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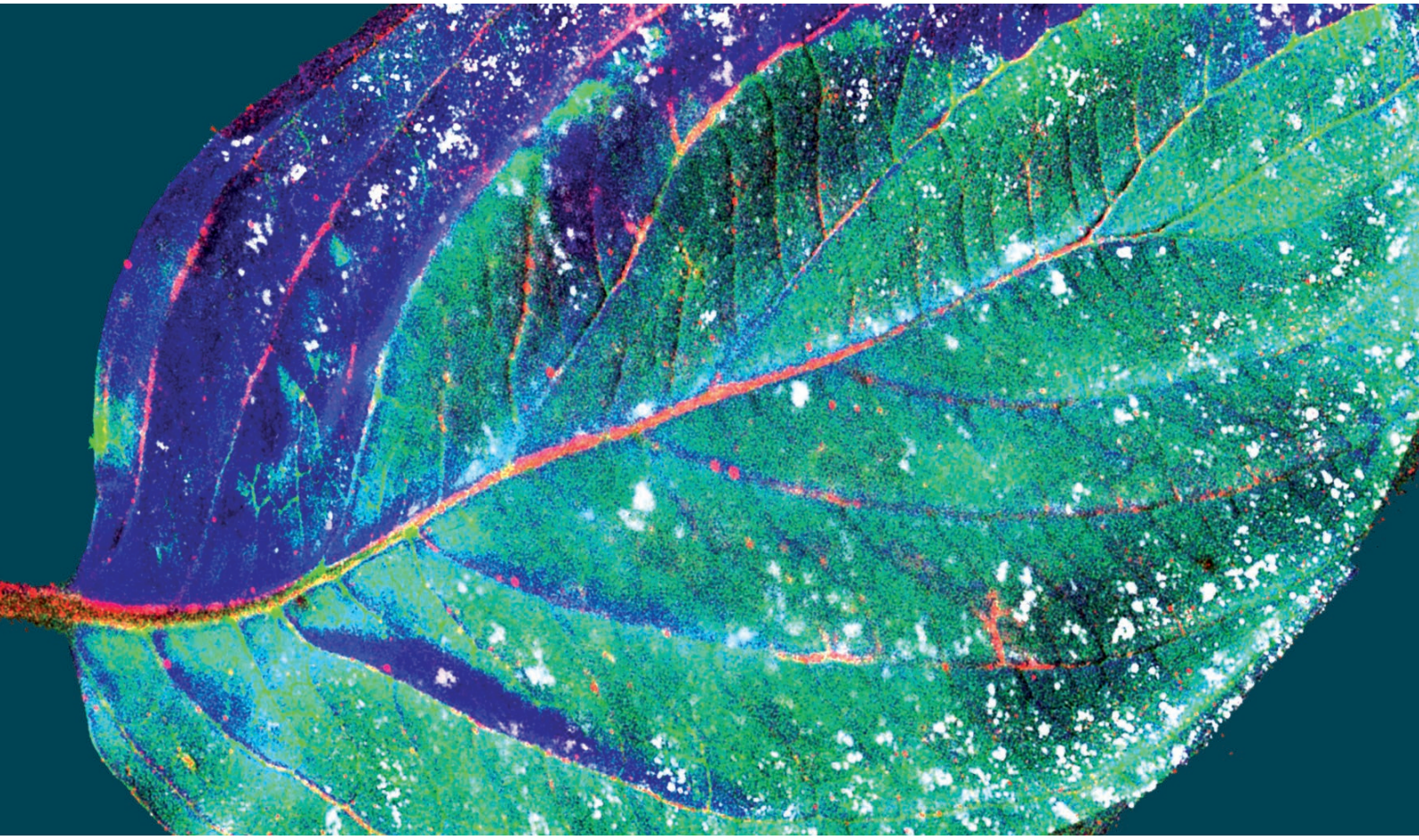

Optical Analytics

in the Capital Region Berlin-Brandenburg

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1 Introduction

The term “optical analytics” describes technologies and methods that we use to measure very different properties of materials or bodies by means of light. Light is a very universal tool capable of measuring the properties of individual atoms as well as the oxygen content in blood, for instance. These methods are usually very accurate and do not require physical contact, thus making many industrial processes possible in the first place.

This report entitled “Optical Analytics in the Capital Region Berlin-Brandenburg” impressively shows in just how many areas of industry and research optical analytics methods are used today. Without them, modern process measuring technology, to name just one example, would hardly be conceivable.

The precision of the analysis, the high processing speed and fast conversion into digital data make optical analytics a crucial tool in modern production methods. For future concepts such as industry 4.0, these measuring methods provide reliable qualitative and quantitative information along each production step.

To develop the necessary methods requires an excellent research environment that is also closely networked with industry. With 22 public and private research institutes that are directly involved with developing methods for optical analytics, Berlin and Brandenburg offer excellent conditions for just that purpose. The technical breadth here is impressive: from astronomy to the healthcare industry, from materials science to mathematical simulation, research institutes with a wide variety of focuses are involved in optical analytics projects here in the region.

The local economy benefits directly from this research infrastructure. For instance, new ideas and technologies are being developed in technology parks in direct cooperation with small and mediumsized companies. Short distances and a sustainably grown network are typical of the science and technology parks in the region. They help to convert research results into marketable products quickly and efficiently.

The intensive exchange above and beyond professional boundaries has led to the development of highly efficient and professional network structures. Especially with regard to the development of new links with industry, they help to save time and money and to find new partners for joint development projects as quickly as possible.

This close networking pays off: High-tech companies from the region are able to stand up to international competition and are continuing to grow. The innovative core of technology companies in the optical analytics focal area currently comprises 55 companies with more than 3,000 employees. In just the last 10 years, more than 1,300 new jobs have been created in the sector.

To support this dynamic development, well qualified staff is needed. In the Berlin-Brandenburg region there are a number of very attractive vocational and academic training opportunities as well as courses for further training. Apart from the 10 universities and technical colleges offering Bachelor, Master and PhD degrees, many companies and research institutes provide the classical dual vocational education with a practical part in the company and a theoretical part in the vocational school.

In this innovative environment of industry, research centers and institutions of higher education, new companies, which are among the best in the world, are consistently being created.

The optical analytics focal area in Berlin and Brandenburg is firmly anchored in research and industry. There are great opportunities here for modern companies to develop new processes and products that will be able to withstand global competition. In this report, you will find an overview of the local offers and structures that will help you to make new contacts and efficiently benefit from the advantages of the capital region.

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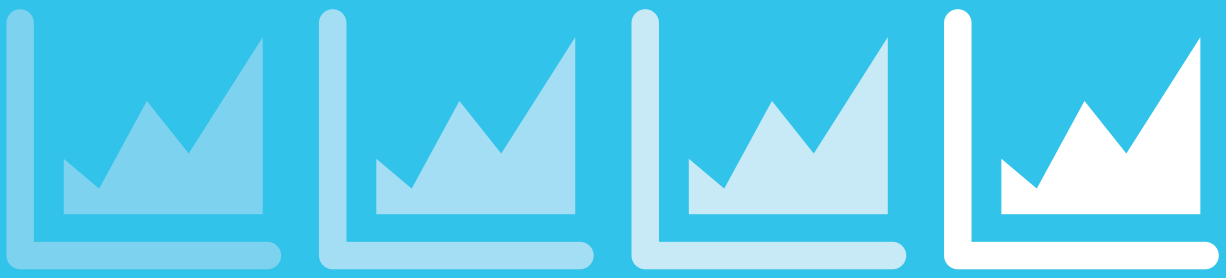

2 Facts & Figures: Optical Analytics in Berlin-Brandenburg

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Structure and Main Applications

In all, 55 manufacturing companies in Berlin-Brandenburg were allocated to the focal area of optical analytics. 48 of which are in Berlin and 7 of which are in Brandenburg. In the science sector, 5 institutions of higher education and 17 non-university research institutions have activities in the sector, a total of 6 in Brandenburg and 16 in Berlin. Three of the companies have more than 250 employees in Berlin and Brandenburg: Berliner Glas, Hach Lange and First Sensor. A further 10 companies have between 50 and 250 employees in the region, 16 have fewer than 10 employees.Optical analytics has a long tradition in the capital region (see chapter 3). However, 10 of the 55 companies were created in the last 10 years and are therefore considered start-ups. The most recent example of which is PDW Analytics from Potsdam, founded in 2014. These companies tend to focus on dynamic application branches such as bioanalytics or process measuring technology. Along with environmental analysis, these are the most frequently addressed areas of application (see fig. 1).

