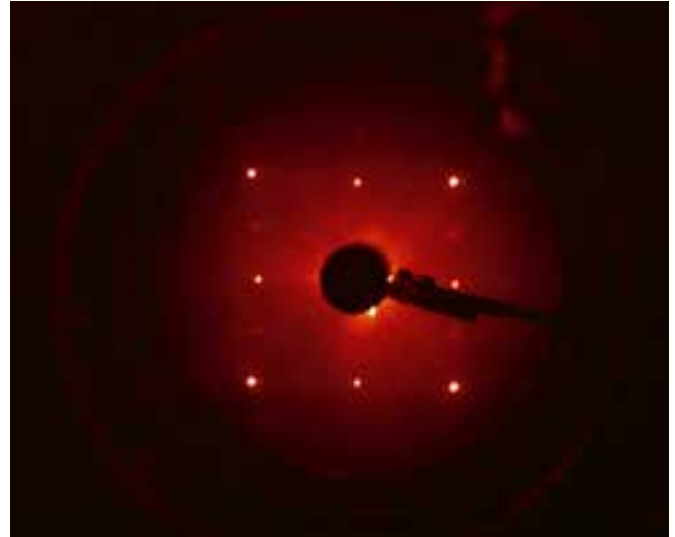


At PVcomB, thin-film photovoltaic technologies and products are developed jointly with the industry.

© Berlin Partner for Business and Technology – Monique Wüstenhagen

Thin-film technologies for photovoltaics

At the **PVcomB Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin** thin-film photovoltaic technologies and products are jointly developed with the industry. Technology and knowledge transfer take place in research projects with industrial partners and through the training of highly qualified specialists. PVcomB offers support for industrial partners at the start of production or in the further development of industrial processes. It enables the research of promising new high-risk concepts and operates the transfer and upscaling of results from the theoretical research performed at HZB and TU Berlin up to the PVcomB standard size of 30 x 30 cm². Industrial partners can use the PVcomB reference lines as benchmarks, for example for new or alternative materials, analytics, and process con-



LEED diffraction image

© greateyes GmbH

trols. In a close collaboration between Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), Technische Universität Berlin (TUB), the University of Applied Sciences Berlin (HTW) and other partners, PVcomB educates qualified engineers and academics.

www.helmholtz-berlin.de/projects/pvcomb/index_en.html



LEED imaging and measuring layer thickness in the EUV range

Low-energy electron diffraction (LEED) can be used to study the arrangement of atoms on surfaces and in thin films. The material being investigated is illuminated with an electron beam. The electrons scattered on the sample surface are displayed on the monitor and create a characteristic diffraction pattern for the surface. This pattern provides information about the arrangement of the atoms and thus the composition of the sample. In the adjacent example image (LEED diffraction image), a sample was bombarded with electrons and the resulting diffraction pattern was recorded by the GE 1024 1024 BI MID camera from **greateyes GmbH**. The camera's high sensitivity makes even weak diffraction reflections visible.

www.greateyes.de/en



Industrial Image Processing

Industrial image processing is used in almost every application imaginable. Today it is impossible to conceive of all sorts of production processes, as well as many testing and service areas, without it. The applications are correspondingly wide, ranging from agriculture to mechanical engineering, from the pharmaceutical industry to aerospace, to name but a few. Industrial image processing is a cornerstone of Industry 4.0, but there are also many prospects for research: the possibilities range from automated microscopic examination to the automatic acquisition and evaluation of aerial images. Industrial image processing technology is used to handle a wide range of tasks, including lighting, sensors, data transmission, and data processing. This Report reveals close ties to such topics as lighting and colorimetry (chapter 2.2 “Lighting Technology”), sensor technology (chapter 2.6 “Microelectronics and Microsystems Technology”), but also to transmission technologies (chapter 2.3 “Photonics and Quantum Technology for Communications and Sensors”) and to various sensor topics described here.

ISRA Vision Graphikon GmbH is based in Berlin-Adlershof. The company was integrated into ISRA Vision AG in 2010 to take advantage of growth opportunities in the solar market. Today, ISRA Vision AG in Darmstadt is one of the world’s leading companies in the machine vision sector. Among its most important applications are robot vision, surface vision, and quality inspection.

www.isravision.com



A relatively new company is **5micron GmbH**. The current portfolio of 5micron GmbH is divided into two segments: surface measurement technology and special lighting systems. In the field of surface measurement, the company is developing projects based on optical methods primarily for the aerospace industry. The methods with resolutions in the micrometre range include deflectometry, the shadow-casting method, and pattern projection. The company’s work in special lighting systems concentrates on data transmission by light.

www.5micron.de



The main area of business for **Bi-Ber GmbH & Co. Engineering KG** is the development and manufacture of image processing systems for quality control during production. The focus is on the development, construction, and commissioning of turnkey optical measuring and testing systems, especially for the printing, automotive parts, medical technology, and electronics industries. Standard solutions are also supplied for quality assurance in the confectionery industry, e.g. image processing systems to ensure candy moulds are empty, 3D inspections of broken moulds, and final product inspections.

www.bilderkennung.de



Camera on axis in front of a printing web
© Bi-Ber GmbH & Co. Engineering KG

The company **OEG GmbH** develops and manufactures measuring systems for optical, geometrical, and physical parameters, for example for the measurement of effective focal length, back focal length, centering, MTF, MTF of image intensifier tubes, small angles (prism angle, deflection angle). Moreover, the company supplies optical instruments like collimators and autocollimators. The scope of supply covers the complete manufacturing process from the development to the principle, the mechanical construction and manufacturing, development of software and electronics, the assembly and on-site installation. The measuring systems are usually software controlled and based on image processing for data acquisition. Beside the measuring systems for optical parameters OEG GmbH produces special optical measuring systems for drawing tools, contact angle

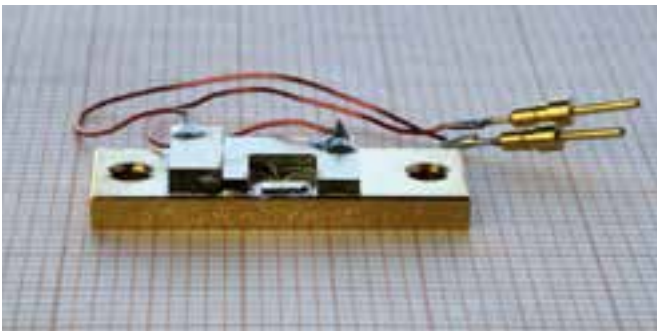
meters for the semiconductor industry with wafer robot, car windshield scanners, and precision wafer scribes

www.oeggmbh.com



THz Waves create completely New Insights

In the electromagnetic spectrum, the terahertz (THz) regime lies in the hard-to-reach range between the wavelengths of infrared radiation and radio wavelengths (frequencies approx. 0.1 THz to 10 THz, wavelengths approx. 30 μm to 3 mm). This results in different approaches to beam generation. The fully electronic systems based on the multiplication of millimetre wave radiation sources typically reach frequencies of up to 1.4 THz, and even 2.5 THz in exceptional cases. The **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH)** in Berlin and **IHP – Innovations for High Performance Microelectronics** in Frankfurt (Oder) are developing the components for such radiation sources. In optoelectronic systems, THz radiation is generated by mixing the frequency of two infrared lasers. Depending on the technical realisation, frequencies can be as high as 2.5 THz or, if a pulsed laser is used, even 10 THz.



THz-quantum cascade laser from GaAs/(Al,Ga)As
© PDI

In Berlin, the **Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute HHI** is a pioneer in this field. For some years now, a special type of laser, the quantum cascade laser, has increasingly come into use. This makes laser spectroscopy methods in the THz range applicable for the first time. The **Paul-Drude-Institut für Festkörperelektronik (PDI)** in Berlin is one of the world's leading developers and manufacturers of these lasers and the **German Aerospace Center (DLR) Institute of Optical Sensor Systems** in Berlin is a global leader in the application of these lasers for

spectroscopy. One example is the unique quantum cascade laser system developed by DLR and PDI for high-resolution spectroscopy with the SOFIA astronomy aircraft, which has been providing unique data about our universe since 2014. THz radiation can permeate materials such as paper, plastics, or textiles, while metals or water are largely resistant. As a result, THz radiation can be used to illuminate objects, but without the harmful properties of X-rays. This results in interesting applications in inline sensor technology, analytics, non-destructive material testing, and imaging. A new field of research is communication by means of THz radiation.

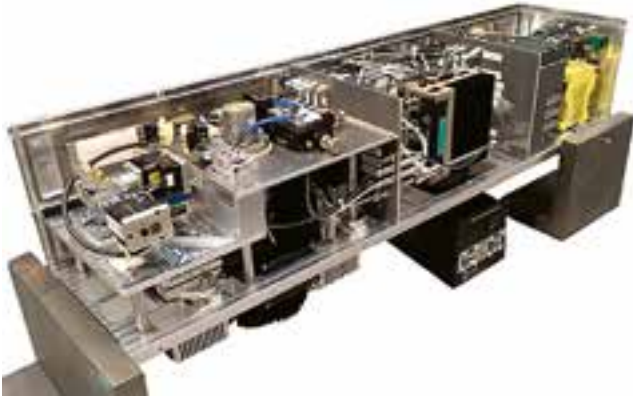
The technology is seeing its first applications in industrial settings. In gas analysis, THz measurements allow highly sensitive and highly specific analyses of gas mixtures, a task which previously required low-temperature turbo bolometers. Non-contact layer thickness measurement on plastic components, foams, and multilayer coatings has only been made possible with THz technologies. THz near-field microscopy allows high-resolution material analyses for the semiconductor industry. The Federal Institute for Materials Research and Testing **Bundesanstalt für Materialforschung und –prüfung (BAM)** and the **Physikalisch-Technische Bundesanstalt (PTB)**, both in Berlin, are active in the field of non-destructive testing with THz radiation, providing a one-of-a-kind calibration service for THz detectors.

In addition, the capital region is very well positioned to conduct theoretical research with THz radiation. These include Berlin's universities, the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, and Helmholtz-Zentrum Berlin. In a national and international comparison, the Berlin Brandenburg region has a unique bundling of competencies in theoretical and applied THz research and development.

Many approaches for developing THz sources, components, and systems

Transferring THz technology into new fields of practical and commercial use requires the development of the necessary components and systems as well as powerful measurement methods. The research institutions in Berlin and Brandenburg are active in many areas.

The **FBH** is currently expanding its THz activities systematically, with a focus on fully electronic components in frequency ranges up to 0.5 THz. This is based on a transferred substrate process with indium phosphide hetero-bipolar transistors for the manufacture of integrated circuits. This is complemented by a measuring station for on-wafer measurement of up to 0.5 THz and the associated design activities.



THz laser system for the stratospheric observatory for infrared astronomy
© DLR

www.fbh-berlin.com/research/iii-v-electronics/terahertz-electronics



The **IHP – Innovations for High Performance Microelectronics** focuses on the research and development of technologies, circuits, and systems for millimetre waves and THz applications. Among other things, it is developing complex SiGe BiCMOS technologies purpose, which operate with special silicon-germanium hetero-junction bipolar transistors (HBTs) and frequencies from 0.5 to 0.7 THz. Together with the electrophotonic technologies developed by IHP, these can be used to realise high-frequency circuits for wireless as well as electrical and electro-optical broadband communication.

www.ihp-microelectronics.com



The **Paul-Drude-Institut für Festkörperelektronik (PDI)**, a Leibniz Institute in Forschungsverbund Berlin e. V., is developing quantum cascade lasers (QCLs) for the THz range (2 to 5.7 THz) based on the material systems GaAs/(Al,Ga)As and GaAs/AlAs. These QCLs are narrow-band radiation sources and are used for such things as spectroscopic applications and imaging methods developed at the German Aerospace Center in Berlin. At PDI, they are designing and manufacturing the laser structures using molecular beam epitaxy. The QCL structures are then processed in laser strips and the operating parameters determined by Fourier transform spectroscopy.

www.pdi-berlin.de



THz spectrometers for mobile use

The **German Aerospace Center (DLR), Institute of Optical Sensor Systems** in Berlin is developing THz spectrometers based on QCLs and electronic THz emitters and receivers. These spectrometers can be used in a variety of ways: for high-resolution molecular spectroscopy and the highly sensitive detection of trace gases. An outstanding example is the THz QCL laser system developed by DLR for SOFIA, the Stratospheric Observatory for Infrared Astronomy. It is based on a QCL made by PDI. This unique technology allows a new way to peer into the universe and offers new applications beyond astronomy. For applications in THz imaging, for imaging spectroscopy, and for applications in security and material testing, the DLR imaging process is based on a single-pixel camera and compressed sensing methods. In addition, DLR is researching superconducting THz detectors, with a focus on highly sensitive nanostructured bolometers. The technology is also used to detect ultrashort (ps) THz pulses.

www.dlr.de/os/en



The research conducted at **Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI** includes fast optoelectronic THz emitters and detectors. The use of mature technologies and components from indium-phosphide-based telecommunication enables the production of robust and powerful THz systems covering the frequency range from 0.1 to 6 THz. These glass-fibre-based systems have become the worldwide standard for optoelectronic THz systems in recent years, as many beam sources and components are available in high quality. The THz transmitters and receivers developed at Fraunhofer HHI are used both in THz spectroscopy



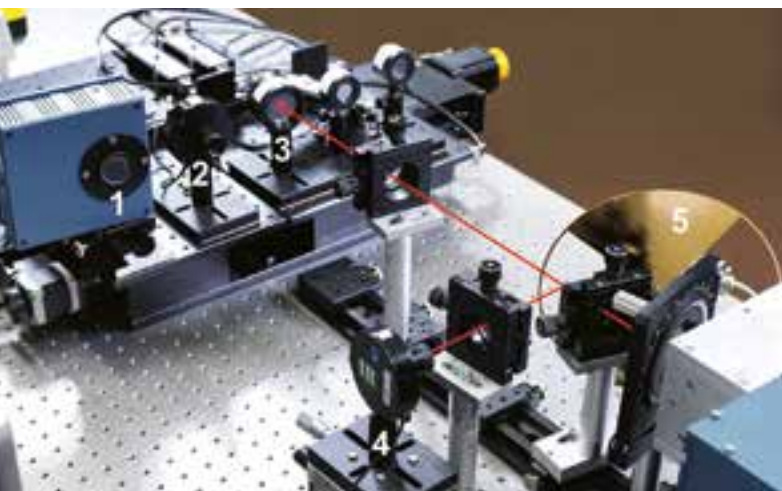
THz module for mobile use from Fraunhofer HHI
© Fraunhofer HHI



Pyroelectric measuring heads for THz radiation
© SLT Sensor- und Lasertechnik GmbH

copy and increasingly in the field of non-destructive testing and process control. One example is the non-contact measurement of the wall thickness of plastic pipes during the manufacturing process with an accuracy of less than 10 μm . Based on this technology, HHI launched an integrated fibre-coupled THz transceiver in 2016 that combines a THz transmitter and receiver on a single indium phosphide chip. This configuration enables THz reflection measurements under vertical beam incidence, resulting in very compact, robust, and powerful THz probes. This is one of the most important prerequisites for further applications for THz technology.

www.hhi.fraunhofer.de/en



THz calibration measuring station with THz camera (1), standard detector (2), and device under test (3) being hit by the THz laser beam (red line). When the gold-plated chopper (5) interrupts the beam, the monitor detector (4) measures the THz output.