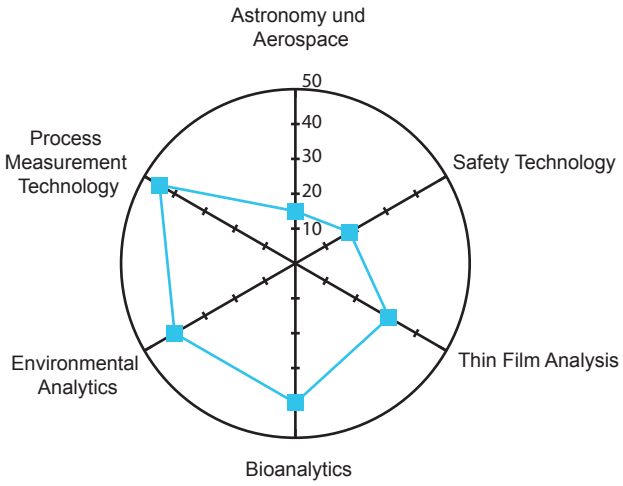


Figure 1: Percentage distribution of the main applications of companies in the optical analytics focal area in Berlin and Brandenburg (contains allocations to more than one).
Source: Berlin Partner for Business and Technology, own survey

Revenue and Employment Development

Revenue of the Berlin-Brandenburg companies increased from 2004 to 2014 from about 266 to about 608 million euros, representing an average annual growth of more than 12% (see fig. 2). For 2014, the surveyed companies expected a moderate 5% increase in revenue. The number of employees in Berlin and Brandenburg increased from 1,730 in 2004 to 3,170 in 2014. This means that 1,440 new jobs were created in the last 10 years in the sector. The expected employment growth in 2014 is just under 4%. Revenue per employee increased from 153,800 to 191,800 euros between 2004 and 2014. Despite the increased need for employees made necessary by growth, a shortage of skilled workers is not a pressing problem for the companies surveyed (see fig. 3). When recruiting employees, the companies seem to benefit not least from the wealth of training opportunities (see chapter 6) as well as from the attractive living conditions in the capital region. The skilled worker situation is considered slightly worse for research institutions. One possible reason could be due to the compensation restrictions of publicly funded facilities that make it difficult for schools and institutes to compete with the salaries paid in the market

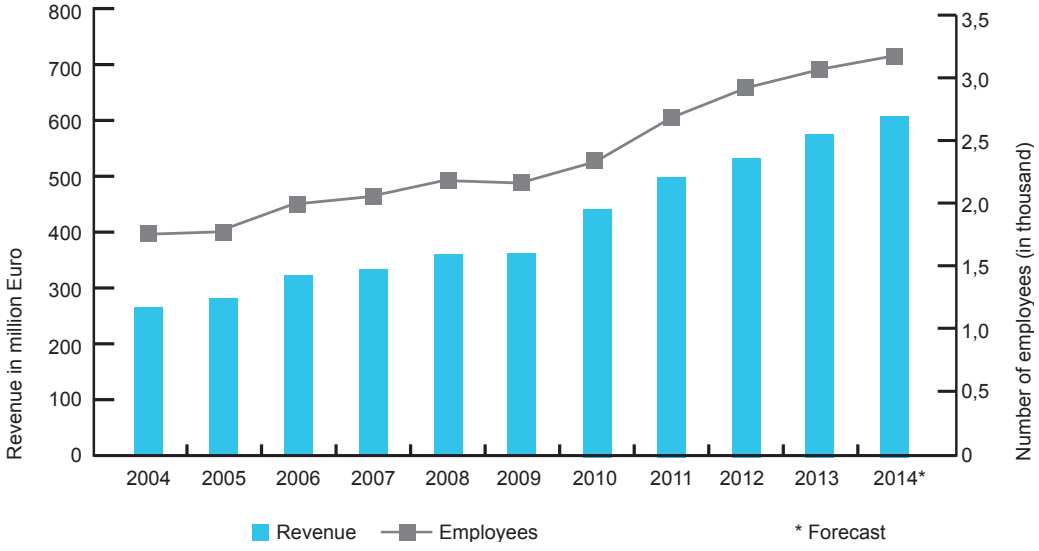


Figure 2: Revenue and employment development in the optical analytics focal area in Berlin and Brandenburg.
Source: MARKUS; Berlin Partner for Business and Technology, own survey

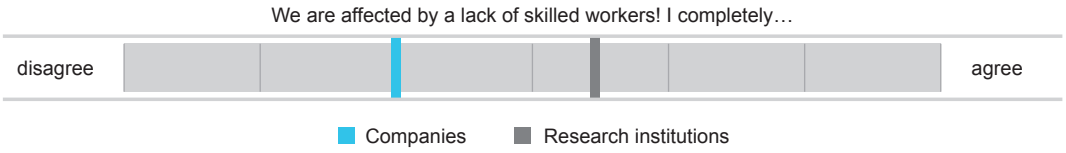


Figure 3: Evaluation of the shortage of skilled workers
Source: Berlin Partner for Business and Technology, own survey

or, in part, for top researchers in other countries. The surveyed companies' and research institutions' assessment of the current business situation supports the positive conclusion and is consistently positive (see fig. 4). 58.8% of participants assess their situation positively; there were no negative evaluations.

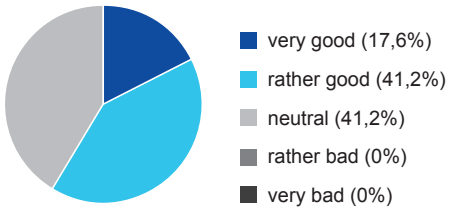


Figure 4: Assessment of the current business situation in 2014
Source: Berlin Partner for Business and Technology, own survey

Industrial Research and Development

Optical technologies are among the research and knowledge-intensive industries. Germany is playing a leading role in global competition, which is in particular based on a knowledge and technology lead over other economies. In order to maintain this competitive position, companies invest an above average amount in research and development. The Berlin-Brandenburg optical analytics companies have invested nearly 17% of their revenue on average in 2013 on applications and personnel in research and development. The willingness to continue to invest in developing new products and improving existing products is also shown. Nearly half of the surveyed companies assume that their investment in research and development will increase in the coming years. Only 5.9% expect a slight decline (see fig. 5).

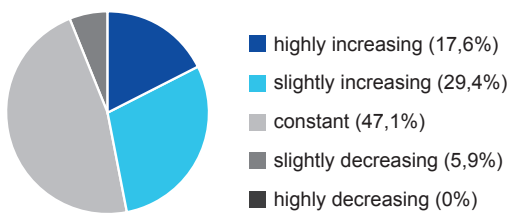


Figure 5: Assessment of the development of R&D investments in the coming years (as of 2014)
Source: Berlin Partner for Business and Technology, own survey

Foreign Trade

High export quotas are another feature of high-tech industries. Although Germany is, for the most part, the most important sales market for the Berlin-Brandenburg optical analytics companies' products, 56% of revenue in 2013 was generated abroad. 41.7% of the surveyed companies expect the export rate to increase. On the other hand, 11.8% expect the export rate to decline (see fig. 6).

Figure 7 provides an overview of how the companies assess the relevance of geographic sales and procurement markets. The most important sales markets are Germany, Western Europe and North America. The most important procurement markets are the German-speaking countries. These structures are not expected to vary much in the next few years. It is also striking that in Berlin-Brandenburg, as well as throughout Germany, the significance as procurement market outweighs the significance as sales market, including in regions that are traditionally associated with the procurement of cheaper components.

One reason for this may be that in the high-tech sector, supplier relationships in particular are easier to manage due to their complexity within a legally and culturally unified system and are thus more attractive despite higher costs. This thesis is supported by the research institutions' assessment, which is represented by the gray column. The significance of Berlin-Brandenburg as the location of cooperation partners for research institutions is assessed nearly as highly as the significance of the rest of Germany. Other regions, however, are far behind.

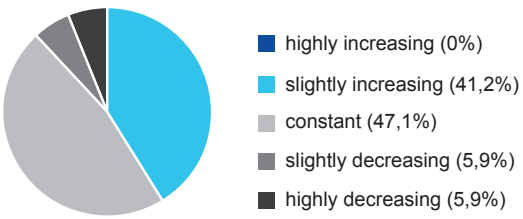


Figure 6: Assessment of the development of the export rate in the coming years (as of 2014)
Source: Berlin Partner for Business and Technology, own survey

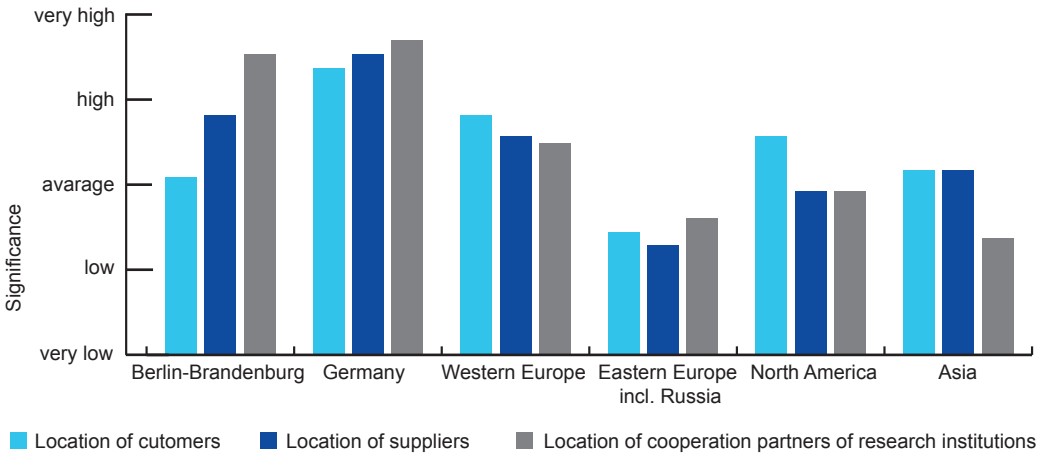


Figure 7: Assessment of the development of R&D investments in the coming years (as of 2014)
Source: Berlin Partner for Business and Technology, own survey

Location Evaluation

Even with the general assessment of the location of Berlin-Brandenburg, the link between research and industry plays a significant role (see fig. 8). While from the companies' perspective there is pent-up demand for the settlement of industrial users, the offer to suitable research institutions is assessed as clearly positive. The research institutions' assessment in every area is even more positive, even if they also desire a wider range of users. The pronounced research landscape is one of the biggest location advantages of the capital region, as is the concentration of many actors in a relatively small area and their networking intensity.