© PTB

Pyroelectric THz detectors not requiring cooling were developed in a partnership between the **Physikalisch-Technische Bundesanstalt (PTB)** in Berlin and **SLT Sensor- und Lasertechnik GmbH** based in Wildau. In 2017, the development team received the special “Young Company” award

from the AMA Association for Sensor and Measurement Technology for this innovation. As a unique selling point, these detectors exhibit a constant spectral sensitivity in the entire THz spectral range and have been successfully sold with individual PTB calibration certificates by SLT worldwide. These detectors are the first that allow the measurement of the THz output of the THz emitters developed at Fraunhofer HHI.

www.pyrosensor.de



The Federal Institute for Materials Research and Testing **Bundesanstalt für Materialforschung und -prüfung (BAM)** in Berlin is working on potential applications of commercially available time-resolved THz spectrometers (THz-TDS) for the spectroscopic investigation of dielectrics. Their initial THz activities in the field of spectral material characterisation of liquids, fires, and hazardous substances were supplemented by questions on contactless and non-destructive material testing for the detection of internal defects and structural structures of planar and spherical objects. For the characterisation of multiple layers in planar dielectric composite systems using the THz TDS, a THz time-of-flight optical layer model was developed to measure the layer build-up in terms of material thickness and identify defects by scanning a dielectric object. The THz-TDS-SAFT tomography was developed for the non-destructive testing of three-dimensional dielectric components. It is used to reconstruct the internal structures of components after scanning with THz radiation. The focus is on the visual detection of material defects, such as pores or cracks in 2D and 3D images. BAM focuses its activities primarily on materials testing. THz TDS is being prepared for use in industry applications such as the non-destructive testing of polymers, ceramics, and high-performance materials. The hope is that it will offer a viable alternative to existing test systems.


www.bam.de/Navigation/EN/About-us/Organisation/Organisation-Chart/President/Department-8/Division-83/division83.html



Calibration and standards

The **Physikalisch-Technische Bundesanstalt (PTB)** in Berlin is the only place in the world where the spectral sensitivity of THz receivers can be traced back to the SI. This calibration service with a THz molecular gas laser not only serves

the leading manufacturers of THz detectors in the frequency range from 700 GHz to 5 THz, but above all customers working in the research and development of THz systems and their users all over the world. In addition, a further measuring station with a state-of-the-art fibre-coupled THz TDS system from Fraunhofer HHI permits precise characterisation of material properties (transmission, reflection, and absorption) in the THz spectral range. SLT's pyroelectric THz detectors are the basis for the first calibrated THz reference material for use in precisely measuring transmission and reflection. In addition, the PTB in Berlin-Adlershof operates the Metrology Light Source electron storage ring, which can generate coherent THz radiation. PTB carries out spectroscopic work in the THz spectral range on a dedicated THz beam tube, partly as part of its several partnerships.

www.ptb.de/cms/en/ptb/fachabteilungen/abt7/fb-73/ag-734.html 

Promoting collaboration

Berlin is a popular place to go for international research in the field of THz waves. And collaboration within the region itself is helping to ensure success in national and international competition. One example is a partnership between Berlin-based **eagleyard Photonics GmbH** and the DLR, FBH, Humboldt University, and PDI to develop compact THz quantum cascade lasers for spectroscopic applications. This has resulted in the world's most compact THz laser system.

As part of the **PolyPhotonics** joint project, Fraunhofer HHI is developing a technology platform that can also be used in the THz range. The special feature here is the material: the core of the platform consists of a chip with optical waveguides made of polymer material, which can accommodate further passive elements such as glass fibres, thin-film filters, and micro-optics as well as active components such as photodiodes or laser chips (see chapter 2.3 "Photonics and Quantum Technology for Communication and Sensors").


www.polyphotonics-berlin.de 

Beyond THz

... is where the radar range begins. What is traditionally associated with large rotating antennas at airports or on ships can now be accommodated on a microchip. Such technology was developed at IHP in Frankfurt (Oder) and brought to market by **Silicon Radar GmbH**. Its high-frequency switching is used in radar solutions, phased array systems, and wireless communication applications. Silicon Radar is developing customer-specific ASICs and standard components in the frequency range from 10 GHz (X-band) to 200 GHz and beyond. These miniature radar systems, which can be used for precise distance measurements or as fill level sensors, were awarded with the Brandenburg Future Prize in 2016.

www.siliconradar.de 

Contact: Dr. Michael Kolbe

Spokesperson Focus Area Optical Analytics 

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2.5 Biophotonics and Ophthalmic Optics – Photonics in Life Sciences

Whether prevention, diagnostics, therapy, or analytics: without optical methods, modern medicine could only achieve a part of what it is now capable of. Reliable diagnostics are essential in medicine in order to achieve therapeutic success. The precise analysis of chemical compounds, biological macromolecules, cells, and microorganisms has enabled many new insights in recent years. Microscopy and spectroscopy are the cornerstones of this progress.

Nowadays, more samples can be analysed thanks to new methods in fluorescence microscopy. The 2014 Nobel Prize in Chemistry was awarded to William Moerner, Eric Betzig, and Stefan Hell (Director at the Max Planck Institute for Biophysical Chemistry in Göttingen), demonstrating the groundbreaking character of these developments. This has opened up a completely new area beyond the resolution limit in microscopy not only providing impulses in research but also changing medical practice in future.

“There are many new developments and trends, especially in optical technologies. Laser technology has become an indispensable part of ophthalmology, there are new imaging methods and optical measuring methods, and we are training the needed specialists herein in Berlin Brandenburg.”

Prof. Dr. Justus Eichstädt | Spokesperson Focus Area Biophotonics and Ophthalmic Optics, TH Brandenburg and Chairman of the Board of Laserverbund Berlin-Brandenburg e. V.



Research and Healing

Optical technologies in dermatology and cancer therapy

As the most research-intensive hospital in Germany, Berlin's **Charité** is very interested in testing new optical and photonic technologies. Such new technologies can be implemented particularly quickly in fields like dermatology, since these methods do not work endoscopically and do not need to be miniaturised. Scientists and doctors at the **Center of Experimental and Applied Cutaneous Physiology (CCP)** are investigating basic dermatological questions as well as new medical applications.

<https://ccp.charite.de/en/>



Optical and photonic methods now play a decisive role in almost all research projects. The team led by Prof. Jürgen Lademann (Head of the CCP) was for the first time successful in using modern spectroscopy to show that nanoparticles can also be absorbed by hair follicles. A new field seeing tremendous growth internationally is using cold plasmas to heal wounds. Such plasmas approximate skin temperature and have great potential to disinfect protracted wounds and

enable the healing process to start. Here, too, spectroscopic methods are playing a decisive role in characterising the entire process.

Using Raman resonance spectrometry, the researchers led by Prof. Lademann were able to quantify harmful excretions of chemotherapeutics in cancer patients via the skin. This enables new treatment methods for this often very unpleasant side effect of chemotherapy.

https://derma.charite.de/en/metas/person_detail/person/address_detail/lademann/



Protecting oneself from the sun's rays is a particularly important step in preventing malignant skin cancers. Absorption spectra were used to determine that not only UV radiation is harmful. Longer wavelength components in the visible and infrared light can also increase stress on the skin by increasing the number of free radicals.

Magnosco GmbH offers an optical analysis method for malignant skin cancer, allowing non-invasive and painless examination of atypical and dysplastic skin lesions.

Magnosco was founded in 2014 by LTB Lasertechnik Berlin. LTB had developed the method for the early detection of melanomas which uses infrared laser light to excite the skin pigment melanin. Fluorescence allows the early detection of the molecular structure of melanomas.

www.magnosco.com/home



Multiphoton tomography from **JenLab GmbH**, now also based in Berlin, offers non-invasive, marker-free in vivo examination of the skin with the highest spatial and temporal resolution to date. Intra- as well as extracellular structures can be investigated with a resolution of only 300 nm within seconds on the screen. This is due to clinical multiphoton tomography, a new form of high-resolution imaging using femtosecond lasers. This allows individual mitochondria, melanosomes, and cell nuclei as well as the elastin and collagen network to be mapped three-dimensionally in situ without any staining.

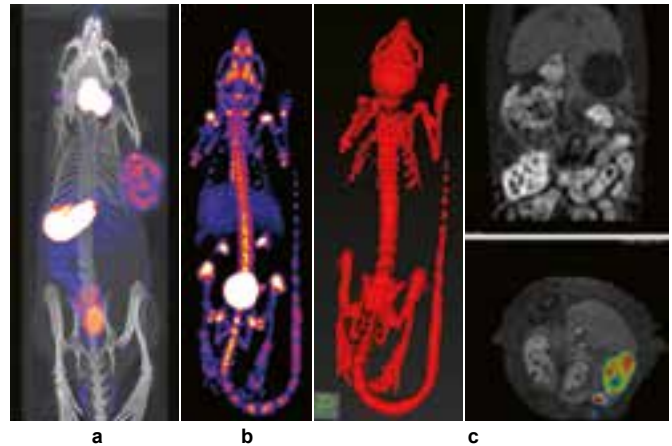
www.jenlab.de



Multi-photon tomographs can perform optical skin biopsies within seconds
© JenLab GmbH

Both nationally and internationally, the Charité plays a pioneering role in medical imaging. Thanks to its excellent equipment, the imaging value chain is almost completely covered, supporting scientific excellence and collaborative projects.

The **Berlin Experimental Radionuclide Imaging Center (BERIC)** as the core facility of the faculty, together with the Clinic for Nuclear Medicine, offers all modalities of modern



a) SPECT/CT of a mouse with sodium iodide symporter (NIS-)transfected subcutaneous tumour (Tc-99m pertechnetate uptake)
b) Tc-99m MDP skeletal scintigraphy of a mouse (left) and quantification
c) PET/MRT of a rat with liver tumour (below: FDG uptake)
© Berlin Experimental Radionuclide Imaging Center, Charité Universitätsmedizin – Berlin

hybrid imaging of experimental animals with radiopharmaceuticals. Molecular imaging using single-photon emission computed tomography (SPECT) and positron emission tomography (PET) with corresponding radioactively labelled tracer substances enables non-invasive quantitative characterisation of physiological and pathological processes in the organism with high sensitivity, e.g. for the diagnosis of tumours, neurodegenerative diseases including brain perfusion measurements, infections, and metabolic diseases such as bone metabolism disorders. The BERIC, partly funded by the German Research Foundation and the Future Fund of the State of Berlin, is equipped with a modern high-resolution small animal SPECT/CT (nanoSPECT/CT plus, Bioscan/Mediso) and a state-of-the-art small animal PET/MRT (PET/MRI, Mediso). The BERIC is generally available as a core facility for external academic working groups as well as for contract research.

https://www.charite.de/en/research/research_support_services/forschungsinfrastruktur/imaging/



Imaging methods in neurology

The **Berlin Center for Advanced Neuroimaging (BCAN)** offers research infrastructure for neuroscientific imaging in the heart of Berlin. The BCAN houses two state-of-the-art Siemens 32-channel 3-Tesla magnetic resonance tomographs for cognitive, neurological, and psychiatric experiments.

www.berlin-can.de



Brain imaging is a key technology in theoretical and clinical strokes research. To better address these problems, the **Small Animal Imaging Center** was opened at Charité's Virchow campus in 2010. In addition to classical light microscopy, newly developed fluorescence tomography methods are used to investigate pathophysiological processes on animal models and to study the efficacy of new therapeutic approaches.

The new center was made possible by the cooperation of Charité and industrial partners and driven by the **Imaging Network Berlin**. The network brings together academic institutions including the Charité, pharmaceutical companies, large-scale equipment manufacturers, and small and medium-sized enterprises from Berlin. All stakeholders agree that they see great potential in medical imaging for the medicine of the future. And with it for the Berlin Brandenburg region: both in terms of equipment and scientific excellence, the players represent the value-added chain of medical imaging.

www.healthcapital.de/en/medical-technologies/portrait/



Diagnosis of biofilm infections

The Imaging Network is not the only initiative in the region that is working on the development of optical methods for use in medicine by connecting companies and research institutions. **DiagnostikNet-BB** is bringing together diagnostics and equipment manufacturers, suppliers and users from clinics, and routine laboratories as well as research institutions in the Berlin Brandenburg region to promote innovations in the field of in vitro diagnostics.

www.diagnostiknet-bb.de/en/



The Federal Ministry of Education and Research has set up the **iSOLID** joint project to develop an innovative digital image diagnostic system for the specific diagnosis of biofilm infections. Infectious diseases are among the ten most frequent causes of death in Europe. Many of these infections are caused by biofilm infections that are difficult to diagnose. The goal of iSOLID ("Integrated Solutions for Infection Detection") is the fast and reliable detection of such infections using digital image diagnostics and the recommendation of a suitable therapy.

<http://isolid.org>



Among others, the **Biofilm Center of the German Heart Center Berlin** is involved in this joint project. Specific - of biofilm-induced infectious diseases are possible using fluorescence in situ hybridisation (FISH). This diagnostic method is based on fluorescence-labelled DNA probes and combines the advantages of molecular biology, fluorescence microscopy, and histology. However, the FISH method uses very large amounts of image data, the analysis of which is complex and time-consuming. Within the framework of the iSOLID joint project, a digital method for image analysis will be developed to allow the automatic detection and quantification of microorganisms.

www.dhzb.de/en/departments/cardiothoracic_and_vascular_surgery/research/biofilm_center_of_the_german_heart_center_berlin



Optical technologies facilitate everyday life in wheelchairs.
© Makea Industries GmbH

Optical technologies in everyday life

Optical technologies will also make an important contribution to better integration of people with disabilities. As part

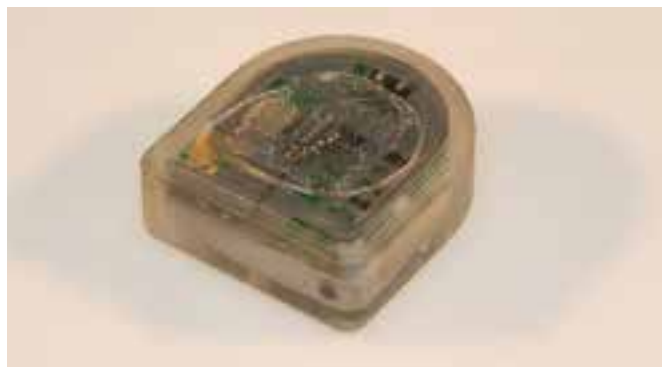
of the “Light Cares” competition, ten projects that make everyday life easier for people with disabilities were awarded prizes at **FabLab Berlin** in 2016. Many of these helpful ideas have come from the “maker scene”. Participants in this do-it-yourself movement, which is popular around the globe, use digital photonic manufacturing processes such as 3D printing and laser cutting. Two of the ten winners come from Berlin, one from Potsdam; the others are spread across Germany. **Makea Industries GmbH** from Berlin won two awards, one for its precision-fit prostheses made with a 3D printer, and the other for its freely producible products for wheelchairs. All in all, a digitally accessible open source solution has been created. **Wissenschaftsladen Potsdam** also won a prize with its project “Fabricate Your Living Aid and Digital e. V. Transformation of Laboratories”.

www.fablab.berlin



New Technologies for Medicine

The gap between microelectronics and biotechnology has narrowed considerably in recent years, a process mainly driven by the fact that methods using nanoscale structures are being developed in both areas. Based on this convergence, the new field of bioelectronics has emerged. It addresses the integration of electronic systems into biological environments and investigates the interaction between these different material worlds. The most important developments are currently taking place in the field of biosensors where the increasing miniaturisation allows to integrate micro-sensors into biological or biotechnological systems. **TU Berlin** and the **IHP – Innovations for High Performance Microelectronics** operate a Joint Lab for Bioelectronics.



Biosensor implant encapsulated in silicone
© IHP – Innovations for High Performance Microelectronics

www.bioprocess.tu-berlin.de/menue/joint_lab_bioelectronics



Precise optical sensors are indispensable for determining the seriousness of tumours and the concentration of such substances as hemoglobin in blood. Several companies in Berlin Brandenburg is working on such devices, which will need to be reliable enough for everyday clinical use. This includes the photometer specialist **ROBERT RIELE GmbH & Co KG** as well as **Chembio Diagnostics GmbH** (former opTricon), which produces point-of-care diagnostic devices.

www.riele.de
www.chembiogermany.de/en



The **Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI** is also developing compact sensors for biomedical applications. These sensors contain silicon nitride chips, which are available in large numbers. They are highly sensitive and can quickly detect molecules in liquids, gases, and powders. All biological fluids such as blood serum, whole blood, urine, saliva, sweat, etc. can be analysed with this measuring principle. Even gases such as traces of explosives (TNT) or poison gas can be placed on the surface of the chips for analysis. In cooperation with the medical applications centre of the Charité, First Sensor AG and SCIENION AG are finding ways to bring this knowledge to market.

www.hhi.fraunhofer.de/en/departments/pc.html



In June 2017, Berlin-based start-up **DiaMonTech GmbH** won the prestigious “Start me up!” award of the business magazine BILANZ. The team led by Frankfurt biophysicist Werner Mäntele won for its non-invasive blood glucose measurement system. The device is currently still the size of a shoe box, but soon it will be reduced to the size of a watch that can be readily worn by patients.

www.diamontech.de



Berlin-based **Humedics GmbH** has specialised in the fast and precise measurement of liver function by analysing the air exhaled by patients. The test can be performed directly at the bedside and provides physicians with accurate information for therapeutic decisions on diseases involving liver

insufficiency. It can thus contribute to an improvement of the treatment result. The technology has already been used with thousands of patients and was awarded with the Berlin Brandenburg Innovation Prize in 2014.

www.humedics.eu



Another globally active group with its headquarters in Berlin is **W.O.M. World Of Medicine GmbH**. It offers a broad portfolio of minimally invasive medical products. In minimally invasive medical interventions, surgical teams insert cameras and special surgical instruments into the body through small incisions. For surgeons to operate on the abdomen, knee, or shoulder laparoscopically, good camera images and the right light are necessary. The optics experts at W.O.M. have therefore developed the light sources, primarily on an LED basis, for integration into the camera systems. Together, the two ensure natural colours and optimal resolution on the OR monitors.

www.wom.group/en



GETEMED Medizin- und Informationstechnik AG specialises in cardiological functional diagnostics as well as in outpatient monitoring and telemonitoring of vital signs in high-risk patients. **Medipan GmbH** offers radio-immunoassays for thyroid gland examinations and tests for the measurement of auto-antibodies for type-I diabetes. Immuno-fluorescence can also be used to detect autoimmune diseases. Fluorescence markers allow rapid measurement of DNA damage and repair processes.

www.getemed.net/en
www.medipan.de/en



Smedo GmbH develops a technology to seamless and contactless measuring of vital signs in ECG grade within a distance of up to 7 meters to the target – even in the absolute dark, through fabric and during motion.

www.smedo.de



Adlershof-based **MGB Endoskopische Geräte GmbH** specialises in the development of high-quality endoscopes. From suitable light sources to cameras, the company supplies systems for many types of medical applications.

www.mgb-berlin.de



Fiagon GmbH is also developing new concepts for computer-assisted surgery, including electromagnetic navigation. This allows surgical instruments to be tracked directly at the tip.

www.fiagon.de/ous/



Xion GmbH offers complete endoscopy systems for every kind of minimally invasive surgery including endoscopes, cameras, and illumination systems as well as software for analysis, processing, and archiving. **Karlheinz Gutsche GmbH** also produces micro-optical components for endoscopes.

www.xion-medical.com/en
www.gutsche-feinoptik.de/en



Nano Bio Analytics specialises in optical spectrographs, process Raman systems, and microparticle sensor systems.

www.nanobioanalytics.com



The Potsdam-based start-up **Colibri Photonics** develops and manufactures optical sensor systems for oxygen measurement. These can create a three-dimensional image of the oxygen distribution, which can be precisely controlled during the growth process and adapted to the different needs of individual cell types with suitable control mechanisms. **ASKANIA Mikroskop Technik Rathenow GmbH** offers a wide range of microscopes. Its employees develop, design, and build special light microscopic solutions for measuring instruments used in quality assurance processes for industry and research.

www.colibri-photonics.com
www.askania.de/en/



Ingenieurbüro Dr. Türck provides services in the field of optics development and data analysis, from the initial concept phase to calculations and design to tolerance analyses and preparation for production. This also includes optical measuring methods for medicine, such as the development of a new point-of-care measuring devices for medical diagnostics. A model-based design approach reduces the susceptibility to errors and significantly increases the development speed from concept to finished product.

www.tuerck-ing.de/en/



NIRx Medizintechnik GmbH is a specialist for functional near-infrared spectroscopy (fNIR). The company's equipment enables tomographic imaging in highly scattering media such as the brain and opens up new possibilities for neuroimaging.

<https://nirx.net>



The dental microscopes from **dentaZOOM GmbH** combine high magnification with excellent illumination in the smallest of spaces.

www.dentazoom.com



Major research institutions for the medicine of the future
 Seven Fraunhofer Institutes have joined forces in the **Fraunhofer Group for Life Sciences**: the Fraunhofer Institutes for Biomedical Engineering IBMT, Interfacial Engineering and

Biotechnology IGB, Molecular Biology and Applied Ecology IME, Toxicology and Experimental Medicine ITEM, Process Engineering and Packaging IVV, Cell Therapy and Immunology IZI (located in Golm), and the Fraunhofer Institute for Marine Biotechnology and Cell Technology EMB. The network works on a wide range of medical issues, including biohybrid test systems with specific sensors for optical and acoustic imaging systems.

www.lifesciences.fraunhofer.de/en.html



A completely new acceleration model has been developed over the past years: at the laser wakefield acceleration, a high-intensity laser pulse is chased into a suitable plasma. The result is a small wave that moves quickly through the plasma and in which enormous electric field strengths prevail. This in turn accelerates the electrons in the plasma to high energies. This technology offers the possibility of building particle accelerators for protons or ions in much smaller spaces than were previously needed. Scientists at the **Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy**, among others, are working on devices that will enable precise tumour radiation in the future.

www.mbi-berlin.de



Bioanalytics

The precise analysis of chemical compounds, biological macromolecules, cells, and microorganisms is an important task in many areas of science, industry, and medicine. Typical technologies are micro- and spectroscopic methods. High-performance liquid chromatography (HPLC) with UV fluorescence detectors is particularly popular to analyse a large number of biological samples.

One example is **KNAUER Wissenschaftlicher Gerätebau GmbH**. KNAUER's main business is the development and production of liquid chromatography systems. The product portfolio includes UHPLC systems, biochromatography systems, and sample preparation systems. The HPLC solutions offered for sample purification range from preparative HPLC to simulated moving bed (SMB) chromatography.

www.knauer.net



Automation also plays an important role in medical technology or the pharmaceutical industry. This includes, for example, pipetting tasks or the optical analysis of biological samples. The CytoFa analysis system from **pi4_robotics GmbH** combines robot-based liquid handling with automated image acquisition of biological samples in a compact laboratory device. The CytoFa contains a motorised microscope with a high-resolution camera and a 3-axis robot with an additional rotary axis for liquid handling. Due to its spatial isolation and integrated temperature control, CytoFa is particularly suitable for the handling of light- and temperature-sensitive materials. Depending on the microscope configuration, various illumination and contrast methods can be set in the control software and integrated into the automated process. With this methods fluorescence images of biological samples can be provided, for example.

www.pi4.de



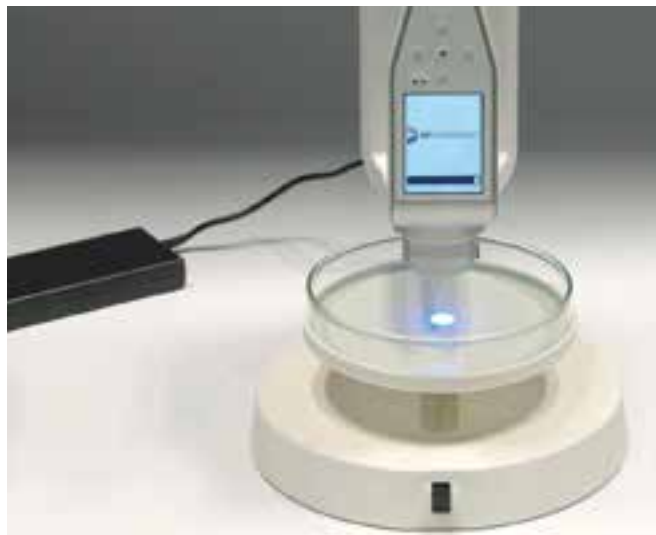
CytoFa laboratory device for robot-based liquid handling
© pi4_robotics GmbH

The **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoehstfrequenztechnik (FBH)** develops laser beam sources for Raman spectroscopy. These include diode lasers that emit light with two wavelengths at a fixed distance of about 1 nm from a chip. This makes them ideal for “Shifted Excitation Raman Difference Spectroscopy (SERDS)”. SERDS allows Raman signals to be separated from interfering backgrounds such as fluorescence or ambient light. In combination with micro-optics, the lasers come in small sizes, allowing mobile applications in medicine. FBH uses this technology, among other things, to provide beam sources in the yellow wavelength range.

www.fbh-berlin.com



In 2003, **sflux GmbH** was founded by scientists and technicians working in the field of optical semiconductor development. They are experts in UV radiation and produce components for measuring ultraviolet (UV) radiation. In addition to waterworks, the beverage industry is one of sflux’s customers. However, the sensors are also used in dialysis machines, to monitor heating burner flames, and to measure



RF-KombiSCAN as laboratory device
© Fraunhofer IZM

the UV portion in the sun’s rays. sflux is also a member of the UV For Life Consortium, which addresses the development of UV LEDs (see chapter 2.2 “Lighting Technology”).

www.sflux.de/en



Mobile analysis technology is also being developed at the **Fraunhofer Institute for Reliability and Microintegration IZM**. The RF-KombiSCAN is able to determine the quantity and composition of various substances by their different irradiation wavelengths. This new, portable, handheld optical measuring device radically simplifies and accelerates measurement procedures by integrating fluorescence and Raman spectroscopy. The mobile scanner can be used both as a laboratory research device and in industrial applications.

www.izm.fraunhofer.de/en.html

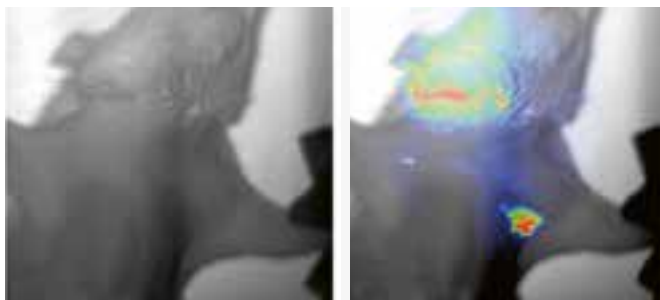


Chemical reactions and separation operations in liquid systems are often diffusion-controlled. A reduction of the reaction systems (“lab-on-a-chip”) can therefore significantly reduce the reaction time and also the sample consumption and thus greatly simplify medical analyses. Microchips with a total size of only a few square centimetres open up the possibility of integrating several functional reaction units in a very small space. At the **Leibniz-Institut für Analytische Wissenschaften – ISAS e. V.**, corresponding methods and structures are being researched. In combination with fast and sensitive detection methods, a fully miniaturised total analysis system (μ TAS) can be set up to automate sample injection, separation, and detection.

www.isas.de/en

Fluorescence in vivo Imaging

The principle of fluorescence in-vivo imaging is based on the properties of fluorescent dyes which are in the excited state when irradiated with certain wavelengths and emit fluorescence to return to the ground state. **greateyes GmbH**, a Berlin specialist for high-resolution cameras, offers a camera that is particularly sensitive in near-infrared to record these emissions. Fluorescence in vivo imaging is used, for example, in detecting the presence of cancer cells in lymph nodes. An intravenously applied dye is absorbed by the lymph node tissue. The detection of the weak fluorescence penetrating the tissue requires a highly sensitive camera and the aid of a special filter.

www.greateyes.de/en

Scattered light image (left), superimposed with the fluorescence signal on the GE 1024 1024 DD NIR camera (right)

© greateyes GmbH

Time-resolved optical nanoscopy

The **Department for Bioenergetics** at TU Berlin's Institute of Chemistry applies microscopy and spectroscopy, electrophysiological methods, and their combination with optical methods to living cells. Wide-field fluorescence microscopy with high spatial and time resolution single photon detectors for multichannel FLIM measurements enable spatially resolved microscopy of dynamic processes and simultaneous fluorescence correlation spectroscopy in each pixel with 100 ps temporal resolution and a measurement duration of 10 μ s. These techniques overcome previous limits in precision, parallelisation, and speed. They have a particularly high application potential in industrial projects, in pharmaceutical drug research, and cell-based diagnostics.

www.bioenergetik.tu-berlin.de/menue/bioenergetik/parameter/en/

In the course of a research project on time-resolved optical nanoscopy, a wide-field fluorescence microscope with the ultra-high spatial and time resolution is being set up to perform nanoscopic fluorescence experiments using time- and location-correlated single photon detection. The technique is designated TSCSPC (time- and space-correlated single photon counting) or FLIN (fluorescence lifetime imaging nanoscopy). For example, the fluorescence lifetime distribution of photosynthetically active proteins in unicellular organisms can be detected with unprecedented precision in order to investigate important regulatory processes in photosynthesis. Using biological or chemical reference structures, the aim is to determine to what extent the technology is suitable for breaking through the diffraction limit caused by the spatial resolution in optical microscopy.

A leading manufacturer of single photon detectors is **Becker & Hickl GmbH**. The company, also based in Berlin, not only offers highly efficient detectors, but also picosecond lasers and analysis software as well as its own confocal fluorescence microscope.

www.becker-hickl.com

Laser Technology in Medical Therapy

For the surgeon, light can do so much more than just provide orientation. It can also be used as a tool, such as laser light which is increasingly being used for surgeries. **Newport Spectra-Physics GmbH** is one of the world's largest companies in the field of laser surgery and has its German branch in Stahnsdorf, Brandenburg. The company mainly develops and produces diode-pumped femtosecond lasers. In addition to industrial applications, their applications extend to life and health sciences, microscopy, and biotechnology. The ultra-fast lasers are suitable for both LASIK surgery for eyes and other precision laser surgery.

www.spectra-physics.com

Laser systems have also proven to be a good alternative to other treatment methods in the destruction of gallstones and kidney stones. In clinical practice, interesting, unexpected effects have been seen here: certain laser types are better suited for the Asian market because the stones are darker there than in Western countries due to the different eating habits and their maximum absorption is therefore at different wavelengths.

Berlin-based **Limmer Laser GmbH** specialises in the development and manufacture of medical lasers. The company's products are used in almost all disciplines of human, dental, and veterinary medicine. The range extends from conventional CO₂ lasers to diode lasers and various special devices. Limmer Laser now offers fourth-generation CO₂ lasers, which deliver high performance and sharp beam diameters.

www.limmerlaser.de/en

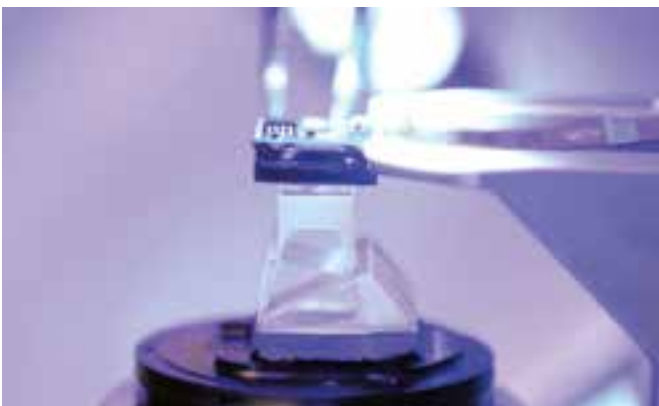


Quantune Technologies GmbH develops and markets microscopic infrared laser spectrometers for highly innovative consumer products based on patented quantum cascade laser and photoacoustic technologies.

www.quantune.com



In addition, there are companies that develop and manufacture peripherals and individual components for lasers, spectroscopic systems, and other diagnostic and therapeutic applications of optical principles in medicine.



Adjustment and gluing of a prism assembly for camera systems in medical technology
© Berliner Glas KGaA



Medical glass fibre for laser treatment of vascular diseases with an inverted cone for lateral optical radiation (without cap)
© Fraunhofer IZM

The **Berliner Glas Group** is one of the world's leading companies when it comes to precise optical components, opto-mechanical and electro-optical modules, assemblies, and systems. Production and assembly take place worldwide, including Germany, Switzerland, and China. Berliner Glas is a driving force in the continuous further development of medical technology. The products and solutions are primarily found in the healthcare market segments of dental medicine, endoscopy, and ophthalmology, as well as in the field of life sciences.

Berliner Glas manufactures many different optical systems: from prism assemblies and beam guidance systems to RGB LED cold light sources for endoillumination, endoscopy, and minimally invasive surgery.

www.berlinerglas.com



FCC FibreCableConnect GmbH manufactures laser cables and other fibre-optic connections, mainly for spectroscopy, biotechnology, and medicine. A specialty is the development of prototypes per special customer requirements and the transfer of the technology into serial production. Its products include high-performance fibre cables for industry, transmission fibre cables for medicine, optical fibre bundles and probes for spectroscopy, as well as optical fibre couplers.

www.fibrecableconnect.de/en



OBERON GmbH Fiber Technologies develops and produces fibre-optic bundles, splitters, probes, and cables with different numerical apertures, coatings, and sheaths to apply for UV-VIS-NIR wavelengths in the range of 190 nm to 2,200 nm. OBERON manufactures multi-arm fibre bundles, cross section

transducers, reflection probes, transmission probes, and vacuum feedthroughs for various applications in spectroscopy, sensor technology, and analysis technology.

www.oberonfiber.com



Loptek GmbH & Co KG is another company in the region working with fibre optics, fibre probes, and optical measuring heads for use in medicine and biotechnology. Loptek actively advises its customers on the design of fibre-optic systems, individual design services, and completely new developments. **escotec Lasertechnik GmbH** offers laser-manufactured micro-joints, especially for stainless steel and titanium.

www.loptek.de/en
www.escotec.com/en



In March 2017, **CLS GmbH** was founded as the German subsidiary of the Swedish company **Clinical Laserthermia Systems AB** in Berlin-Adlershof. The work being done in Berlin focuses on the development and production of diffusely radiating optical fibres, which are introduced into tumour tissues to destroy it thermally with laser light. Clinical studies are currently underway in Europe, including the immune response after laser therapy.