Data Collection Methodology

The basis of the indicators presented here is a content-defined group of 55 regional companies and 22 research institutions that develop and produce components, systems and devices belonging to the optical analytics focal area. The calculations for the development of revenue and employment figures are mainly based on surveys from commercial databases. The classification of the sectors of the official statistics for the sector studied here provides no sharp differentiation in content. The primary source is the MARKUS database from Bureau van Dijk Electronic Publishing and the Federation of Creditreform Associations which includes structural, financial and investment data from about 1.2 million officially registered companies. Wherever possible, data gaps were filled using primary data from individual interviews and research. The revenue and employment figures include only manufacturing companies. Service providers and retail companies are not included. With supra-regional companies with multiple locations, only the employees in Berlin-Brandenburg and their proportional contribution to the company's overall revenue were included in the calculations. Between August and October 2014, Berlin Partner for Business and Technology conducted a standardized survey of 55 companies and 22 universities and research institutions in Berlin-Brandenburg in optical analytics. A total of 26 organizations participated in the survey. The evaluated data were included in the analysis of field-specific technology trends and assessments in particular.

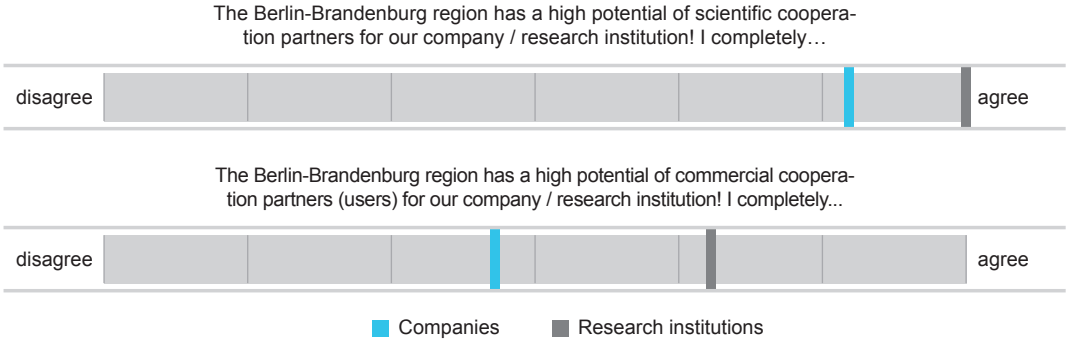
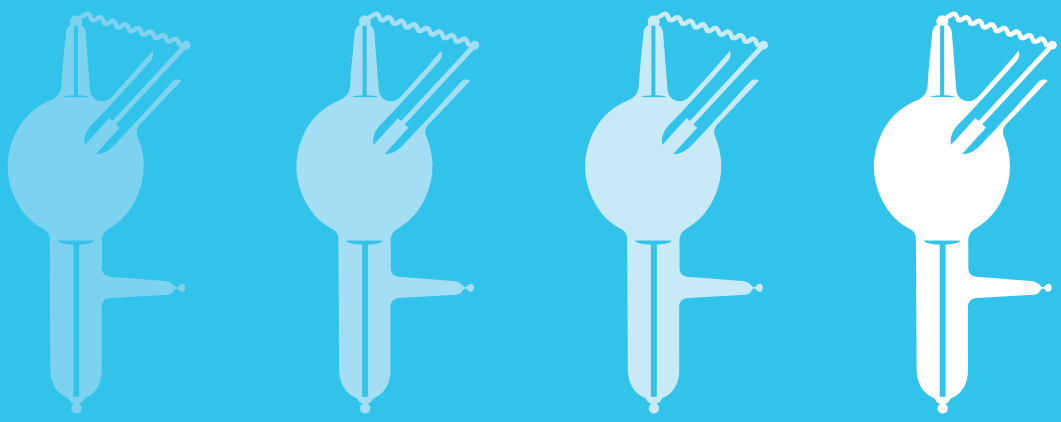


Figure 8: Evaluation of Berlin-Brandenburg as a location
Source: Berlin Partner for Business and Technology, own survey



3 History of Optical Analysis in Berlin-Brandenburg

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Optical technologies have a more than 200-year tradition in Berlin-Brandenburg. Pastor Johann Heinrich August von Duncker (1767-1843) founded the region's first optics firm in 1800 in Rathenow, 80 km west of Berlin. One year later, Duncker patented a grinding machine which he used to manufacture lenses for glasses and microscopes. This optical measurement technology laid the cornerstone for optical analytics in the Berlin-Brandenburg region.

In 1845, Emil Busch (1820-1888), the grandnephew of Duncker, took over production in Rathenow where his company also served as a central training center, thereby helping to establish the tradition of skilled craftsmanship that made Rathenow the "city of optics."

Gustav Robert Kirchhoff (1824-1887) and Robert Wilhelm Bunsen (1811-1899) achieved a major theoretical breakthrough with their discovery of spectral analysis. Kirchhoff presented his findings in Berlin, which were then published in October 1859 in the reports of the Prussian Academy of Sciences (Königlich-Preußische Akademie der Wissenschaften founded in 1700).

In 1875, Kirchhoff became Professor of Theoretical Physics at the University of Berlin (Universität zu Berlin founded in 1810), where he had first qualified as lecturer. Within a few years, Berlin, imperial capital since 1871, had become Germany's economic and scientific hub. In the course of this consolidation, which entrepreneurs such as Werner von Siemens (1816-1892) and researchers like Hermann von Helmholtz (1821-1894) had helped to advance, the Technical College Berlin (Technische Hochschule Berlin – TH Berlin) was founded in 1879, followed by the Physical and Technical Institute of the German Reich (Physikalisch-Technische Reichsanstalt – PTR) in 1887 and the Kaiser Wilhelm Society (Kaiser-Wilhelm-Gesellschaft – KWG) in 1911. While the KWG mainly pursued fundamental research, the PTR was from the outset meant to bridge the gap to technological applications and was mainly devoted to metrology, the science of measurement.

Carl Bamberg: Restored Theodolite (around 1900)

In deciding whether Berlin street lighting would be more efficiently powered by gas or electricity, the PTR optics laboratory focused its attention on measuring the radiation of a black body (an object that completely absorbs light). The researchers were looking for a generally acceptable measure of light and a precisely reproducible lighting standard. The PTR measurements led to a spectacular achievement: that it is possible to accurately determine the spectrum of blackbody radiation. In order to explain the test results in theoretical terms, Max Planck (1858-1947) simply segmented or "quantized" heat radiation in packets of a certain size and then presented his law of radiation on December 14, 1900, in Berlin – giving birth to the revolutionary quantum theory.

Advances in science together with population growth and economic expansion in turn spurred the growth of the optical industry, which by 1900 had clustered around Berlin. This clustering was based on innovative research, specialized suppliers, highly-efficient manufacturers and distributors as well as consumer demand.

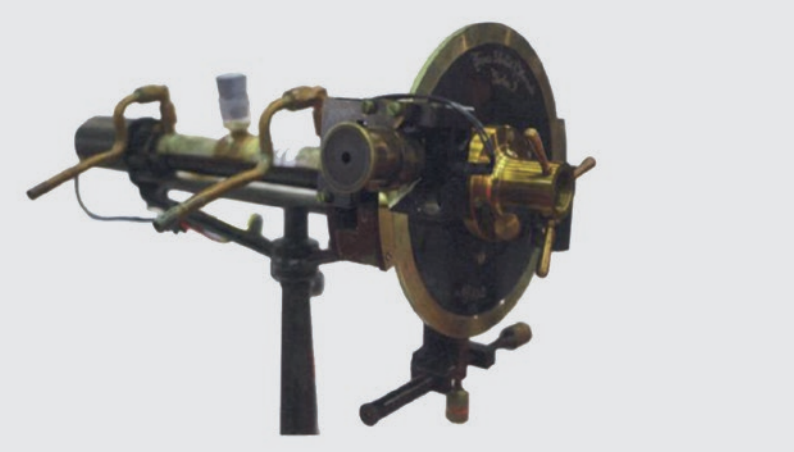
Specialized companies such as Carl Bamberg (established in 1871) and Rudolf Fuess (established in 1865) built optical measuring instruments for applications in the scientific community, such as microscopes and goniometers, used to measure angles, and crystal optical devices for thin section analysis. Carl Bamberg (1847-1892) mostly manufactured telescopes (equatorial, refractory) for observatories, like the Urania in Berlin. Rudolf Fuess (1838-1917) was the leading manufacturer of meteorological instruments, which were so accurate they could be used for calibration. Both entrepreneurs, along with Siemens, Helmholtz and others, were among the initiators who helped found the PTR.