Under precise control with magnetic resonance imaging (MRI), the outer tissue of the tumour is heated to such an extent that the cancer cells die after a delay and antigens are released. The patient's immune system is activated so that tumour cells circulating in the body are deactivated and metastases can no longer form. The method is suitable for the treatment of solid soft tissue tumours such as pancreatic, prostate, or renal cell cancers as well as metastases in the liver and lungs.

www.clinicallaser.se/en/



Growth of Pepper plants indoor using LED devices (inset) and Luminaires that are developed by Crocus Labs

© Crocus Labs UG

AgriPhotonics

Several trends in agri- and horticulture lead to more and more applications of photonic technologies on farms, and along the whole food supply chain. One challenge is the climate change: Increased exposure to sun light changes the fruit development process on fruits leading to sunburn on apples, for example. On the other hand, the growing legal regulation of agrochemicals demands new technologies for weed control. Precision agriculture is one possible response. There, for example, the proper identification of weed requires sophisticated sensor technology, either on the ground, in the air or even on satellites. A third trend is the increased awareness on losses during processing and storing of crops and fruit. Here, optical technologies helps to determine the exact state of food and how long it is edible, thus reducing food waste. The new technological developments most often unite a detailed understanding of the processes in the plants with sensing and data processing technologies. The close proximity of diverse research institutions in the German capital region has sparked a number of successful partnerships in recent years. This has led to company foundations and to a lively regional and international network of academic and industrial partners.



Indoor vertical farming unit by InFarm – Growing Lights
© diephotodesigner.de

Research and Education

A major player in agriphotonics research in the capital region is the **Leibniz Institute of Agricultural Engineering and Bioeconomy (ATB)**. The ATB works with climate, soil and plant data recorded in agricultural production and along the supply chain of plant-based food. Their sensing technology ranges from advanced lab-based microscopy and spectroscopy to mobile spectroscopic systems including time-of-flight analysis and photogrammetry. ATB has developed data processing methods and agronomic models. These models, based on physiological submodels and artificial intelligence, use the sensor data and are aimed at the sustainable intensification of agricultural processes. This includes ecophysiological water and carbon balance, variable rate application of fertilizers, thinning agents and pesticides as well as freshness, storage and packing optimization.

The ATB is initiator of the bilateral network AGRIPHOTONICS funded by Federal Ministry for Economic Affairs and Energy.

www.atb-potsdam.de/en



Photonics for Precision Farming

Photonics plays an increasing role in horticultural plant research. Likewise, in agricultural crop cultivation open field horticulture and in large greenhouses could benefit from sensing with flying platforms as e.g. drones or copters. These kinds of applications, however, are in the early de-



Indoor vertical farming unit by InFarm – Inhub Farming
© diephotodesigner.de

velopment stages. Sensing directly on the plant, however, or fixed sensors in the root zone, soil or substrate, are more common. To create the most optimal conditions for the crop in a given environment various actions can be done. In protected cultivation, in greenhouses and controlled environments, supplementary (electrical) lighting is commonly used. The availability of LED lighting sources is more and more used to create specific light spectra for certain targeted plant responses. With the help of advanced sensing, simulation and lighting technologies, horticulture responds to climate change and to the United Nations Sustainable Development Goals (SDGs) especially “improved nutrition and promote sustainable agriculture” (SDG2), “sustainable cities and communities” (SDG11), and “climate action” (SDG13).

In Berlin and Brandenburg, a well-developed community for LED development and lighting solutions (see chapter 2.2 “Lighting Technology”) meets an agile community of research institutions and start-up companies in agri- and horticulture.

The **Leibniz Institute of Vegetable and Ornamental Crops (IGZ) e. V.** for example, hosts research on “Next-generation horticultural systems”. In this group, they investigate among many other aspects, how LED light sources can be optimally used including light recipes for crop growth and quality performance in controlled environments in combination with the other climatic factors.

www.igzev.de/?lang=en



Several companies exploit already ideas of advanced horticultural concepts. **Crocus Labs UG** is young start-up with a mission to disrupt the indoor horticulture industry. The company is specialised in providing ultra-high efficiency smart lighting solutions that will significantly reduce the electricity costs related to artificial lighting used in greenhouses, indoor & vertical farms while enabling them to grow a wider variety of crops indoor. As the company controls the design of the entire process in-house from LED devices, sensor PCB's, software components all the way to the luminaires, the products can be customised as per customer needs.

www.crocuslabs.com



InFarm – Indoor Urban Farming GmbH is specialised in indoor vertical farming technology for easy scalable and rapidly deployable modular farms. The individual farming units are connected and remotely controlled from a central farming platform that gathers up-to-the minute information about the growth of each plant. They are currently working with 30+ of the world's biggest retailers to grow over 65+ different types of herbs, lettuces, and leafy greens. InFarm has developed novel solutions based on optimized lighting, plant modelling and crops optimisation.

www.infarm.com



The **Stenon GmbH** develops a device for mobile soil analysis in agriculture and particularly in vegetable cultivation. This "smart spade" measures a number of soil parameters such as nutrient concentration, pH-value, temperature and humidity in 0 to 30 centimeters. Furthermore, the soil type and its texture are determined. After about 20 seconds, the data is recorded. In the future, the experts at Stenon want to integrate their sensors into regular agricultural tools such as a plow.

www.stenon.io



When is the right moment for harvesting fruit? And how long is a stored fruit good for sale? To answer such questions, the company **Control in applied Physiology CP** offers sensor systems which measure fruit development in the field and in storage. Their sensors, for example, can be installed on an apple farm and the farmer can see on his smartphone the

current state of his product. Along storage and distribution the technology allows for a quality tracking and certification.

The technology has been developed in cooperation with the Leibniz Institute of Agricultural Engineering and Bioeconomy (ATB).

www.cp-info.de



Sensing plays an important role within the concept of precision agriculture. There, precision refers to a specific treatment of plants: What if every single plant could get exactly the amount of fertilizer it needs? **LOMAGRI GmbH** develops a technology that will help farmers to spray precisely on target. They developed a specific sensor that determines the status of plants continuously and thus, pesticide application along the row/path can be reduced by more than 60 %. The new sensor detects morphological and physiological information from individual plants and entire rows of plants in real time. Applications are expected in gardening, farming and forestry.

www.lomagri.de



Photonic Insights GmbH is offering multiple sensor solutions for applying multiple spectroscopy methods in agricultural applications. See their profile in chapter 2.4 "Optical Analytics".

www.photonicinsights.com



Ophthalmology and Innovative Eyewear

Digitisation is more than just a new trend in ophthalmic optics. It has become essential for the development of new products, processes and solutions. On the medical side, digitisation together with artificial intelligence enables new concepts for diagnosis and treatments. For instance, innovations such as Augmented Reality (AR) contact lenses or wavefront aberrometers and topics like online refraction and tele optometry.

But digitisation also revolutionises the process chain in eyewear production. Today, optometric data for new spectacle

frames can be obtained with smartphones. And the frames can be made with 3D printers completely individually. Which such innovations, research institutions, start-up and established companies in the capital region are paving the way for the future in ophthalmic optics.

Research and education

Several institutions in the region of Berlin and Brandenburg do research and offer academic teaching in the fields of optometry and optical engineering.

The **Department of Engineering** of the **Technische Hochschule Brandenburg (THB)** provides five study programs (Optometry / Optical Device Engineering, E-Mobility, Engineering Sciences, Industrial Engineering and Mechanical Engineering), which lead to the Bachelor of Engineering. Furthermore, several postgraduate programs (Photonics, Energy Efficiency of Technical Systems and Mechanical Engineering) are offered, where the degree Master of Engineering can be obtained.

Three professorships do research in ophthalmic technologies, particularly with regard to image analysis with deep neuronal networks, optical biometry, laser applications in ophthalmology and nano-structuring of surfaces.

<https://technik.th-brandenburg.de/>



The **Beuth Hochschule für Technik (University of Applied Sciences)** in Berlin conducts academic education in Ophthalmic Optics/Optometry on both, the Bachelor and the Master of Science degree. Participants acquire a combination of physics, engineering and medical knowledge. Internships and modules with scientific content enable students to transfer practical and scientific content into professional practice. The course contents are accredited by the European Council of Optometry and Optics (ECOO).

Three chairs at the Beuth Hochschule focus their research on various fields of ophthalmic and optometric devices as well as medical phenomena in the eye.

www.beuth-hochschule.de/b-ao



Excellence in ophthalmic optics

Nowhere else the connection between optical components and treatment of eye diseases is closer than in ophthalmic optics. Rathenow, after all, was the cradle of the German optical industry. More than 210 years ago, Johann Heinrich August Duncker invented the multi-grinding machine here. Today, approx. 1,300 people work in this field in Rathenow. The town is home not only to global player Fielmann. Moreover, more than 25 small and medium-sized enterprises are active in optics.

About 1,000 people work at **Fielmann AG** in Rathenow. The eyeglass company is the parent company of Rathenower Optik GmbH and runs a production and logistics centre in the town. In two-shift operation, more than 19,000 eyeglasses are delivered per day on average and more than 56,000 orders are processed.

In response to new trends such as digitization in the field of ophthalmic optics, they founded **Fielmann Ventures GmbH**. Fielmann Ventures employs a dedicated team that continuously scouts the market for existing solutions and services with disruptive potential. Recent examples has been our investments in augmented reality leaders Fitting-Box and in Ubimax.

www.fielmann.eu

www.fielmann-ventures.com



But Rathenow is also defined by its smaller, specialised companies. For example, **OPTOTEC Optotechnischer Gerätebau GmbH**, which specialises in the manufacture of ophthalmic optics devices. And those who enjoy the luxury of exclusive products will be at home at such Rathenow companies like **MOM GmbH**, where titanium eyeglass frames are manufactured using state-of-the-art laser technology.

www.optotec-shop.eu

www.mom-gmbh.de





Thanks to the screwless joint, glasses can be disassembled and reassembled in seconds by hand and without additional tools (current world record is 3.3 seconds).

© ic! berlin brillen GmbH

Ophthalmica Brillengläser GmbH & Co KG grinds a wide range of plastic and mineral eyeglass lenses. **Obrira Optik Rathenow** offers a variety of special lenses: from magnifying glasses to telescopic lenses and mirror glasses to refraction lenses. Another Rathenow specialist in special lenses is **SOLIRA Sonderlinsen GmbH Rathenow**. It also supplies high dioptr thicknesses and offers various special types of grinding.

www.opthalmica.eu
www.obrira.de
www.solira.de



German and Japanese styles come together at **Aoyama Optical Germany GmbH**. Each year, this frame supplier sells around 300,000 pairs of glasses, not only in Germany, but also in the Scandinavian countries, and Eastern and Central Europe. The frames are manufactured in Japan (titanium) and Rathenow (acetate).

www.aoyama-optical.com



SuperVista AG, the operator of the www.brillen.de website, is based in Wildau and attaches great importance to offering great value for money.

www.specsfactory.co.uk



In Berlin, too, there is a lot of ophthalmic competence. The start-up-friendly climate has led to a number of start-ups that are now operating successfully on the market.

ic! berlin brillen gmbh manufactures and sells screwless glasses and sunglasses in Berlin with a team of 140 employees (as of 2016). The worldwide success is impressive, so much that one in eight spectacle wearers in Taiwan now wears an ic! Berlin frame.

www.ic-berlin.de



Like ic! Berlin, **MYKITA GmbH** was also founded in 2003. The brand offers a screwless eyeglass frame now sold in 80 countries. The company's headquarters with 400 employees (2016) is in Berlin-Kreuzberg, where designers, opticians, marketing strategists, and technicians work in their eyewear factory. In 2016, they were able to set a new milestone in eyeglass production with the integration of 3D scanning and additive frame manufacturing.

www.mykita.com/en



Individual design is also the focus of **Mister Spex GmbH**. Mister Spex claims to be the largest online seller of eyewear in Europe. With its own optician workshop and a partner network of over 500 local opticians, the online optician offers all the advantages of online and in-person shopping from a single source.

www.misterspex.co.uk



The family business **Kaps Vision Brillenglas GmbH** started in 2017 with a clear vision: to replace spectacle lenses consisting of parts of several lenses of different strengths with special lenses made of one piece. The reduced effort results in significantly shorter delivery times. Glasses from minus 220 to plus 60 diopters are offered by the company. A joint project with Prof. Dr. Justus Eichstädt at the TH

Brandenburg has been running from the very beginning, it has proven to be beneficial for the development of the company.

www.kaps-vision.com



Diagnosis and treatment of eye diseases

There is hardly no area in medicine and life sciences in which companies or research institutions in Berlin are working on. The broad range of competencies and its excellence reflects the dynamics of the region. Scientists are already working on future technologies to enable those with diseases to be cured by pushing the limits of what is feasible.

Oculentis GmbH, for example, specialises in intraocular lenses, artificial corneas that are implanted in the event of illness. Applications for the lenses, marketed under the Lentis name, include such diseases like cataracts, corneal curvature, and presbyopia. Since its foundation in 1995, the family-owned company has made an international name for itself with its innovative ophthalmological products.

www.oculentis.com



Together with partners and ophthalmologists, researchers at the **Fraunhofer Institute for Applied Polymer Research IAP** in Potsdam-Golm have developed an artificial cornea for patients who cannot receive a natural cornea due to a lack of suitable donors. ArtCornea® is especially suitable for complicated care situations in clouded corneas. The implanted prostheses can be anchored clearly and tightly in the eye and were proved to heal without irritation over six months without rejection. Clinical tests are running.

www.iap.fraunhofer.de/en/fraunhofer-iap.html



Nocturne GmbH uses the eye as a window to the brain. The start-up is developing software that uses artificial intelligence (AI) to evaluate images of the retina. These images support the diagnosis, therapy and assessment of the course of neurological diseases. The technology combines complex image processing methods with mathematical 3D modeling to compute quantifiable parameters for the smallest disease-related change of the retina's shape. They call this 3D morphometry.

<http://nocturne.one/>



The Berlin-based start-up company **Dopavision GmbH** is currently developing a method that will use a digital, clinically proven therapy to reduce myopia in children and adolescents. The technology delivers light stimulation to specific photosensitive cells on the retina which in turn modulate dopamine, a neurotransmitter that is important for the regulation of eye growth.

www.dopavision.com



Rayner Surgical GmbH is located in Adlershof. Rayner is a British company and the only manufacturer of intraocular lenses in the United Kingdom. In Berlin, Rayner operates a sales and marketing office for the German and Austrian market.

Rayner develops and manufactures intraocular lenses and proprietary injector systems for use in cataract surgery. When Sir Harold Ridley developed the world's first IOL in 1949, he chose Rayner to manufacture his groundbreaking invention.

www.rayner.com



Carl Zeiss Meditec AG is also a major player in the field of surgical ophthalmology in Berlin. At its Berlin site, Carl Zeiss Meditec AG develops and manufactures intraocular lenses (IOLs) that are implanted in patients to restore vision during cataract surgery. A new training centre for cataract surgeons has also opened here.

www.zeiss.com/meditec/int/home.html



The examination and diagnosis of eye movements and the corresponding disorders provide important information on various diseases in addition to ophthalmology. The Chronos Eye Tracker (C-ETD) from **CHRONOS VISION GmbH** enables a comprehensive analysis of all three rotatory eye movements. In refractive surgery such as Lasik procedures, precise real-time measurements of the eye position are required. During the laser operation, the eye position determined by the eye tracker is transmitted to the laser control system in order to optimally achieve the intended lens correction. Due to the very fast tracking, the result of the intervention is optimised and the treatment time is shortened in the patient's favour.

www.chronos-vision.de/en/index_en.html



Oculid UG is a Berlin-based technology company that was founded in 2015. Based on eye-tracking technology and machine learning routines, they have developed a technology to track attention and perception of mobile device users. Using the selfie camera, they can follow eye movements of the user. This way they can provide precise data of what screen areas receive attention.

www.oculid.com



Roland Consult Stasche & Finger GmbH, meanwhile, is a specialist in electrophysiology and imaging. The company's instruments can be used to clarify eye diseases and vision problems, among other uses.

www.roland-consult.com



ALCON Pharma GmbH (Novartis AG) offers a wide range of solutions for the treatment of eye diseases. Laser systems for eye surgery are developed and produced by its subsidiary **WaveLight GmbH**. Special diagnostic systems and innovative eye tracking solutions are among the competencies of the company's location in Teltow.

www.alcon.com

www.wavelight.de/en



OD-OS GmbH is specialised in retinal lasers with its Navilas laser system. The system provides laser photocoagulation to cover treatments for the entire spectrum of retinal diseases, from diabetic macular edema to the treatment of retinal tears and holes. Australian company **Ellex Deutschland GmbH** (with a branch in Adlershof) also offers laser systems for the treatment of a variety of eye diseases, such as cataracts, glaucoma, and retinal diseases.

www.od-os.com

www.ellex.com



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2.6 Microelectronics and Microsystems Technology – the Backbone of Innovations

“Only few industries have developed as rapidly as microsystems technology in recent years. High-performance miniaturised electronics have triggered the digital revolution and opened up new fields of application in sensor technology. With innovative, energy-efficient, and cost-effective products made in Berlin Brandenburg, we are pushing national and international developments in automotive, medical, and communications technology.”

Peter Krause | Spokesperson Focus Area Microelectronics and Microsystems Technology,
Prignitz Mikrosystemtechnik GmbH



When we think today about the next steps in industrial development, terms such as the Internet of Things (IoT), Industry 4.0, cyber physical systems, and Smart-X pepper are discussed in Germany. All approaches are based on the idea of using sensors and actuators to connect the real, physical world with the virtual, in which software-based data processing and information storage take place. Microsystems technology is providing the essential building blocks for these developments.

Through distributed and networked process controls, data acquisition and processing, completely new concepts for the collection, provision, and evaluation of machine, process, or service data are possible. The McKinsey Global Institute (MGI) has said that the so-called Internet of Things, i.e. the intelligent networking of devices and machines via the Internet, might create as much as 11 trillion euros in added value to the global economy by 2025. PricewaterhouseCoopers agrees with this assertion and sees an economic potential of 3.4 trillion euros in production alone through Industry 4.0 applications, as a result of higher productivity, greater energy efficiency, and more secure jobs. The industry association BITKOM does not agree with the assessment in every respect, but nevertheless a trend toward massive technological change is accepted.

Such considerations often neglect where the data comes from and how it is fed into the network and preprocessed. Usually, there is an implicit understanding that miniaturised, multifunctional, and autonomously operating electronic systems will process these data. As “smart systems” they will also have an effect on the systems they control. Because only these are able to produce the necessary interface (hardware and software) between the physical and digital worlds.

For this to be possible, electronics and microsystems technology products must be extremely versatile and miniaturised as well as robust and durable. There is another new aspect:

future electronics will increasingly be integrated into application systems. The time of separate, retrofitted components is being replaced by fully integrated electronics adapted to the application system. This complete integration into the receiving system combined with extended functionality, extreme miniaturisation, robustness, and longevity is making electronic systems even more complex to design. What is now required are integration technologies that can cope with the constantly increasing requirements in terms of smallest sizes, low power dissipation, large frequency ranges, high reliability at low production costs, and even when production runs only moderate.

Berlin Brandenburg, home to so many high-quality, relevant institutions and companies at all stages of the value chain, are an ideal location for such developments.

From research to system integrator

A close cooperation of all partners from the different technical fields using the surrounding research infrastructure is indispensable for such innovations. Berlin Brandenburg offer excellent conditions for this to happen. With the technical universities of applied sciences in Berlin, Wildau and Cottbus-Senftenberg, the strong computer science programmes at FU Berlin, HU Berlin, and the University of Potsdam, plus the internationally recognised, non-university institutes of the Fraunhofer-Gesellschaft, the Leibniz Association, and BAM, the region is home to an almost unique density of quality and quantity.

On the industrial side, Berlin Brandenburg are internationally renowned for the development and manufacture of components such as sensors, actuators, and the associated signal processing. The international reputation is constantly strengthened by the activities of such companies as First Sensor, Pepperl + Fuchs, EPCOS, and the Baumer Group. The region has traditionally been strong in system integrators, i.e. companies that integrate sensors and actuators into a single measuring system.

Regarding SMEs, there are many of the so-called “hidden champions” active in these industries. Companies such as IMC Messtechnik, Prignitz Mikrosystemtechnik, GED Electronic Design, DRResearch, and ESYS may only be mostly known to experts in the field, but they are no less innovative. These companies are complemented by suppliers of materials, printed circuit boards, and packaging services such as micro resist technology, PacTech, hmp Heidenhain Mikroprint, Contag, and AEMtec.

Software plays an important role in the Internet of Things. The companies mentioned above are stimulating rapid development in this area with approx. 500 start-ups per year. As a start-up stronghold in Europe, the region is thus on a par with London and Paris. In addition, there are development centres for such leading international companies as SAP, Bosch, and Software AG.

Small systems for large industries: the Internet of Things

The Internet of Things means that technology providers and users, new and old economies, and hardware and software must all work closely together. The companies mentioned above can rely on a strong industry in the fields of traffic engineering (Bombardier, BMW, Daimler-Benz), control and regulation technology (Hosch, Kieback & Peter), mechanical and plant engineering (Hielscher, Specs), energy technology (Siemens), medical technology (Biotronik, Otto Bock), aerospace technology (Rolls-Royce), security technology (Bundesdruckerei), and logistics (Deutsche Bahn), which are increasingly focusing on technically sophisticated products and integrated services and integrating electronics and IT into their products.

All the players in the region are creating electronic components, intelligent firmware, and new architectures that will lead to disruptive innovations at all levels of the Internet of Things, with focus on the needs of industry, such as in the field of autarkic microsystems:

- robust and maintenance-free (no battery changes during lifetime)
- latency requirements as low as 1 ms
- security comparable to wired sensors
- robust, energy-efficient data transmission
- reliable even under industrial environmental conditions and requiring minimal additional infrastructure (cable laying)

Microsystems unite the Scientific Disciplines in the Region

The great strength of the Berlin Brandenburg region is its networking. And it is particularly valuable in microsystems technology: more than 20 institutions here are conducting research in the various fields of microsystems technology. In Berlin, these include BAM, the Helmholtz-Zentrum Berlin with the electron storage ring BESSY, the Leibniz Institutes FBH and IKZ, the Fraunhofer Institutes IZM and IPK, as well as institutes of the TU and HU Berlin.

In Brandenburg the institutions are closely networked in the region and beyond. The universities in Cottbus, Senftenberg, Potsdam, Wildau, and Brandenburg are also actively involved in new developments. In addition, there are various institutes of the Fraunhofer-Gesellschaft and Leibniz Association which help create a vital research landscape.

Major projects in collaboration

The four **Fraunhofer Institutes FOKUS, HHI, IPK, and IZM** have joined forces to form the **Berlin Center for Digital Transformation**. They are bundling their respective expertise in the fields of information and communication technologies (ICT), data processing, production, and microelectronics. Industrial partners and public institutions have the opportunity to cooperate with the participating Fraunhofer Institutes within the framework of research projects. The centre is developing technologies and solutions designed to further increase digitalisation and networking in all areas of life. It conducts research on enabling and cross-sectional technologies for applications in networked industry and production, networked mobility & future city, networked health & medicine, and networked critical infrastructures and energy.

www.digitale-vernetzung.org/en.html



In the **Research Fab Microelectronics Germany (FMD)** eleven institutes within the Fraunhofer Group for Microelectronics cooperate together with the **IHP – Innovations for High Performance Microelectronics** and the **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hochofrequenztechnik (FBH)**. The participating research institutions will receive a total funding of around 350 million euros from the Federal Ministry of Education and Research for the modernisation and expansion of their facilities and equipment. Already 117 million euros will come to Berlin, to the



Prof. Dr. Johanna Wanka, Federal Minister of Education and Research, at the opening of the FMD
© BMBF, Hans-Joachim Rickel

Fraunhofer IZM and **Fraunhofer HHI**, and Brandenburg, to the IHP. This makes the region the most important location for FMD alongside Dresden. The research factory concept jointly developed by the Fraunhofer Institutes and the Leibniz Association envisages combining technological capabilities in a joint technology pool, coordinating to close equipment gaps, and adapting important laboratory lines for microelectronic technologies to changing technologies. In order to advance research topics in a targeted manner, FMD is organised into four technology parks: silicon-based technologies, compound semiconductors, heterointegration, and design, test and reliability.

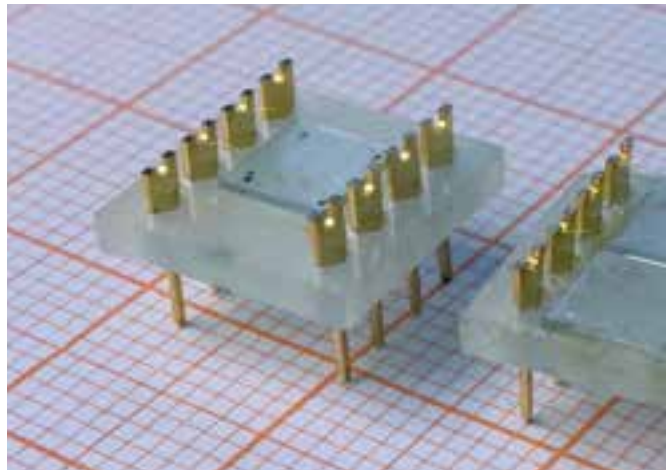
www.forschungsfabrik-mikroelektronik.de/en.html



With its support for the **Leibniz Science Campus Growth and Fundamentals of Oxides (GraFOx)**, the Leibniz Association is setting a clear course for fundamental research into semiconducting oxides, which are particularly suitable for the development of novel (opto-)electronic components and energy applications with outstanding performance capabilities – such as transistors for switching high voltages in power electronics, UV detectors, or memory devices.

GraFOx is coordinated by the **Paul-Drude-Institut für Festkörperelektronik (PDI)**, a Leibniz Institute within the Forschungsverbund Berlin e.V. (Berlin Research Association). Other partners include the **Leibniz Institute for Crystal Growth (IKZ)**, also part of the research network, the **Fritz-Haber-Institute (FHI)** of the **Max Planck Society for the Advancement of Science**, **Humboldt University Berlin**, and **Technical University Berlin**.

grafox.pdi-berlin.de



Gallium oxide sample on chip holder for electrical characterisation
© PDI

Integrating materials science, physics, chemistry, electrical engineering, computer science, and precision engineering – microsystems technology is a research field in which many disciplines come together. At **TU Berlin**, there are several chairs related to microsystems technology in the **Institute for High Frequency and Semiconductor System Technologies (Faculty IV)**. In March 2018, for example, a professorship in silicon photonics was newly created with Dr. Lars Zimmermann as its chair. He also heads the Silicon Photonics Group at IHP in Frankfurt (Oder). He is also the scientific coordinator of the Joint Lab Silicon Photonics, which is jointly operated by TU and IHP.

www.eecs.tu-berlin.de/menue/einrichtungen/institute/ihh/parameter/en/



Research and industry

In September 2017, Dresden and Cottbus were pleased when the Dresden-based **Fraunhofer Institute for Photonic Microsystems IPMS** received a positive evaluation for its **Fraunhofer Project Group “Mesoscopic Actuators and Systems (MESYS)”**. The Fraunhofer project group, which is active in Dresden and Cottbus at the **Brandenburg University of Technology Cottbus-Senftenberg (BTU)**, is led by Prof. Harald Schenk. He is also director of Fraunhofer IPMS and endowed chair of micro- and nanosystems at BTU.

The group is developing a new class of electrostatic bending transducers. These include, for example, novel electrostatic microactuators, so-called nanoscopic electrostatic drives (NEDs), which will be used in microacoustics and microfluidics. Since January 1, 2018, the project group has become a part of the newly founded Fraunhofer IPMS “Integrated Silicon Systems” (ISS) division.

www.b-tu.de/en/micro-and-nano-systems/team/professor
www.ipms.fraunhofer.de/en.html



The **iCampus Cottbus** is a scientific project funded by the German Federal Ministry of Education and Sciences. This project with a volume of 7.5 Million € aims to help develop a hub on microsensors and electronics in Cottbus that inspires local SMEs on finding sensor solutions for their businesses.

Started in 2019 at the Brandenburg University of Technology Cottbus-Senftenberg in cooperation with the Leibniz-Association (Leibniz-FBH and IHP) and Fraunhofer-Foundation (Fraunhofer IPMS and IZM) the iCampus is now working in six sensor groups. The four institutes have been leaders in microsystem technology for years and are working at their branch offices in Cottbus on sensor systems for applications in the fields Industry4.0, Smart Health and Smart Farming.

www.b-tu.de/icampus



The **IHP – Innovations for High Performance Microelectronics** in Frankfurt (Oder) is an institute of the Leibniz Association. The 320 workers at IHP are researching and developing silicon-based systems, high-frequency circuits and technologies, and new materials. They are developing solutions for such applications as wireless and broadband communication, for aerospace, biotechnology, and medicine, for the automotive industry, as well as security technology and industrial automation.

IHP has a 1,000 m² (10,700 sq. ft.) class 1 clean room where a pilot line for technological developments and the preparation of high-speed circuits with 0.13/0.25 μm SiGe-BiC-MOS technologies are operated. This service is also offered to industrial customers.

IHP operates eight joint labs with universities in the region (BTU Cottbus-Senftenberg, University of Potsdam, HU Berlin, TU Berlin, and TH Wildau) as well as with universities in Poland and Turkey. They are intended to bridge the gap between research at IHP and the partners' teaching and research. Topics range from reliable sensor networks (BTU Cottbus-Senftenberg) to wireless broadband communication systems (HU Berlin) and silicon photonics (TU Berlin).



IHP – Innovations for High Performance Microelectronics
 © IHP/Patrick Pleul

www.ihp-microelectronics.com
www.ihp-microelectronics.com/en/joint-labs/overview.html



One of the joint labs is located at the **Technical University of Applied Sciences Wildau (TH Wildau)** in the **Photonics, Laser and Plasma Technologies Working Group**. IHP employees are involved in teaching and students can complete internships and research for bachelor's and master's theses at IHP. Indeed, five graduates from Wildau are now on staff at IHP.

But the research also benefits: IHP and TH Wildau are collaborating on the HOPBIT project, which is developing a technology platform for the integration of photonic silicon organic hybrid (SOH) devices into a silicon-based chip technology. The research project is supported by the European Regional Development Fund (ERDF).

<https://en.th-wildau.de/research-transfer/research-field-3-optical-technologiesphotonics>



Other relevant projects at **TH Wildau** are located in the Mechanical Engineering Department, for example the **Materials Engineering Group** is working on technology for microelectronic wire bonding together with the company Delvotec. With the expertise of the scientists and the help of various microscopic analysis methods, such contacts can be optimised, failure mechanisms can be clarified, and the reliability of electronic assemblies can be improved.

The **Institute for Materials, Development and Production** at TH Wildau is home to the **Microsystems Technology** research group, headed by Prof. A. Foitzik. The group has extensive expertise in the field of plastics technology (CAD, CAM, simulation, as well as material and assembly).

<https://en.th-wildau.de/research-transfer/institute-for-materials-development-and-production>



Ball bond contact on a high-strength aluminium scandium (AlSc) chip metallisation

© U. Geißler/TH Wildau

HTW Berlin University of Applied Sciences even offers a degree programme in microsystems technology. A bachelor's degree can be earned in six semesters and a master's takes additional four semesters. In addition to a solid education in the core engineering skills, the programme also teaches modern simulation and CAD techniques, computer science, electronics, sensor technology, and microtechnology.

<https://mst-master.htw-berlin.de/en>



The **Institut für Dünnschichttechnologie und Mikrosensorik e. V. (IDM)** is a non-profit research institute active in the field of materials science. One focus area is the development of materials for optical technologies. Its work includes the chemical synthesis of optical and sensory functional materials, the development of structuring, processing, and replication technologies, as well as the development of optical and sensory functional elements.

www.idm-teltow.de/idm-english.html



In its current research projects, IDM is cooperating with such companies as **Allresist Gesellschaft für chemische Produkte und Mikrostrukturierung mbH**. Founded in the years after the Wall came down, Allresist is now one of the world's best-known companies in the field of resists development for optical and electron beam lithography. For selected questions and resists, which are applied in innovative technologies of microelectronics, IDM is realising chemical syntheses for material and process development. Allresist then uses these to develop and produce special resists for optical and electron beam lithography as well as the associated process chemicals for the manufacture of electronic components.

www.allresist.com



A hotspot for the miniaturisation and integration of electronics is the **Fraunhofer Institute for Reliability and Microintegration IZM**. Here, too, companies and scientific institutions are supported in developing, establishing, and integrating robust and reliable electronics in applications. Fraunhofer IZM focuses on substrate and wafer level integration as well as the design and reliability of electronic microsystems. For example, work is being done on a universally applicable sensor platform with which sophisticated sensor technology can be made available more cost-effective in the future. Fraunhofer IZM emerged in 1993 from the research focus in microperipheral technologies at TU Berlin. Today, the Fraunhofer Institute and TU Berlin jointly operate the **Berlin Center of Advanced Packaging (BeCAP)**, which is active in every aspect of miniaturisation and system integration.