The firm of Schmidt+Haensch (formed in 1864) focused in particular on measurement tools used in laboratories (spectrometers, photometers, saccharimeters and Tyndall meters), which allowed it to secure niche markets. The company gained prominence through its 1864 trichina microscope, designed according to specifications by pathologist Rudolf Virchow (1821-1902) and the 1905 circular polarimeter, which Alfred Werner (1866-1919) used in his work prior to receiving the Nobel Prize for Chemistry in 1913.

Schmidt+Haensch: Trichinella microscope by Rudolf Virchow (1864)
© Schmidt+Haensch

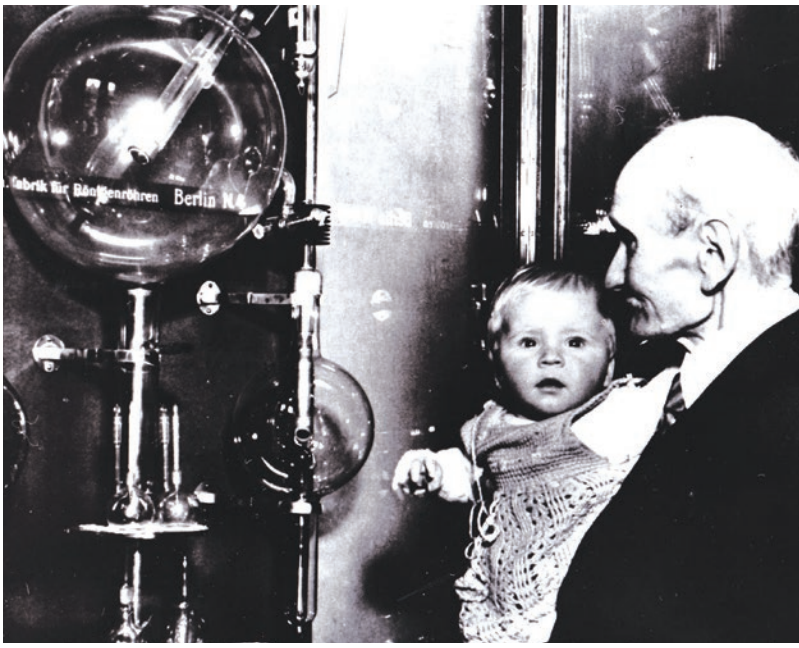
The optical institute of C. P. Goerz proved of paramount importance in the development of the industrial cluster in southwest Berlin. From 1886 to 1926 C. P. Goerz was a global player with several thousand employees and provided military optics to more than 25 states (e.g. binoculars, range finders, periscopes, target visors). Carl P. Goerz (1854-1923) also produced special cameras, projectors and telescopes for natural history studies as well as geodetic and astronomical uses. During and after World War I (1914-18), this product portfolio was expanded to include other optical measurement instruments (aerial cameras, bombsights, heliographs, sun compasses). As a result of the intensified defense conversion that began after 1918, Goerz increased its collaboration with the nearby National Materials Testing Institute (Staatliches Materialprüfungsamt) founded as the Prussian Mechanical and Technical Research Institute (Mechanisch-Technische Versuchsanstalt) in 1871 and the German Research Institute for Aviation (Deutsche Versuchsanstalt für Luftfahrt) founded in Adlershof in 1912. Together they built scleroscopes (to measure rebound hardness), optical pyrometers (non-contacting devices to intercept and measure thermal radiation) and photogrammetry cameras (for aerial surveys).

Thanks to the combination of business-minded practicality and insights in theoretical science, both derived from its origins in optics, the Berlin-Brandenburg region continued to play a leading role in the natural sciences through the early 1900s. Between 1907 and 1933 alone, 12 Nobel Prizes in



Schmidt+Haensch: Circular polarimeter by Alfred Werner (1905)
© Schmidt+Haensch

Physics and Chemistry were awarded to scientists who had worked in Berlin, among them Ferdinand Braun (1850-1918) for his contributions to the development of wireless telegraphy in 1909, Max von Laue (1879-1960) for his discovery of the diffraction of X-rays by crystals in 1914 and Albert Einstein (1879-1955) for the discovery of the photoelectric effect in 1921. The basis for this record of success lays in the tradition of optical measurement instruments described above, including the X-ray tube patented by Reinhold Burger (1866-1954) from Glashütte (Baruth/Mark) in 1902.



Reinhold Burger and his nephew in front of one of his X-Ray tubes in the museum Glashütte/Baruth (1951)
© Axel Burger

Optical measurement instruments continued to be developed throughout the 1920s and 1930s (e.g. Wilhelm Kösters' (1876-1950) inferometers for measuring lengths in 1928 and the PTR's pyrheliometer to measure direct beam solar irradiance in 1931). Of crucial importance was the start of Electron Optics at this time. Ernst Ruska (1906-1988) and Max Knoll (1897-1969) built the first electron microscope in 1933 at the TH Berlin and helped Siemens Company to present the first commercial electron microscope in 1939, which allowed much higher spatial resolution than conventional microscopes. Ruska received the Nobel Prize for his invention more than 50 years later in 1986 together with Binnig and Rohrer from the IBM Labs in Switzerland for their later invention (1981) of the scanning tunneling microscope.

Ernst Ruska: Electron Microscope (1933)

During the Nazi period (1933-45), Berlin lost its leading position as a scientific hub owing to the loss of human capital that resulted from the political circumstances and from accelerated rearmament. The turmoil of World War II (1939-45) eventually led to the division of Germany and Berlin (1945/49), which also had an impact on the optics cluster. In West Berlin, some traditional institutes continued to exist, such as the Berlin Institute of Technology (Technische Universität Berlin – TU Berlin) the successor to TH Berlin since 1946, the Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung – BAM), as well as companies like Schmidt+Haensch and R. Burger & Co (until 1982).

Others developed expertise outside the field of optics or left the enclave altogether. Thus the PTR passed its legacy on to the new National Metrology Institute of Germany (Physikalisch-Technische Bundesanstalt – PTB), which relocated, together with its optics department, to Braunschweig in 1950. What remained in Berlin became a branch of the new PTB. A similar fate befell the KWG Institutes, which joined the Max Planck Society, founded in Göttingen in 1948.

Competition between East and West during the Cold War and Berlin's role as a showcase city led to the establishment of major new institutions, including the "Free University" Berlin (Freie Universität Berlin – FU Berlin) in 1948 and the Hahn-Meitner-Institute Berlin (HMI) in 1959. Occasionally new businesses were also established, such as Berliner Glas (1952) and Semperlux (1948, now Selux).

In East Germany and East Berlin, Humboldt's ideal of unifying research and teaching was abandoned. Humboldt-Universität Berlin (name of the University of Berlin from 1949) was given responsibility for the dissemination of information. But basic research and apparatus engineering in the field of optical analysis was carried out by Carl Zeiss in Jena and by elements of the East German Academy of Sciences (Akademie der Wissenschaften – AdW, reopened in 1946), specifically the Central Institute for Photonics and Spectroscopy (Zentralinstitut für Optik und Spektroskopie – ZOS in 1948/57, the Central Institute of Electron Physics (Zentralinstitut für Elektronenphysik – ZIE in 1950/58) and the Center for Scientific Instrumentation (Zentrum für Wissenschaftlichen Gerätebau – ZWG in 1956/73).

German Academy of Sciences of the GDR (1950)

One element that optical research in East and West Berlin had in common was the rapid assimilation of laser technology, which ultimately forms the basis of optical measuring technology today.

Physicist Theodore Maiman (1927-2007) built the world's first working laser in May of 1960 in the United States, based on preliminary theoretical work by Arthur L. Schawlow (1921-1999), Charles H. Townes (1915-2015) and others. Maiman's ruby laser and his ongoing developments sparked a veritable

“laser euphoria” in the 1960s. Soon after, at the TU Berlin, Horst Weber and Gerd Herziger, both postgraduates in Prof. Hans Boersch’s (1909-1986) laser research group, constructed the first independent solid-state and gas lasers in 1961-62. Physics Department at TU Berlin fast developed into a center of West German laser research. In further consequence, Hans J. Eichler initiated the optical analysis for liquid crystals and photosynthesis in bacteria and green plants on the basis of laser technology.

Meanwhile, In East Germany, Prof. Paul Görlich (1905-1986), research director at Carl Zeiss and co-director of ZOS, initiated a laser development race between Jena and East Berlin starting in 1960. Berlin won the race by a narrow margin, when, in August 1962, Kurt Lenz constructed East Germany’s first laser.

In the years that followed, both East and West Germany achieved remarkable advances with lasers but also with other technological advancements that are now the basis of industrial applications and measuring systems.

In East Berlin, ZOS, for instance, developed lasers for polarization spectroscopy in carbon dioxide as well as for hydrogen carbonate detection using laser-induced fluorescence with fs-pulses. First-class spectrometers used in X-ray fluorescence analysis were among the instruments produced at ZWG, which was headed up by Norbert Langhoff starting in 1970. The Institute from Adlershof supplied precision instruments to all parts of the Soviet bloc, which provided for high levels of performance despite limited resources. In 1991, ZWG had 12 instrument lines and more than 1,700 employees.