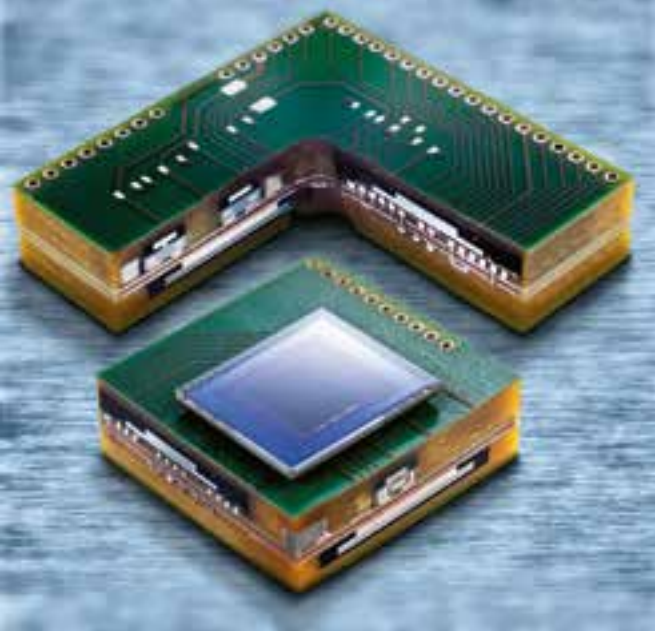
www.izm.fraunhofer.de/en/institut/netzwerk_weltweit/becap.html



The **“Start-A-Factory”** laboratory complex was opened at Fraunhofer IZM in 2017. Together with start-ups, the researchers at IZM investigate which problems repeatedly occur in product development processes and develop tailor-made solutions. In the end, the start-up garage of tomorrow will be built: with high-tech equipment tailored to the needs of young companies.

www.izm.fraunhofer.de/en/institut/wege_der_zusammenarbeit/start-a-factory.html





Microcamera with embedded passive and active components. The high integration density allows the contents of the image to be evaluated within the camera module.

© Fraunhofer IZM/Volker Mai

The **PhoxLab** is also located at Fraunhofer IZM. It is a manufacturer-independent platform for testing photonic components and architectures at different levels of modern data processing: from chip level and rack-to-rack solutions to long-distance connections for the Internet of the future. PhoxLab emerged from the European funding project PhoxTroT.

www.phoxlab.eu

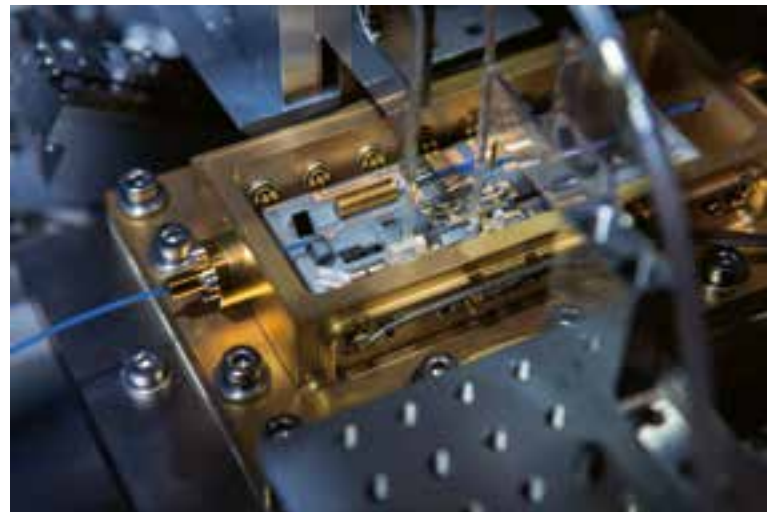


The **Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoehstfrequenztechnik (FBH)** offers microsystems for custom applications from medicine to space technology. For example, a flexible ophthalmology technology platform was developed at FBH. At its core, infrared laser light is efficiently converted to the yellow frequency range: the source delivers more than 2 W at 561 nm. The FBH also uses the same principle with different wavelengths for sensor and analytical applications. Compact measuring systems are created that deliver results quickly and reliably in situ.

FBH's laser systems for use in outer space also offer the highest integration densities on the smallest possible surface area. They work reliably even under adverse conditions such as space radiation, large thermal differences, or

mechanical loads during rocket launch. FBH developed an ultra-precise microintegration assembly for this purpose. It offers positioning tolerances below 100 nm.

www.fbh-berlin.com



Precision assembly of a fibre-coupled diode laser module for space applications at FBH

© FBH/schurian.com

In addition, research is being conducted into new, compact diode laser sources that deliver high-precision pulses in the pico- and nanosecond range with high beam quality. Among other things, they use optimised HF microwave electronic components as controls. The flexibly adaptable sources are indispensable components in such applications as LiDAR (Light Detecting and Ranging), the laser-based radar required for autonomous cars and robots.

Arquimea Deutschland GmbH, a subsidiary of the Spanish company Arquimea, is also working on space applications. In Frankfurt (Oder), it is developing radiation-hard circuits for space technology. The high-quality chips are then produced in smaller quantities at IHP.

www.arquimea.com



An important aspect in the cooperation between science and industry is the spin-off of innovative companies from research institutes. One example is **GOLARES GmbH**. GOLARES was founded out of the Leibniz Institute for Crystal Growth (IKZ) in Berlin-Adlershof. The core idea of

the company is an innovative plasma source that allows low-damage processing through low-ion energies and conformal coating with conductive and insulating layers at high rates and low tension. The company offers consulting services on such as processes as well as coating and microstructuring of optoelectronic and microelectronic devices. In March 2017, the two founders were awarded the Leibniz Start-up Prize.

www.golares.com



SMEs are shaping Microsystems Technology

Sensors, actuators, signal processing and functional materials

Industry 4.0 is based on a network of sensors. This image alone gives an idea of the demands made on modern sensors today: they need to be small, robust, and yet precise. They should last a long time and their price as low as possible. Their development takes place in a highly technical environment that combines intensive research with a high-volume industry. Both fields are well represented in Berlin Brandenburg; indeed, local companies are among the world's top companies in their respective fields.

First Sensor AG is one of the world's leading suppliers in the field of sensor technology. With almost 800 employees (as of the end of 2017), the company develops and manufactures standard sensors and customer-specific solutions for the growing industrial, medical, and mobility markets. For example, the company supplies avalanche photodiodes (APDs) for LiDAR systems to leading companies such as the American manufacture. V.lodyne. The long-standing partnership was further strengthened in 2017 with a standing order worth several million dollars.

Avalanche photodiodes are a decisive component in LiDAR systems for autonomous vehicles.

© First Sensor AG



First Sensor creates products ranging from chips to complex sensor systems.

© First Sensor AG

Today's First Sensor AG started in 1991 as Silicon Sensor GmbH at the traditional industrial location of Berlin-Oberschöneweide. Its vision was to supply the reunited technology market of Germany with innovative sensors. Today, it is a globally active company with sales in the millions offering goods and services along the entire value chain from sensor chips to sensors and complex sensor systems.

www.first-sensor.com/en



Other major players have production facilities in Berlin Brandenburg. For example, **Pepperl + Fuchs GmbH**, a specialist for proximity, acceleration, and ultrasonic sensors, offers a wide range of sensors in image processing and positioning aids. In 2017, approx. 6,000 people were employed at various locations in Germany, the United States, Singapore, Hungary, India, Indonesia, Vietnam, and the Czech Republic. One of its locations is in Berlin, the result of a takeover of Visolux company in 2000.

www.pepperl-fuchs.com



Another family-owned business trading internationally with its expertise in sensor technology, rotary encoders, measuring instruments, as well as components for automated image processing is the **Baumer Group**, headquartered in Switzerland. It is represented by the **Baumer Hübner GmbH** in Berlin- as a competence centre for encoders and tachometer generators with heavy-duty technology. It also opened a new building for its motion control competence centre here in 2010. The location includes development and production facilities as well as a training centre.

www.baumer.com/de/en/



The **Bundesanstalt für Materialforschung und -prüfung (BAM)** has its own department for fibre-optic sensors. Sensors can measure a variety of physical parameters such as temperature, expansion, pressure, humidity, vibration, sound, or radioactive radiation. Special fibre optics can secure not only infrastructure, but also energy technology systems and individual materials to allow damage to be detected and localised at an early stage. Modern fibre optics allow systems that run for miles to be monitored with an accuracy in the metre range.

www.bam.de/Navigation/EN/About-us/Organisation/Organisation-Chart/President/Department-8/Division-86/division86.html



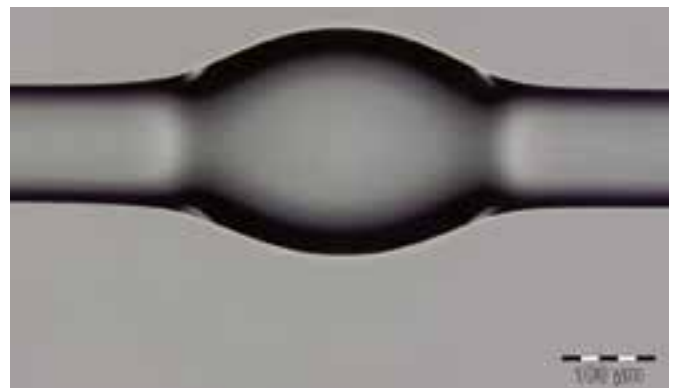
The Baumer Group is represented by Baumer Hübner GmbH in Berlin Charlottenburg.

© Baumer Group

iris GmbH infrared & intelligent sensors develops and produces sensors for automated passenger counting. IRMA (InfraRed Motion Analyzer) is a passenger counter

for public transport. iris GmbH uses a variety of physical principles for its counters. It has special expertise in the fields of thermal infrared sensors (FIR, passive IR), near-infrared sensors, three-dimensional distance measurement (TOF, or time-of-flight), and the necessary signal processing. The various sensor technologies have led to the development of a correspondingly broad product portfolio, from which customers can select the right solution.

www.iris-sensing.com



Fibre-optic resonator for optical position determination and biochemical sensor technology

© Fraunhofer IZM

SCHMIDT + HAENSCH GmbH & Co. is one of the capital's long-standing companies. It has existed since 1864 and remains family-owned. From the very beginning, it has specialised in precision optical metrology. It now offers an extensive portfolio of optoelectronic analytical instruments, 80% of which are exported worldwide. In addition to polarimetry, refractometry, and colour measurement instruments as well as dosage and density measuring instruments, the company also increasingly produces special sensors. Moreover, the networking of different laboratory instruments, intelligent sensors, and software is becoming increasingly important. Due to the introduction of new reference methods, the company has become one of the leading providers of analytics in the sugar industry.

www.schmidt-haensch.com



imc Meßsysteme GmbH offers hardware and software solutions for physical metrology. The company was founded in 1988 and has about 200 employees. It produces

hardware and software for various measuring systems at its Berlin location. imc systems measure pressures, forces, speeds, vibrations, noises, temperatures, voltages, and currents. In addition to the automotive industry, imc also supplies train and aerospace manufacturers and suppliers.

www.imc-tm.com



Raytek GmbH is a specialist for non-contact temperature measurement in industrial applications. As a member of the Fluke Group, the company develops, produces, and markets a wide range of infrared pyrometers for non-contact temperature measurement from – 40 up to 3,500 °C. The company offers measuring heads, thermometers, sensors, and line scanners as well as complete surveillance systems and thermal imaging cameras.

www.raytek.com



Prignitz Mikrosystemtechnik GmbH, located in Wittenberge, is a specialist for pressure, temperature, and humidity sensors. It also offers special sensors for fill level measurement and chemical analysis. The production of highly sensitive sensor technology takes place in its own clean room. Founded in 2001, the company now has over 60 employees (2018), a large proportion of whom work in research and development. Prignitz Mikrosystemtechnik sells about a third of its products to customers in the United States, China, and Russia, while 40% of its products are sold in Germany. Sensors from Wittenberge are used, for example, in filter and ventilation systems, in oil and water tanks, and in truck anti-lock braking systems (ABS).

www.prignitz-mst.de/en/home-2.html



The Stahnsdorf branch of **Endress+Hauser Messtechnik GmbH + Co. KG** also specialises in silicon-based pressure sensors. Such sensors are used in many industries, such as food, life sciences, energy, water/waste water management, raw materials/metals, chemicals, oil, and gas. The site was founded in 1994 and is expected to expand significantly in 2018. Indeed, the company has just doubled its workforce to approx. 180 employees in the first quarter of 2018. Further expansion over the next few years is planned.



Electronic measurement technology for pressure, level, temperature, humidity and analysis

© Prignitz Mikrosystemtechnik GmbH

www.endress.com/en/Endress-Hauser-group/product-center-competencies/Competence-Center-Level-Pressure/Maulburg/stahnsdorf

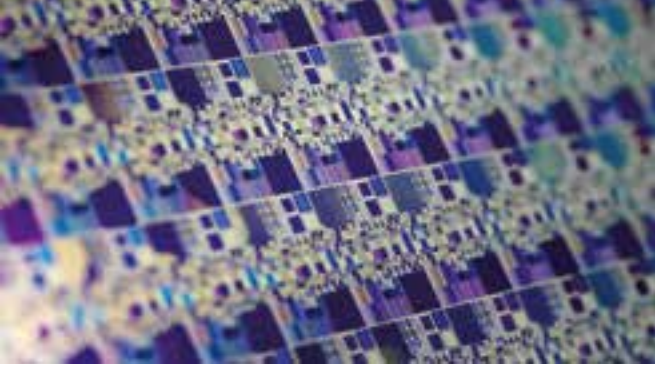


GED Electronic Design GmbH is based in Frankfurt (Oder) and primarily works in the development and design of customer-specific circuits, so-called ASICs (application-specific integrated circuits). The experts work on the complete design flow from the defining specifications to readiness for serial production. They develop test hardware and software and transfer it to series testing at their partner, Elmos Semiconductor AG. The products GED has developed for customers include transponder ICs, various sensor ICs, motor control ICs, as well as LCD and LED drivers.

www.ged.de/english/home.html



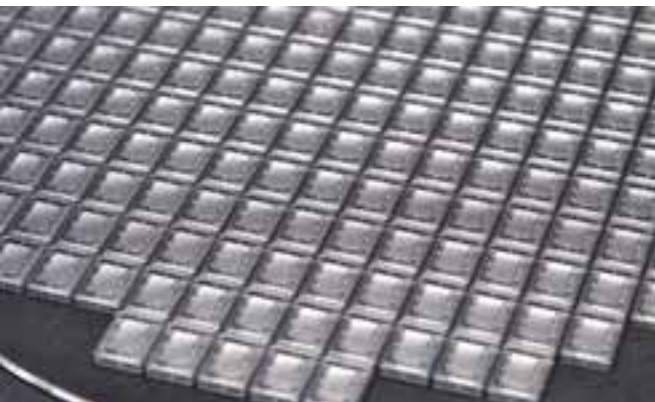
micro resist technology GmbH is specialised in the development and production of polymer-based chemicals used in lithography processes for micro- and nanostructuring. The company based in Wuhlheide Berlin, supplies innovative polymer products and ancillaries that are used in the microelectronics and semiconductor industry. The specialty



Innovative polymers and photopolymers for microoptics and photonics
© micro resist technology GmbH

chemicals also enable basic technologies for micro-optics, photonics and microfluidics, which find applications in the pharmaceutical, food or environmental analysis industries as well as consumer electronics.

www.microresist.de



Complex micro-optical elements made from hybrid polymers from
micro resist technology GmbH
© Fraunhofer IOF

Since 1996 **PolyAn GmbH** develops and manufactures high-performance consumables for multiplex diagnostics and LifeScience research. Based on its Molecular Surface Engineering technology PolyAn offers microarray consumables, fluorescent micro- and nanoparticles as well as selection of reactive microplates for high-end applications.

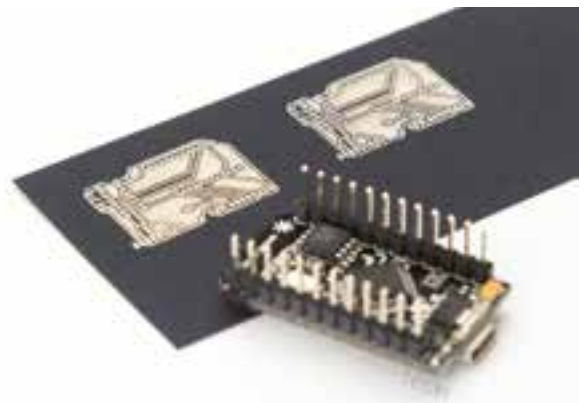
www.poly-an.de



OrelTech GmbH is a high-tech start-up that produces nanoparticle-free conductive inks for printed electronics and catalysis. Their proprietary technology empowers the next generation of electronic devices to be simple, cost-efficient and green. As a pioneer in the conductive ink industry, they developed an alternative approach to metallizing surfaces, which enables high-precision metallization on a wide range of surfaces, including temperature-sensitive plastics and textiles or active organic materials. Metallic layers printed with OrelTech's inks are much thinner and more compact. Besides the significant cost benefit that this introduces, it also enabled the development of their flagship product transparent silver ink (OTech T) with up to 85 % transparency, giving a true alternative to existing transparent electrodes. Besides silver, OrelTech offers gold and platinum inks as well.

After winning INAM's acceleration program Advanced Materials Competition in 2017 OrelTech moved from Israel to Berlin. Chapter 4.2 "Networks" gives a look at INAM.

www.oreltech.com



Silver electrode printed on paper with OTech Jet nanoparticle-free
conductive ink
© OrelTech GmbH

System integration as the key to the future

With Industry 4.0 and the Internet of Things, it's not just the components that matter, but also the integration technologies. Electronics and microsystems technology are increasingly merging with the project in terms of both material and form: separate, retrofitted components are being replaced by fully integrated solutions adapted to the application system. This depends on having the right integration technologies.

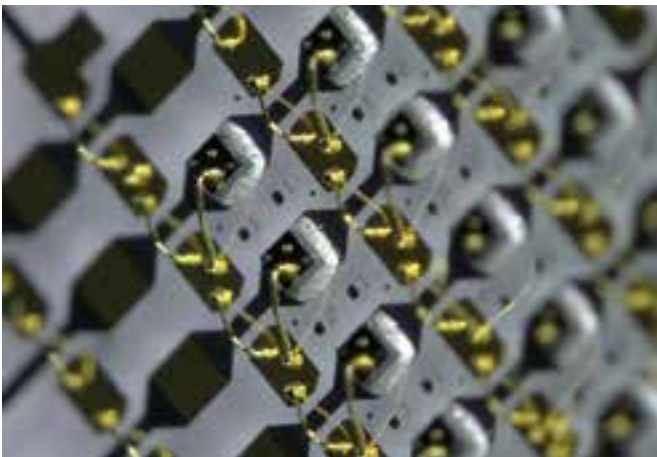
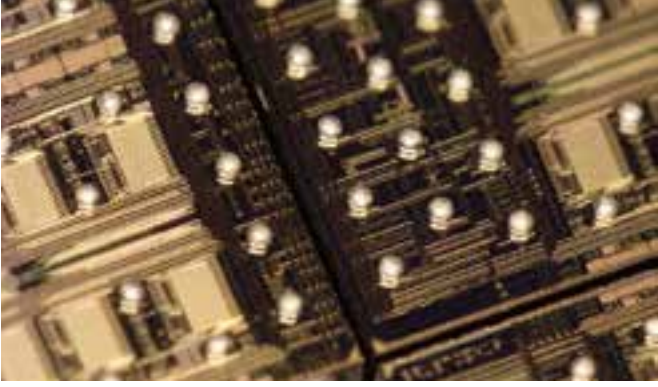


Image 1 Fully automatic UBM and balling of wafers

Figure 2 High-precision placement of optoelectronic components

© AEMtec GmbH

In addition to physical integration into the application environment, which is not always easy, these technologies must also ensure that the structures are miniaturised, robust, and durable, because the deep integration of electronics and microsystems technology makes this indispensable while complicating repairs.

The traditional ways component and assembly manufacturers and suppliers of electronic systems have cooperated are not transferable to the creation of such integrated solutions. Instead, those who want to incorporate electronic components into their products need to include them from the outset. New approaches are also needed in research and the development of new products.

Berlin Brandenburg is well prepared for this development because the companies here are focusing on technically sophisticated products and integrated services. The trend towards increasingly integrated electronics fits well with the automotive industry, for example, where 90% of all innovations are associated with the use of electronics and microsystems technology.

The industries in which Berlin Brandenburg are particularly strong are following this trend and are increasingly integrating electronics and microsystems into their products. These industries include control and regulation technology, mechanical and plant engineering, energy technology, medical technology, aerospace technology, and logistics. This is where companies in the region can play a major role. They enjoy strong ties to research and development, have an excellent knowledge base, are very flexible, and are well networked with each other as well as with institutions active in system integration research.

AEMtec GmbH is a medium-sized company with a broad technology portfolio (wafer back-end, flip chip, chip on board, SMT, box build) to produce microelectronic and optoelectronic modules with high-precision positioning accuracy in the submicrometre range and 30 years' experience in integrated circuit packaging. In addition to design and development, its services include prototyping (NPI), qualification, production, testing, as well as supply chain management along the entire product lifecycle.

www.aemtec.com/en/



Finetech offers manual, semi-automated and automatic bonding systems for optoelectronics and microelectronics.

© Finetech GmbH & Co KG



The wireless sensors below the insulators enable the monitoring of high and extra-high voltage lines.

© Fraunhofer IZM

Pac Tech – Packaging Technologies GmbH is another high-tech supplier with roots in Berlin Brandenburg. The company develops and sells machines for applying semi-conductors to printed circuit boards. It offers both the machines and the services: it can place electrical contacts on microchips. Major providers such as Intel and Samsung are among its customers.

The company was founded in 1995 as a spin-off from Fraunhofer IZM. Since then it has been a real success story: it opened its first manufacturing plant in Nauen, Brandenburg, in 1997. It added a second in California in 2001 and a third in Malaysia seven years later. By 2015, the company had already shipped its 1,000th system. The Japanese NAGASE Group also took over the company in full that year.

www.pactech.com



F&K Physiktechnik GmbH in Potsdam develops and manufactures assemblies and processes that are used for chip contacting in microelectronics manufacturing worldwide. The focus of F&K Physiktechnik is on assembly and connection technology for microsystems technology.

The product range includes generators and transducers for ultrasonic wire and dye bonding. Special measuring and test equipment were developed so that the ultrasonic systems in the bonding machines can be optimally set up and monitored. This includes a transducer test system and optical vibration amplitude measurement technology (laser vibrometer). This equipment is suitable both for service on the bond machinery and for quality assurance. This makes it possible to document the condition of the ultrasound system within the framework of quality management systems. The use of the measuring equipment also makes preventive maintenance and servicing of the ultrasonic systems of the bonding machines possible for the first time.

www.fkphysiktechnik.com/index_e.htm



Finetech GmbH & Co KG is a special machine construction company and offers customised equipment solutions for high-precision assembly applications in optoelectronics and microelectronics. Manual, semi-automated, and automatic bonding systems are available and offer maximum process flexibility due to their modular design. The products support a wide range of modern joining technologies, including ultrasonic bonding, thermocompression bonding,



Sensor system for monitoring the ensiling process in biogas production
© Fraunhofer IZM

bonding technologies, laser soldering, and soldering in different environments. Typical applications are the assembly of laser and photodiodes, laser bars, sensors, VCSEL, and MOEMS. The applications range from basic research and development of innovative semiconductor products to fully automated production environments with high throughput.

www.finetech.de



ESYS GmbH develops and manufactures low-energy miniaturized electronics with a focus on mobile applications. Since 1992, the Berlin-based company has been successfully implementing its own standard products as well as customer-specific hardware and software developments. These include in particular battery-powered long-term miniature data loggers for temperature, humidity, motion, acceleration, shock, and position. They are used, for example, for the remote location and fleet management of vehicles, machines, and containers.

www.esys.eu/home.html



Applications for Sensors

New sensors for agriculture

The quality of the silage-making process is decisive for the efficient production of biogas. Until now, there has been no suitable sensor system that could monitor the silage process from the opening of the silo to the removal of the silage. With the multisensor technology developed by Fraunhofer IZM, the Julius Kühn Institute in Braunschweig, and ESYS GmbH, it is now possible for the first time to monitor compaction at critical points such as edge areas during

start-up and simultaneously record the pH value. Likewise, disturbance variables during the ensiling process and after removal are detected at an early stage and can be eliminated before a reduction in silage quality occurs. The use of a common software standard in harvest data management also ensures that the sensor data can later be integrated into already established software solutions and thus transferred directly into practice.

Sensor network for high voltage lines

The autonomous sensor network ASTROSE monitors operation-relevant parameters of high-voltage overhead lines in order to make optimum use of their transmission capacities. Field trials have shown that capacity reserves can be raised by as much as 20% in this way. For this system developed jointly with colleagues from Fraunhofer ENAS and First Sensor Microelectronic Packaging, software tools are provided for storing the acquired data in a relational database. In addition, a user interface for better visualisation and more complex evaluation of the data has been created. In a further development with partners DResearch in Berlin and LTB in Neuenhagen, the system is currently being equipped with an image sensor for visual environment detection.

Sensors are with us everywhere we go today: from position and GPS sensors in smartphones to highly specialised systems for various product categories, our lives and the modern economy can no longer be imagined without sensors. The number of applications seems enormous.

However, a few basic principles can be observed: sensors need to be small, robust, and precise and have good connectivity. The development and optimisation of the corresponding technologies is underway at a large number of companies and research institutions in Berlin Brandenburg. With their work, they will also secure a technological lead for the region in the future.

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Microsystems Technology

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3 Education and Training



3 Education and Training in Optical and Microsystems Technologies in Berlin Brandenburg

The career prospects in optical and microsystems technologies are excellent, for industrial and academic young talents as well as specialists who have already started their careers. Growth forecasts for these high-tech fields suggest that employment figures will continue to rise steadily within the next years. However, technology companies and research institutions increasingly struggle with finding suitable employees. The Berlin Brandenburg region meets this challenge with a multitude of attractive offers and effective measures promoting higher education, vocational education and training (apprenticeships), and continuing professional training.

Higher Education and Summer Universities

The universities in Berlin Brandenburg offer more than 40 courses related to optics, photonics, and microsystems technology, either as stand-alone courses or as specialisations/modules for studies in “Engineering” or “Natural Sciences”.

At each of the three major universities in Berlin, several chairs and institutes are engaged in training the next generation of specialists in optical technologies. The two Brandenburg technical universities of applied sciences TH Wildau and TH Brandenburg jointly offer a master’s degree in “Photonics”.

Five universities in the region provide courses in microsystems technology. HTW Berlin also offers a separate degree in “Microsystems Technology”. TH Brandenburg has recently launched its degree in “Ophthalmic Optics/Optical Instrument Technology”. Microsystems technology can also be studied at TU Berlin, Beuth University of Applied Sciences Berlin, and TH Wildau as a specialisation or focus area.

Company-based Apprenticeships

Not only the scientific staff, but also well-qualified and skilled workers contribute significantly to the success of the region’s companies and research institutes. More and more high-tech companies are recognising the value of training their own apprentices. In addition to core competencies in microtechnology and photonics, numerous further professions are highly valued: chemical and physics laboratory technicians keep the research in high-tech laboratories going and mechatronics, automation electronics, and industrial technicians ensure that state-of-the-art equipment functions smoothly.

Nevertheless, too few young people know about promising training opportunities in high technology, as reveals a structural analysis of the labour market in the optics and photonics industry in Berlin Brandenburg. To change this and to get the urgently needed skilled workers, ANH Berlin, a network for high-tech training and education, located at the Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH) advises and supports companies and research institutions regarding all questions on training and apprenticeships. In addition, ANH informs students, teachers, parents and other multipliers about fascinating career opportunities in the Photonics Cluster.

In order to improve the region’s training structures in the long term, ANH Berlin counsels interested companies and research institutions on training and education and helps recruiting suitable applicants. Many of the companies that are active in the cluster have been offering high-level training for years to constantly improve the attractiveness and quality of vocational education and training and to reduce drop-out rates. ANH Berlin additionally promotes the regular exchange of information and know-how among its members. In this way, all companies providing training benefit from the respective know-how.

The “Microtechnology Training Association Berlin Brandenburg” was founded in 1998 – a successful example for regional networking within industrial training, in which training companies work together and support each other. Training content that is not covered by individual companies can be provided by network partners or in central training courses.



Berliner Glas offers apprenticeships in photonic technologies, because highly motivated and well-trained employees are indispensable.
© Berliner Glas Group



Trainee microtechnologist
© ZEMI/Wiedl

The network is coordinated by the Lise Meitner School of Science, the only vocational school for microtechnology training in the region. It is financed jointly by the Berlin Senate and the companies as part of the non-profit proMANO association.

Training the Next Generation

The ANH Berlin network, in close cooperation with OpTecBB e.V., has expanded its vocational orientation and marketing efforts addressing students, teachers, parents and multipliers. Existing events like school career days, Girls' Day, and the Long Night of Sciences are a regular platform to promote interesting training and job opportunities which are still fairly unknown to the public. At regional education and technology trade fairs (Vocatium, Apprenticeship Days, Parentum, etc.), the network informs about future-oriented training and career options in STEM (fields of Science, Technology, Engineering and Mathematics).

The exchange of experience and the development of innovative concepts and media to recruit young people for photonics were also taken on the European level. ANH Berlin has been an active member of the European consortium ECOP for many years, promoting innovative outreach programmes to attract young people – especially girls – to STEM.

Since 2010, OpTecBB e.V. supported by the FBH has been publishing the education and training atlas for optical and microsystems technologies in Berlin Brandenburg every two years. The atlas provides an overview of relevant degree programmes, orientation for young people when choosing a suitable field for an apprenticeship or study, and offers an overview of further education courses in the cluster.



School Lab MicroLAB
© LMS/FBH

Initial Vocational Education and Training & Further Training

In summary, training and education issues have become more and more important for the cluster as a whole due to technological and demographic changes. As a result, the cluster management jointly with the ANH Berlin network management will continue to promote activities informing about career opportunities in natural sciences and attracting young people to STEM. At the same time, the partners will carry on to support companies and institutes in their training and education efforts. To do so, a new association proANH e.V. was founded in May 2019 uniting 22 companies and institutes. This can be regarded as an important milestone as companies for the first time contribute directly with member

fees to the sustainability of the network. However, as the personal and financial resources of this still fairly small association are very limited and successful networking in this field is quite challenging it has (again) become clear that continual and sustainable activities depend on regional, national, and European grants on a project-by-project basis.

For example, the BM=x³ project, funded by the Federal Ministry of Education and Research will stimulate the development and implementation for innovative concepts for initial vocational and further training. It will activate and bundle competences and infrastructure to improve quality and to make VET more attractive to both employers and staff as well as potential apprentices.

Contact: Uta Voigt

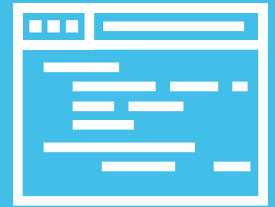
ANH Berlin (Aus- und Weiterbildungsnetzwerk Hochtechnologie)
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Education and Training Atlas for Optical and Microsystems Technologies in Berlin Brandenburg – further information can be found at www.anh-berlin.de



4 Industry Platforms



4.1 Fairs, Conventions, and Conferences

Optics and photonics in Berlin Brandenburg combine a multitude of themes and initiatives. Nearly 400 technology companies and over 30 university and non-university research institutions in the region work in these fields. In order to connect research and industry in Berlin Brandenburg and support the transfer of knowledge and technology, the cluster offers various networking platforms. The aim is to increase competitiveness and achieve intelligent, sustainable, and integrative growth.

Under the leadership of Berlin Partner for Business and Technology, OpTec-Berlin-Brandenburg (OpTecBB) e. V. and Economic Development Agency Brandenburg (WFBB) organise the cluster's work together with their local partners.

In order to focus on advancing the development of the core competencies of the regional economy, six focus areas have been identified for the cluster's work:

- laser technology
- lighting technology
- photonics and quantum technology for communications and sensors
- optical analytics
- biophotonics and ophthalmic optics
- microelectronics and microsystems technology

Regular conferences are organised for all six focus areas with presentations, opportunities to engage in direct conversation, and keep up-to-date with the latest news recently with a new focus on cross-cluster topics. Every two years, a cluster conference on optics and photonics is held alternately with the OpTecBB Networking Days.