West Berlin optics research also continued to develop, as exemplified by the research contributions of HMI. An important prerequisite for this development was the establishment of large-scale facilities such as the Berlin Experimental Reactors BER (1958) and BER II (1973) in Wannsee, used to study nuclear chemistry and the effects of radiation as well as the Berlin Electron Storage Ring Society for Synchrotron Radiation (Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung – BESSY) in 1979. The synchrotron radiation furnished by BESSY I was used in research with ultraviolet and X-rays as well as in the measurement of spectrometers.

With German reunification in 1990, optical analysis in Berlin-Brandenburg once again faced major upheaval, which the two parts of the country were able to overcome by successfully finding common ground. Though the former AdW institutes were liquidated, important workgroups were preserved in newly established institutions. These included the Ferdinand-Braun-Institute (Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik – FBH), which emerged in 1992 from ZOS and ZIE; as well as the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (Max Born Institut für Nichtlineare Optik und Kurzzeitspektroskopie – MBI), another successor of ZOS which was established in 1991-93.

In Berlin-Adlershof, former AdW members founded about 100 companies. Among them was Prof. Langhoff from the ZWG, who founded the Institute for Equipment Building (Institut für Gerätebau GmbH, now the Institute for Scientific Instruments GmbH – IfG) in 1993. IfG focuses its research on X-ray optics and constructs patented X-ray color cameras, among other things.

Together with West German physicist Dr. Helmut Wittek, Dr. Albrecht Kruger, formerly of ZWG, founded SENTECH Instruments GmbH in September 1990. The company, which started with four people, is now one of the leading producers of thin film measurement technologies and also manufactures spectroscopic ellipsometers. In 2014, the company’s global operations employed over 50 people.

Other AdW spin-off companies include Lasertechnik Berlin GmbH (LTB, founded in 1990) and LLA Instruments GmbH (LLA, founded in 1993). The LTB specializes in short-pulse lasers in the whole optical spectral range, and in different spectrometers and laser-based measuring techniques, now

The Berlin Electron Storage Ring for Synchrotron Radiation – BESSY I (1982)

Center for Photonics and Optical Technologies (2015)

marketing its products world-wide. Since 2008 it is a wholly family-owned business with more than 30 employees in 2014. LLA focuses in imaging spectroscopic measuring technology and is especially well known for its near-infrared spectroscopy used in waste sorting facilities and in food quality control. In 2014, the company had more than 20 employees and was able to secure a global niche market thanks to its synthetics identification technology.

The innovation-friendly climate in Adlershof has continuously generated start-up and spin-off companies. More examples are, LayTec AG (a TU Berlin spin-off established in October 1999), which has been a leading manufacturer of integratable measurement technology for thin film processes; as well as the many FBH spin-off companies (e.g. TESAG AG 1999, now part of Jenoptic Diode Lab GmbH, eagleyard Photonics GmbH 2002, Brilliance Fab and Beaplas GmbH 2013).

The broad research and business landscape associated with optical measuring technology in Berlin-Adlershof has a magnetic effect on large corporations and renowned scientists. The driving force behind the international character of the Berlin area has been BESSY II, inaugurated in 1998. This new synchrotron radiation generator provides unique research conditions and is operated by the Helmholtz-Center Berlin (Helmholtz-Zentrum Berlin – HZB), created in January 2009 from BESSY and HMI.

Outside Adlershof and also representative of the Capitol region's history in laser development as well as optical measurement is the Laser- und Medizin-Technologie GmbH, Berlin (LMTB), that emerged in 1995 from the Laser-Medizin-Zentrum (LMZ) founded in 1985 and the Festkörper-Laser-Institut (FLI) founded in 1986 as an affiliated institute of the TU Berlin. Support by medical and optical companies with the goal of the development of laser therapies and diagnostics, LMTB has worked in collaboration with all three universities in Berlin and serves as an interface institution between research and industry focusing on biomedical optics in medical technology and applied laser technology.

It is owing to this favorable combination of circumstances that Berlin-Brandenburg continues to welcome research institutes and companies, such as the Leibniz-Institute for Analytical Sciences – ISAS – e.V., which was founded in 1952 in Dortmund and has been operating a branch in Adlershof since 1992; as well as Raytek, which established its European head-quarters here and specializes in optical temperature measurement.

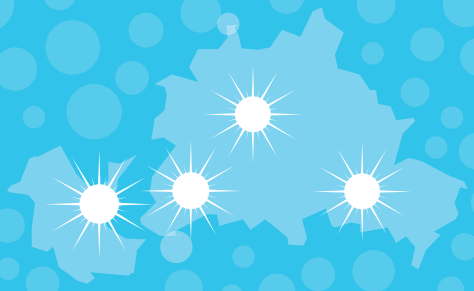
Major corporations also monitor developments closely and have sought to secure their positions through acquisitions (e.g. Röntec AG by Bruker in 2005 and u2t AG by Finisar in 2014), thereby participating in the potential the region has to offer.

Lastly, it should be noted that Berlin-Brandenburg is able to look back on a rich tradition of optical analysis, which has found expression and still continues to be expressed through efficient technologies, research institutes, universities and business ventures.

Some technological methodologies, such as X-ray analysis and laser optics, have proven successful over decades, thus ensuring success for generations – an example being family-owned Schmidt+Haensch, which celebrated its 150th anniversary in 2014.

Berlin's potential, grounded in experience, was reaf-firmed through the successful transformation of numerous East German institutions. The history of optical analysis in Berlin-Brandenburg can therefore be considered an intra-German success story.

Special thanks to Dr. Frank Lerch, Michael Graurock, Dr. Stefan Florek, Prof. Dr. Norbert Esser, as well as Dr. Stephan Mory and Prof. Dr. Hans. J. Eichler for their advice and friendly support with the research for this article.



4 Locations

4.1 Technology Park Adlershof

Analytic City Adlershof

Analytic City Adlershof represents the efforts of local partners, working together with science and industry, to create a network in the field of analytics and develop an internationally recognized clustering of expertise. This essentially involves the confluence of three institutions: the university research institutes at the Humboldt-Universität zu Berlin, non-university-affiliated research institutes, as well as small and medium-sized high-tech companies that are already making intense use of available local potential.

Given the location's long and successful tradition in practically every relevant area, Berlin Adlershof provides the best possible conditions for an internationally recognized cluster of analytical expertise. From basic research and teaching to the development of methodologies, scientific instrument design and on through to services and sales, the entire value chain is represented here.

Applications ranging from material, environmental and process analysis to biology, medicine and food chemistry are firmly established in the Adlershof Technology Park.

Practically all current analytical methods and technologies, such as chromatography, spectroscopy, surface and structure analysis, microscopy, as well as special processes, are represented here through more than 80 institutions. You can find more details, such as the types of analysis methods being used and the research groups working with them, in a separate report entitled "Analytic City Adlershof," published by WISTA Management GmbH.

Humboldt-Universität zu Berlin Department of Chemistry

With respect to „Analytic City Adlershof," WISTA Management GmbH has formulated the following objectives:

- Create a structure for cross-sector cooperation throughout the entire value chain
- Determine and describe Adlershof's analytical capacities
- Develop national and international public relations campaigns and market the site's analytical capacities
- Acquire leading international analytical companies and institutions to enrich the park's portfolio

www.adlershof.de/en[1]

University Research

A crucial event in the history of the Adlershof research site was the construction of the **Humboldt-Universität zu Berlin (HUB)** Adlershof Campus. With over 8000 students, the campus is now the vibrant center of "Berlin Adlershof – City of Science, Technology and Media." The buildings, which were built or renovated between 1998 and 2003, offer the departments of chemistry, geography, computer science, mathematics, physics and psychology a first-class setting for teaching and research.

www.hu-berlin.de/en

Adlershof is home to Humboldt-University's **Institute of Chemistry (IfC),** one of the world's leading research and teaching institutes in the field of analytical chemistry. IfC has been focusing its technical expertise on two promising areas of research:

- The synthesis of functional materials for catalytic processes and optics, as well as
- Chemical Biology (conformational dynamics function with particular emphasis on DNA/DNA, DNA/protein and protein/protein interactions)

Close extra-university contacts to the Institute of Applied Chemistry in Adlershof (ACA), the Federal Institute for Materials Research and Testing (BAM), the Max Born Institute (MBI) and the Institute for Crystal Growth (IKZ) are indicative of the intensity of research networking going on at Adlershof.

1 www.adlershof.de/en/sectors-of-technology/analytic-technologies/info

1 3B Pharmaceuticals GmbH
2 Accelero Bioanalytics GmbH
3 ANAU Berlin-lab GmbH
4 ANiMOX GmbH
5 art photonics GmbH
6 ASCA GmbH Angewandte Synthesechemie Adlershof
7 Astro- und Feinwerktechnik Adlershof GmbH
8 AZBA Analytisches Zentrum Berlin-Adlershof GmbH
9 BAM Bundesanstalt für Materialforschung und -prüfung
10 Berliner Nanotest und Design GmbH
11 BESTEC GmbH
12 Biopract GmbH
13 biotechrabbit GmbH
14 BIOWORX Biotechnologielabor - Thomas Grimm
15 Bruker Nano GmbH
16 Chromicent GmbH
17 ColVisTec AG
18 Crystal Photonics GmbH
19 Dr. Lerche KG
20 Dr. Michael Himmelhaus - nanoBioAnalytics
21 EHA Institut
22 Eurofins Sofia GmbH Chemisches Labor für Softwareentwicklung und Intelligente Analytik
23 Eurofins Umwelt Ost GmbH
24 FOC Fibre Optical Components GmbH
25 GNF Gesellschaft zur Förderung der naturwissenschaftlich-technischen Forschung e. V.
26 Greateyes GmbH
27 GxP brain GmbH
28 HF Biotec Berlin GmbH
29 Histalim
30 Humboldt-Universität zu Berlin - Geographisches Institut
31 Humboldt-Universität zu Berlin - Institut für Chemie
32 HZB - Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronenspeicherring BESSY II
33 I.U.T. Institut für Umwelttechnologien GmbH
34 ifG - Institut für Scientific Instruments GmbH
35 Institut für angewandte Photonik e.V.
36 IsoAnalysis UG
37 IUT Medical GmbH
38 JP-ProteQ
39 JPT Peptide Technologies GmbH
40 JTL-BioTec-Analytics
41 Kartheinz Gutsche GmbH
42 Leibniz-Institut für Analytische Wissenschaften - ISAS e. V.
43 Leibniz-Institut für Katalyse e.V. an der Universität Rostock, Berliner Büro
44 Leibniz-Institut für Kristallzüchtung (IKZ)
45 LLA Instruments GmbH
46 LTB Lasertechnik Berlin GmbH
47 microParticles GmbH
48 Pensatech Pharma GmbH
49 Physikalisch-Technische Bundesanstalt (PTB)
50 PiCA Prüfinstitut Chemische Analytik GmbH
51 PicoQuant GmbH
52 PlasmaChem GmbH
53 Privatinstitut Galenus GmbH
54 Proteome Factory AG
55 RTG Mikroanalyse GmbH Berlin
56 Scienion AG
57 SCW Process Technology Development GmbH
58 Sentech Instruments GmbH
59 SI US INSTRUMENTS GMBH
60 skytron energy GmbH
61 SLM - Speziallabor für angewandte Mikrobiologie GmbH
62 Solardynamik GmbH
63 Surflay Nanotec GmbH
64 TRIOPTICS Berlin GmbH
65 W&P GEAT GmbH Gerätebau und Automatisierungstechnik
66 WITEGA Laboratorien Berlin-Adlershof GmbH

The graduate program at the **School of Analytical Sciences Adlershof (SALSA)** was initiated by the IfC as part of the Excellence Initiative in 2012. This comprises the construction of application labs to interdisciplinary development of new materials and analytical methods, including in close cooperation with local companies. SALSA will move into new buildings in 2016. A laboratory building was built for this purpose in 2014 on Albert-Einstein-Straße in Berlin-Adlershof. At the beginning of the new year, the Photonics Application Lab will be the first to move in. Later it will be home to a new professorship in nano-analytics.

www.chemie.hu-berlin.de/en | fakultaeten.hu-berlin.de/en[2]

Humboldt-Universität zu Berlin (HUB) is one of Germany's eleven "Universities of Excellence." At the center of Humboldt-University's strategic concept aimed at creating ideal conditions for top-level research is the Integrative Research Institute's (IRI) HUB research format. As an interdisciplinary institute, IRI promotes strong research partnerships. These include, for instance, bridge professorships that allow scientists to conduct research and teach at several different institutes within or outside the university.

One of these institutes, the **Integrative Research Institute for the Sciences (IRIS)** has been an established part

Integrative Research Institute for the Sciences IRIS
© IRIS Adlershof

2 fakultaeten.hu-berlin.de/en/mnf/forschung_internationales/grs/salsa

Leibniz-Institute for Analytical Sciences – ISAS – e.V. Berlin-Adlershof

of Adlershof since 2009. It serves as an important catalyst through these bridge professorships, as well as through the development of a collaborative infrastructure and enhanced cooperation with the private sector. Concretely, IRIS Adlershof takes an interdisciplinary approach to the exploration of novel hybrid materials and functional systems with previously inaccessible optical, electronic, mechanical and chemical properties. This involves fundamental research on the structure and dynamics of matter at extreme scales of length and time and in complex systems.

www.iris-adlershof.de/en

Entrepreneurial Spirit and New Start-ups

In addition to teaching and interdisciplinary research, HUB in Adlershof has also created the conditions to efficientlly convert research results to commercial purposes. The **Spin-Off ZONE Campus Adlershof** was founded as part of its technology transfer program. It offers potential entrepreneurs an efficient infrastructure consisting of:

- 52 workstations with telephone, Internet and printer
- A large conference and seminar room for appointments with investors or customers
- Hands-on training with experts
- An entrepreneur lounge to swap ideas in an informal and creative atmosphere

In the course of the next spin-off growth phase, the question of whether or not to relocate to the Science and Technology Park Adlershof will be studied in cooperation with WISTA and IZBM (Innovations-Zentrum Berlin Management GmbH).

www.humboldt-innovation.de/en | www.adlershof.de/en[3]

Non-University Research

In addition to HUB, Adlershof also has a dynamic non-university research landscape. A total of more than 1800 people work at ten institutes, 1000 of whom are actively engaged in science and an additional 180 are working on their dissertations. These institutes have joined together to form the Joint **Initiative of Non-University Research Institutes in Adlershof e.V. (IGAFA)**. The goal of IGAFA is to promote interdisciplinary cooperation and support greater public understanding of science. It also provides science infrastructure, by, for instance, assisting international guests, organizing events, managing meeting centers and supplying scientific literature.

www.igafa.de/en

Work at the **Leibniz-Institute for Analytical Sciences – ISAS – e.V. (ISAS)** is focused on two key topics: “new materials” and “biomolecules” – both of which are being handled at the Berlin-Adlershof and Dortmund locations. ISAS projects cover the spectrum, ranging from fundamental research to the development of new or improved analytical procedures, techniques and instruments on through to the production of prototypes as well as validation and testing of research results for applications in other scientific fields.

The basic goal is to better understand as many of the following parameters as possible: type of molecule, molecular structure, number of molecules, location and time, all of it aimed at answering the question: What amount of which substance is where at what point in time?

In 2009, to further enhance ISAS’s profile, projects focusing on related topics were grouped together thematically in two long-term fields of research. The project groups for material analysis and interface spectroscopy now belong to

3 www.adlershof.de/en/real-estate-start-ups/start-up-services/gruenderhaus-adlershof

Research Department I (Material and Interface Analytics), whereas the project groups for proteomics, metabolomics and miniaturization were integrated into Research Department II (Bioanalytics).

www.isas.de/en

One of the largest research institutes in Berlin is the **Helmholtz Center Berlin for Materials and Energy (HZB)**.The HZB operates two separate large-scale research facilities in Adlershof and Wannsee – the synchrotron radiation source **BESSY II** and the neutron source BER II (see Chapter 4.4). Research on complex material systems is carried out to help in dealing with a variety of current challenges, such as the ongoing transition to sustainable forms of en- ergy (Energiewende). One focus at HZB is on materials for thin-film photovoltaics and for converting solar energy into chemical energy carriers (e.g. molecular hydrogen).

BESSY II emits extremely brilliant photon pulses ranging from the long wave terahertz range to hard X-rays. Users can choose the energy range and polarization of the radiation. Around 50 beamlines at the undulator, wiggler and dipole sources provide the approximately 2500 users with a combination of brilliance and photon pulses, which makes BESSY II the ideal microscope in terms of space and time. Its scales go down to femtoseconds and picometers. Through the BERLinPro project, HZB aims to develop new accelerator technology and to put the principle of “Energy Recovery Linac” on a new technological foundation. Construction work on the linear accelerator should be completed in 2016.

The Helmholtz Center Berlin and the Max Planck Society have joined together to build an X-ray beamline at the synchrotron source BESSY II that is designed for analyzing materials for renewable energy generation. This large-scale project has been dubbed EMIL (for Energy Materials In-situ Laboratory Berlin) and comprises two laboratory complexes: SISSY (Solar Energy Materials In-Situ Spectroscopy at the Synchrotron), which HZB is creating for studying photovoltaic materials; and the CAT (Catalysis Research for Sustainable Energy Supply) laboratory for researching (photo)catalytic processes, which is being financed by the Fritz-Haber-Institut and the Max Planck Society.

www.helmholtz-berlin.de[4]

4 www.helmholtz-berlin.de/quellen/bessy/index_en.html

Electron Storage Ring BESSY II
© HZB

The **Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI)** also researches processes in the femtosecond range. MBI conducts basic research in the field of nonlinear optics and ultrafast dynamics involving the interaction of light with matter and pursues applications that emerge from this research. It develops and employs ultrafast and ultra-intense lasers and laser-driven short-pulse light sources in a broad spectral range. These sources are used at MBI to research ultrafast and nonlinear phenomena in atoms, molecules, clusters and plasmas as well as on surfaces and in solids.