Presentation of Research Fab Microelectronics Germany by former Cluster Spokesman Prof. Günther Tränkle at the 2017 Photonics Cluster conference © Economic Development Agency Brandenburg (WFBB), Marschalsky

An overview of the wide range of events can be seen in the event calendars.

Photonics Cluster website:

www.photonics-bb.com



The website of the competence network OpTecBB e. V.:

<https://optecbb.de/en/>



In addition to the six focus area conferences, the cluster also offers various workshops and events on specific interdisciplinary topics such as:

- funding and financing (e.g. information events on current calls)
- securing a skilled labour force (e.g. Summer School)
- internationalisation
- technology scouting with users of optical technologies
- start-ups (e.g. start-up accelerator AdMaCom, the Photonics Venture Forum, Entrepreneurship in Photonics)

The start-up theme has gained in importance in the capital region in recent years. In 2016, the Innovation Network for Advanced Materials INAM was founded, which brings together innovative founders with experienced producers through a new format. At the beginning of the year, the network is calling for submissions to the Advanced Material Competition (AdMaCom) from start-ups from all over the world. This exchange of experiences has delivered very good results in its first three years, with several companies moving to the region, new spin-offs, and various collaborative projects. EPIC, the European Photonics Industry Consortium, is also committed to the topic of start-ups and regularly organises Europe-wide workshops and specialist events, such as the Photonics Venture Forum.

Entrepreneurs are the driving force behind innovation and profitability. The photonics industry offers countless opportunities for this. Entrepreneurs are typically the founders and managing directors of companies but can also be found in a variety of other positions. Entrepreneurship in photonics is a topic which the Photonics Cluster has been working on for many years and for which it provides content, together with such international partners as the EPIC Consortium and the European Optical Society (EOS).

Some formats have already become stand-by events that have become an indispensable part of the annual calendar. They range from the “Laserstammtisch” in Berlin to events in Brandenburg such as

- Profs-on-Tour
- Made in Brandenburg
- Brandenburg Optics Day
- Students-on-Tour

to large international conferences that stop off in Berlin or Brandenburg.



In addition to the “Laserstammtisch”, Laserverbund Berlin-Brandenburg e. V. regularly organises user meetings on site.

© Laserverbund Berlin-Brandenburg e. V.

In addition, there are international trade fairs and conferences, such as

- LASER World of Photonics in Munich
- Optical Fiber Communications Conference (OFC), a touring trade fair in California, United States
- European Conference and Exhibition on Optical Communication (ECOC), a touring trade fair in Europe
- Optics & Photonics International Exhibition (OPIE) in Yokohama, Japan

The capital region is represented with a large joint booth at each of these events.



Berlin Brandenburg Pavilion at LASER World of Photonics in Munich 2017
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Local and International: Photonic Days Berlin Brandenburg

In recent decades, there has always been a need for a joint event in Berlin und Brandenburg to present the diverse activities pursued by researchers in optics and photonics, including presentations, a trade show, and various networking activities.

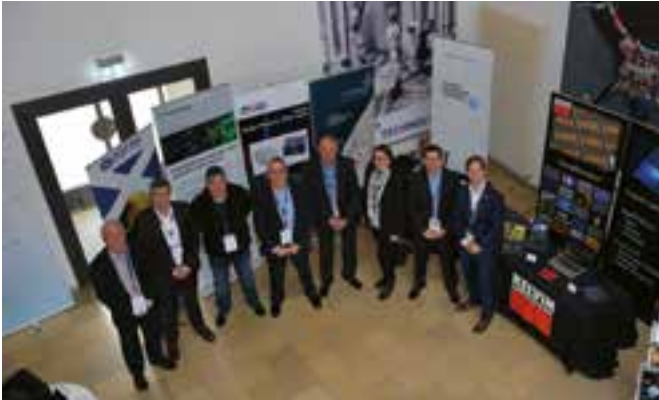
The Photonic Days Berlin Brandenburg were initiated in 2017. It has its origins in the “Laser Optics Berlin” (LOB, later “micro photonics”) trade fair founded at Berlin-Adlershof in 1996, but it now has a different emphasis.

Over the course of a single week, a cluster conference and two focus area meetings are held, together with nine different workshops and conferences. In addition to the lectures and the accompanying trade show, the initial outing for the event welcomed over 500 attendees, including guests and delegations from the United States, Japan, Brazil, Poland, Great Britain, Switzerland, Spain, Italy, France, and Israel.

The Photonic Days Berlin Brandenburg have thus become the most important event in the capital region for this sector. The organiser is OpTec-Berlin-Brandenburg (OpTecBB) e. V. supported by the Photonics Cluster Berlin Brandenburg.



Accompanying exhibition at Photonic Days Berlin Brandenburg 2017
© Berlin Partner for Business and Technology



Scottish exhibitors at Photonic Days Berlin Brandenburg 2017
© Berlin Partner for Business and Technology

After the success of the first event, the Photonic Days are planned for each autumn. The range of topics is orientated towards the cluster's focus areas but will clearly go beyond for certain topics. At the first Photonic Days 2017, topics ranged from innovative optical components to quantum optics and networked sensor systems in autonomous vehicles, laser material processing, water analysis, and the new innovative topic of PolyPhotonics.



Focus area conference in Photonics for Communications and Sensors, October 19, 2017; topic: quantum optics and secure optical data transmission.

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In particular, the international activities of the various cluster members are given a platform here. A typical example was the workshop on laser material processing in 2017 organised jointly by the cluster and Laserverbund Berlin-Brandenburg e. V., where experiences and new ways of international cooperation in the field of laser technology were discussed. The Fraunhofer Institute for Production Systems and Design Technology IPK is a pioneer in this field. Since 2012, IPK experts have been working with SENAI, Brazil's national service for industrial education, to develop strategies and business plans for the development and implementation of 23 research institutions in Brazil.

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4.2 Networks

OpTec-Berlin-Brandenburg (OpTecBB) e. V.

More than ten years ago, a discussion was initiated by representatives of research and industry into which sub-disciplines optical technologies should be developed in Germany in order to become or remain internationally competitive and to develop them into innovation drivers. This action programme was called “German Agenda for Optical Technologies for the 21st Century”, and this led to the programme “Optical Technologies Made in Germany” funded by the Federal Ministry of Education and Research (BMBF). The formation of competence networks for optical technologies was part of this programme. They became new infrastructure elements for promoting the process of cluster formation and accelerating the transfer of knowledge and technology from research to industry in important optics and photonics regions in Germany. OptecNet Deutschland e. V. has become an umbrella organisation for all these networks and organises their constructive cooperation.

OpTecBB e. V. arose out of this strategic process and was founded on September 14, 2000, by 14 companies, research institutions, universities, and associations with the support of the responsible state ministries of Brandenburg and Berlin. From the very beginning OpTecBB e. V. has been closely networked with all important regions in Germany via OptecNet Deutschland e. V. and has also developed many international contacts to key markets in Western Europe, North America, and Asia through its own activities.

OpTecBB e. V. and its members have set themselves the following goals:

- to bundle and connect the existing potential in the region in the fields of optical and microsystems technologies
- to promote the transfer of knowledge and technology from research to business
- to initiate R&D projects and support partnerships
- to create a platform for communication and sharing information
- to organise joint marketing activities and trade fair appearances to promote the companies, research institutions, and the Berlin Brandenburg region
- to inform and advise the state governments and economic development institutions
- to promote education and further training in the field of optics/photonics, to make the region known as a leading training location, and to secure the next generation of skilled workers

The competence networks for optical technologies, founded on the initiative of the BMBF, are primarily oriented towards regional players and their cooperation in the region. In technical terms, the activities concentrate on these focus areas in the capital region: laser technology, lighting technology, photonics and quantum technology for communications and sensors, optical analytics, biophotonics and ophthalmic optics, as well as microelectronics and microsystems technology. The concrete development in these focus areas is outlined in the master plan for Berlin Brandenburg. With the formation of the Photonics Cluster, other players in the region became involved in the effort to facilitate cooperation along the value chain. As part of the cluster management, together with Berlin Partner for Business and Technology and the Economic Development Agency Brandenburg (WFBB), OpTecBB e. V. appoints the Cluster Spokesman to represent the fields of optics, photonics, and microsystems technology.

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Laserverbund Berlin-Brandenburg e. V.

The Laserverbund Berlin-Brandenburg has been dedicated to the regional promotion of laser technology since 1993. To this end, the association uses traditional and modern event formats to facilitate the exchange between practitioners and scientists in the fields of research, development, and application.

The association directly and exclusively pursues non-profit purposes. Currently, it has 24 institutional and 90 individual members. The Laserverbund has developed into the region's point of contact for laser technology and laser applications.

Laserverbund Berlin-Brandenburg e. V. offers:

- contacts to experts in the field of laser technology
- seminars and workshops on current topics in laser technology
- opportunities to exchange experiences using the event “lasers in materials processing”
- exchange among experts in regular laser-related meetings, called “Laserstammtisch”
- a wide range with suppliers of products and services for laser technology in the Berlin Brandenburg region

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Members of Laserverbund Berlin-Brandenburg e. V. at a 2018 meeting in Jena

© Laserverbund Berlin-Brandenburg e. V., photo: Matthias Baumbach

OABB optic alliance brandenburg berlin e. V.

The capital region Brandenburg Berlin has long been a centre for classical and ophthalmic optics. It is home to very successful companies, significant research and development potential, and a well-developed infrastructure in education and research.

Within the framework of a company-led industry network, a nationwide and supra-regional network, the OABB optic alliance brandenburg berlin e. V. is rightly regarded as one of the most important networks in the field of innovative ophthalmic optics in Germany and Europe. It was established to promote cooperation, coordination, and bundling of these potentials.

The network seeks to further develop and establish the Berlin Brandenburg region as a nationally and internationally known centre for ophthalmic optics. The aim is to open up innovation interfaces between large companies, SMEs, and regional research institutions, including the optical trade. Thus, the involvement of the opticians' guild of the state of Brandenburg with its education and technology centre, the Technische Hochschule Brandenburg University of Applied Sciences, and Oberstufenzentrum Havelland is important. With this, the network actively faces the challenge of the further expansion of the Berlin Brandenburg region as a centre of academic and vocational education and training in the field of optics.

Innovation, competence development, internationalisation, market development, the creation of strategic partnerships in international metropolitan areas of ophthalmic innovation as well as industry and location profiling are the targeted focal points of the work of OABB optic alliance brandenburg berlin e. V. The network partners have all the important competences in the ophthalmic technology fields with their products and services: spectacle lenses, special lenses, magnifying vision aids, spectacle frames, optical production equipment, workshop technology, salesroom design and training. Thus, the location with its complexity, bundling and company concentration represents a complexity of optical competence in Germany and is one of the most modern production sites in Europe.

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OABB optic alliance brandenburg berlin e. V.



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GRW-Cooperation Network ERT-BB

The “Electronic-Relevant Topics and Spheres of Activities in the Region Brandenburg - Berlin” (ERT-BB) Network managed by GFWW e. V. with currently 19 members was founded in 2018, to develop new concrete application solutions in electronics relevant fields and to expand value chains. In order to make these potentials visible to other industries, network activities are closely integrated into the Photonics Cluster development of coming years, especially in the fields of action “Photonics and Quantum Technologies for Communication and Sensor Technology” and “Microelectronics and Microsystem Technology”. Based on technological developments in semiconductor industry, especially silicon-based nano-, micro-, power electronics and photonics, smart and innovative sensor technology in its application plays a key role for the network with use of cross-clustering.

Aim is to develop completely new technology processes and manufacturing methods/tools that can supplement or even replace previously complicated technologies in chip and sensor production. This will enable applications based on integrated sensor chip solutions with combination of actuators, integrated evaluation electronics and data transmission as well as high reliability under extreme conditions. Application is particularly focused on following key technologies: Automotive (e. g. engine control, autonomous driving); automation, industry 4.0 (e. g. robotics and production monitoring, remote diagnosis, maintenance); health, life sciences; agriculture, forestry; information and communication technology, including wireless, Internet of Things; safety, security. New solutions in packaging and interconnection technology are crucial, e. g. for the coupling of electrical and optical signals and integration of new materials.

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Innovation Network for Advanced Materials (INAM) e. V.

INAM supports the development of innovative and marketable products that focus on the production of functional materials and their applications and processes. These include developments in the fields of sensor technology, wearable technologies, lighting technology, optoelectronic components, and photovoltaics. The interest lies in bundling competencies and resources in order to bring innovations to the market faster.

The network was founded at the beginning of 2016 and is already supported by 20 partners: Osram, Weitnauer, Berlin Partner for Business and Technology, Humboldt University Berlin, Pilotfish, IRIS Adlershof, Fab Lab Berlin, Wista Management, Humboldt Innovation, Rudolph Graad, Specs, Inuru, Start Alliance, InnoEU, JNC, Würth Elektronik, Sabc, Robert Bosch, and Takata. The network is based in Berlin and



Since 2016, innovative start-ups in the AdMaCom accelerator programme have been matched with experienced mentors.

© Berlin Partner for Business and Technology

operates as an international association. It offers its members a series of events such as workshops, meetings, members' dinners, and presentations on diverse platforms for sharing information and exchanging ideas.

The Advanced Materials Competition (AdMaCom) organised in Berlin each year by INAM is an accelerator programme in photonics, micro- and nanoelectronics, and new materials. The international focus attracts start-ups from all over the world to apply for this high-tech matchmaking/mentorship programme.

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PolyPhotonics Berlin e. V.

PolyPhotonics Berlin e. V. represents well-known and established players in the field of optical communication and sensor technology with a regional focus on Berlin and Brandenburg. The aim of the association is to promote science and research in connection with the research and development of optical basic elements for compact functional components using the PolyPhotonics Berlin technology platform. The core elements of the hybrid integration platform are waveguides made of plastic, combined with active components such as lasers, gain elements or photodiodes, as well as passive components such as thin-film filter elements and grin lenses. Typical fields of application are in the field of telecom/data-com as well as in analytics and sensor technology.

Further fields of application in quantum technology and medical technology are opened up.

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The PHOENIX+ Cooperation Network

The Photonics and Optoelectronics Network PHOENIX+ is organised by the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI, the Fraunhofer Institute for Production Systems and Design Technology IPK, Berlin Partner for Business and Technology, and OpTecBB e.V. within the Photonics Cluster Berlin Brandenburg.

The project team has set itself the task of promoting the initiation of business-related and cross-border research and development partnerships in the field of optical technologies between Berlin and partner regions in Poland, Japan, Israel, and the United States. In addition, they provide ongoing information on new calls for proposals, such as those issued by the Federal Ministry of Education and Research (BMBF), which could be of interest to the international network and support the application process for funding.

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- provides an overview of the most important growth industries in Berlin.
- develops the five clusters of the joint innovation strategy of the states of Berlin Brandenburg.
- provides support with patent issues.
- provides support in permit-related and visa matters in connection with your investments.
- brings partners from business and science together in order to improve products and processes.
- offers platforms for productive exchange and collective projects.

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Economic Development Agency Brandenburg (WFBB)

The Economic Development Agency Brandenburg (WFBB) is the central point of contact for investors, companies based in the state of Brandenburg and technology-oriented start-ups. With our expertise and comprehensive support in all industry sectors, and our contact to relevant stakeholders and networks we offer service packages for economic development and the promotion of employment tailored to you. Our service is free of charge and completely confidential.

Brandenburg Invest provides support during the establishment of a company and its expansion, promotes innovations, internationalisation and networking, and assists the acquisition and qualification of a skilled workforce. WFBB advises on financing and funding options and guides you through public administration. Furthermore, we support the development of sector-specific innovation clusters in the state of Brandenburg and the German capital region. As Brandenburg's Energy Saving Agency, WFBB is closely linked to the implementation of the state's energy strategy.

For the establishment and expansion of clusters with high development potential, WFBB is carrying out the ERDF-funded project "Paths and strategies for sustainable cluster development and for cluster-connecting challenges in Brandenburg 2018–2020". The central task of the cluster is to implement the topics of the respective master plans together with the partners and to help players network intentionally.

With its headquarters in Potsdam, five regional offices in Cottbus, Eberswalde, Frankfurt (Oder), Neuruppin and Potsdam, and the airport region service centre in Schönefeld the company is represented across the whole state of Brandenburg.

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Berlin Partner for Business and Technology and the Economic Development Agency Brandenburg would like to thank all those involved for their cooperation in this Cluster Report, including the provision of the photographic material. The selection of companies and research institutions portrayed is exemplary for the region and does not claim to be complete.

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