MBI maintains close ties with the three Berlin universities. Its directors were each appointed by the institute and one of the universities.

www.mbi-berlin.de/en

The work of the **Leibniz Institute for Crystal Growth (IKZ)** is devoted to investigating problems associated with growing crystalline materials, involving everything from basic research right on through to technological maturity. Like MBI, it is a part of Forschungsverbund Berlin e.V. and a member of Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz. And, also like MBI, it emerged in the early nineties from institutions that were originally part of the former East German Academy of Sciences. In addition to developing new functional materials for industrial and research uses, IKZ also specializes in techniques and equipment for characterizing crystals.

Materials currently being developed are mainly used in micro-, opto- and power electronics, photovoltaics, in optics and laser technology, as well as in sensors and acoustic electronics. The IKZ research spectrum encompasses volume crystals, crystalline layers and nanostructures as well as the development of crystal growth technologies using a variety of materials.

www.ikz-berlin.de 

In October 1990, the German Science Council recommended that the **Federal Institute for Materials Research and Testing (BAM)** should develop methods and reference materials for quality assurance in analytical chemistry. BAM was meant to serve a role in the field of chemical measurement technology similar to that played by the Physikalisch-Technische Bundesanstalt (PTB) in the field of physical measurement technology. BAM followed up on this recommendation by creating the Adlershof branch of BAM.

Today, BAM at Berlin-Adlershof is engaged in multiple areas of investigation, including: quality assurance and methods of chemical analysis, process analysis, bioanalysis, matrix reference materials, trace analysis, mass spectral coupling methods, magnetic resonance spectroscopy, vibration and time-resolved spectroscopy and the secondary properties of reference materials.

www.bam.de/en 

The Business Environment

According to WISTA, the number of companies in Adlershof exceeded 1000 in 2014. Among them are 140 companies in the media sector, 380 commercial enterprises, as well as shops, hotels and restaurants. At its heart, however, are a variety of small to medium-sized high-tech companies. Around 100 businesses and research institutes in a variety of analytical fields make Adlershof a location demonstrating dynamic growth. These enterprises constitute a complete value chain, from fundamental research through the development of methods and devices right on through to serial production, a compact range of services as well as sales.

The report entitled “Analytic City Adlershof” offers a thorough overview of what the site offers. In addition to university-affiliated research, the 2014 edition lists companies and institutes engaged in the following areas:

- Life Sciences
- Analytical Chemistry
- Surface Analytics
- Optics / Photovoltaics
- Process Analysis

The development of Adlershof is characterized by the fruitful interaction of the various players co-located there. In addition, regional and supra-regional meetings serve to promote local and regional networks. Not only was the summer 2014 conference on “Optical analysis for medical and industrial applications” held in Adlershof, for instance, so, too, was the annual meeting of the EOS European Optical Society.

Alongside these industry gatherings, “Analytic City Adlershof” has developed a number of other ideas as well. Along with its regularly published report, the initiative is also planning workshops, exhibitions and a testing laboratory. And, under the umbrella of WISTA, an expanded Internet presence is also planned, which will allow specialists in analysis to exchange ideas as well as submit requests and offers of collaboration.

www.adlershof.de/en | www.wista.de[5] 

5 http://www.adlershof.de/en/wista-management-gmbh/about-us

4.2 Potsdam-Golm Science Park

The town of Golm – now part of Potsdam – is able to look back on more than 750 years of history. For a long time, the town's history was dominated by agriculture; since the mid-1990s, however, Golm has become home to the largest science park in the state of Brandenburg.

Not only do the University of Potsdam, the Max Planck Society and Fraunhofer Gesellschaft currently have institutes in the **Potsdam-Golm Science Park**, there are also a growing number of young, innovative firms located there as well.

A total of more than 2500 people are employed at the science park, alongside 9,000 enrolled students. Golm offers a pleasant work environment, situated right alongside a landscape conservation area, as well as both a good quality of life in the city of Potsdam and surrounding areas together with an extremely family-friendly atmosphere.

Projects currently in the pipeline include a daycare center, student accommodations, a number of retail outlets, not to mention the expansion of the institutes currently resident there.

Professional site management is promoting the development of the science park through targeted expansion of infrastructure and by bundling together the strengths and interests of all the institutions, institutes, organizations, and businesses located in the Potsdam – Golm Science Park.

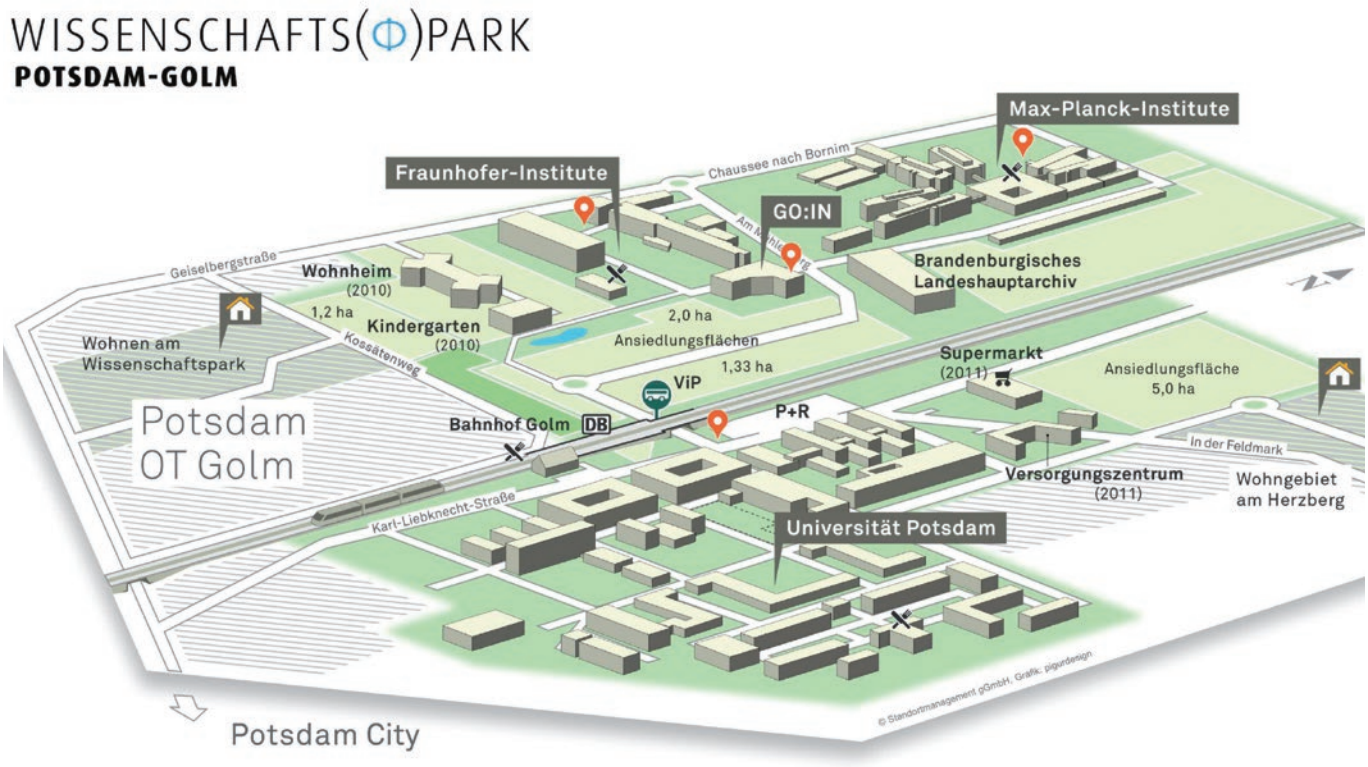
Companies interested in moving to the park and young entrepreneurs alike benefit in particular from existing networks and can also draw on the experience and support provided by prestigious institutes and prominent figures working at the park.

www.wisspark.de/en

University Research

The **University of Potsdam**, founded in 1991, has located parts of its departments of Mathematics and Natural Sciences as well as its Human Sciences Department at the Potsdam-Golm Science Park.

Close collaborative relationships have been established between the Faculty of Mathematics and Natural Sciences and non-academic institutes at the science park through jointly appointed professorships and numerous research



Fraunhofer Institute for Applied Polymer Research
© Till Budde

projects. Institutes of the Faculty of Mathematics and Natural Sciences located on the Golm campus are:

- Institute of Biochemistry and Biology
- Institute of Chemistry
- Institute of Geography
- Institute of Environmental Science
- Institute of Earth Science
- Institute of Physics and Astronomy

These university institutes use a variety of analytical methods in research and teaching. Of particularly interest are the questions being addressed in the field of biology. At the Institute of Biochemistry and Biology (IBB), for example, there are in-house working groups on molecular bioanalytics and bioelectronics (joint appointment with the Fraunhofer Institute for Biomedical Engineering IBMT), life science materials (joint appointment with the GKSS Research Centre Geesthacht) and in microscopy.

www.uni-potsdam.de/en | www.wisspark.de/en[1]

Non-University Research

The Fraunhofer Gesellschaft and Max Planck Society each have a campus of their own in Golm and are represented by several institutes.

The **Fraunhofer Institute for Applied Polymer Research (Fraunhofer IAP)** focuses on the entire spectrum of polymer applications.

In addition to the environmentally friendly and cost-effective manufacture and processing of polymers on a laboratory and pilot plant scale, the institute also provides polymer characterization.

There are broad array of potential applications, ranging from biotechnology, medicine, pharmacy and cosmetics to electronics and photonics, applications in packaging, in environmental and sewage technology as well as in the automotive, paper, construction and paint industries.

www.iap.fraunhofer.de/en

The Bioanalytics and Bioprocessing Branch of the **Fraunhofer Institute for Cell Therapy and Immunology (Fraunhofer IZI-BB)** researches and develops lab-on-chip technologies as well as cellular and cell-free biotechnology for use in the fields of bioanalytics and molecular diagnostics.

www.izi.fraunhofer.de

The Max Planck Society is represented by three institutions in Golm. They share a central building with a lecture hall, seminar rooms, administrative offices and cafeteria, but are otherwise completely independent.

The **Max Planck Institute for Gravitational Physics (Albert Einstein Institute)** has established itself as a leading international research center for gravitational physics since its founding in 1995.

www.aei.mpg.de

1 www.wisspark.de/en/institutes.html

The **Max Planck Institute of Colloids and Interfaces (MPIKG)** was founded in 1992. Current research topics include polymeric films, membranes, organic and inorganic nanostructures, microcapsules, biomineralization, nano- and microreactors, molecular motors and filaments as well as the chemistry and biology of carbohydrates. Research is also currently being conducted on biomimetic systems. Drawing on examples from nature, new hierarchical materials and active systems are being investigated that can be adaptive, self-healing or self-assembling.

www.mpikg.mpg.de

The **Max Planck Institute for Molecular Plant Physiology (MPI-MP)**, founded in 1994, is mainly concerned with studying processes that determine or affect plant growth and biomass production. In this context, analysis focuses on substances absorbed through the roots, the assembly and disassembly of ingredients, their transport, storage and mobilization, as well as the question of how these processes are regulated. The methods used make it possible to examine the ingredient composition and gene activities of a large number of samples. Using bioinformatics, computer models can be generated from the mass of data gathered.

Other research topics at MPI-MP include the physiology and genetics of cell organelles as well as the molecular mechanisms involved in the evolution of plant genomes. The range of methods applied includes techniques from molecular biology, genetics, physiology, biochemistry, biophysics and bioinformatics.

www.mpimp-golm.mpg.de

Business Concentration in the Golm Innovation Center

The Golm **Innovation Center GO:IN** is an innovation and start-up center oriented around the natural sciences. It offers an ideal setting in terms of infrastructure together with an inspiring scientific environment for research and development start-ups and SMEs in the fields of biology, physics and chemistry.The available infrastructure not only includes state-of-the-art laboratories and well-appointed offices, but, more importantly, business-related services, individualized consulting and integration into regional networks.

The Golm Innovation Center GO:IN in Potsdam
© Thomas Ritschel

The **GO:INcubator** offers support to graduates, academic staff, postdocs, professors, entrepreneurs and independent inventors from across Germany in developing their projects, start-ups and business ventures. As of the end of 2014, a total of 18 companies were located at GO:IN.

www.goin-potsdam.de | www.goincubator.de

4.3 Campus Charlottenburg

In the middle of City West lies the Campus Charlottenburg, an urban space where the worlds of science, business and private life meet. Two internationally renowned universities are located here, along with a polytechnic institute, four institutes of the Fraunhofer Gesellschaft, as well as other institutions not affiliated with a university. In addition, there are many small and mid-sized companies, as well as several major international companies. Numerous associations and interest groups also have their headquarters in the immediate vicinity.

www.campus-charlottenburg.org

University Research

More than 8300 people work, teach and conduct research at **Technische Universität Berlin (TU Berlin)**. Approximately 32,000 students can choose from about 100 course offerings, making it one of the largest technical universities in Germany. Owing to its forward-looking range of course offerings – with everything from engineering and the natural sciences to planning, social sciences, economics and humanities – it provides education to the next generation of desperately needed skilled professionals. TU Berlin is highly networked, possesses an international reputation, helps create around 20 start-ups each year and received 178 million euros in third-party funding in 2014, in addition to 295 million in government grants.

www.tu-berlin.de

The **Institute for Optics and Atomic Physics (IOAP)** at the TU Berlin brings together efficient physical measurement methodologies along with their applications under a single roof. This serves primarily to facilitate method-oriented work mainly in (non-linear) light optics, laser physics, spectroscopy, optical technologies, electron microscopy and holography, as well as X-ray spectroscopy, X-ray analysis and X-ray optics. The establishment of an endowed chair at the institute has lent a special emphasis to X-ray analysis. There are 11 different working groups currently at the IOAP. In addition, the institute has established joint professorships and lectureships with various research institutes in Berlin, including with Max-Born Institute (MBI), the National Metrology Institute of Germany (PTB), Fritz Haber Institute (FHI), Beuth University of Applied Sciences, Fraunhofer Heinrich Hertz Institute (HHI), Ferdinand Braun Institute (FBH) and Helmholtz Center Berlin (HZB).

www.ioap.tu-berlin.de

Together with the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI), TU Berlin operates the **Berlin Laboratory for innovative X-ray Technologies (BLiX)**, which is equipped with an X-ray microscope with a highly brilliant laser-produced plasma source at an emission wavelength of 2.48 nm in the spectral range of what is known as the “water window”. Another laser-produced plasma source for the soft X-ray range below 1.2 keV is available for different variants of X-ray fluorescence spectroscopy. In addition, there are two structures with X-ray tubes for X-ray absorption and emission spectroscopy, which can be used to perform chemical speciation on transition metals. There is also a method for three-dimensional imaging of the distribution of elements in samples. BLiX is part of the endowed professorship in “Analytical X-Ray Physics” held by Prof. Birgit Kanngießer. The goal of TU Berlin is to use such innovative labs to create institutions where university and non-university research institutes can work together with companies on innovative products. Through its collaboration with the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI), a member of the Leibnitz Association, BLiX also acts as a Leibniz application laboratory.

www.blix.tu-berlin.de/en

The **Unifying Concepts in Catalysis (UniCat)** cluster of excellence conducts studies in the field of catalysis, an area of significant economic importance. This involves research on and development of catalysts that can provide for the more efficient and environmentally friendly use of natural energy and material resources as well as the investigation of new "smart" enzymes for the production of antibiotics.

The excellence cluster has received funding for the period 2007 – 2017. The spokesperson for the cluster of excellence is Prof. Matthias Drieß from the **Institute of Chemistry at TU Berlin**. The cluster's interdisciplinary research alliance encompasses about 50 working groups, drawing together scientists and researchers in the fields of natural science and engineering from the TU Berlin, FU Berlin, Humboldt-Universität zu Berlin, the University of Potsdam, the Fritz Haber Institute of the Max Planck Society, and the Max Planck Institute of Colloids and Interfaces in Potsdam. The research work currently being done by the scientists participating in the cluster focuses on the oxidative conversion of methane (natural gas and biogas) into ethylene, the activation of carbon dioxide, the production of biological hydrogen for microbial fuel cells, and the development of new agents based on natural substances.

www.unicat.tu-berlin.de

Non-University Research

The **Fraunhofer Institute for Production Systems and Design Technology (Fraunhofer IPK)** is housed at the Production Technology Centre Berlin (PTZ), under the same roof as TU Berlin's Institute for Machine Tools and Factory Operation (IWF). Fraunhofer IPK conducts applied research and development for the entire manufacturing process chain – from product development to actual production, the maintenance of capital goods and product recycling as well as the design and management of factory operations. In the field of automation technology, the institute has specialized in automated optical measurement and testing technologies, making it possible to reconstruct torn documents automatically, for instance.Fraunhofer IPK works closely with BAM and Charité.

www.ipk.fraunhofer.de/en

The **Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute (Fraunhofer HHI)** was founded in 1927 as the "Heinrich-Hertz-Institut für Schwingungsforschung (HHI for research on oscillations)". In 2003, the Institute was transferred to the Fraunhofer Gesellschaft and acquired its current name.

The core competencies of Fraunhofer HHI include optical communication networks and systems, mobile broadband systems, optical components and electronic imaging technology. Among other things, Fraunhofer HHI develops and manufactures electro-optical components and modules. The portfolio covers lasers and detectors built on indium phosphide, polymer optical waveguides and diffractive optical elements.

Additional primary research topics include video- and audio-coding and transmission (video over IP) as well as 2D and 3D image processing, mixed-reality displays, autostereoscopic 3D displays, human-machine interfaces, information management as well as image and video archiving.

www.hhi.fraunhofer.de

Applied mathematics plays an important role in many areas of industry and research. At **MATHEON – the Centre for Applied Mathematics**, more than 200 scientists work with mathematical modeling, simulation and optimization methods on solutions for current and future issues having to do with the environment, energy, resource scarcity, transport, communications, manufacturing, new materials and health. Matheon was established as a DFG Research Center in 2002 by mathematicians from the FU, HU, and TU as well as the Weierstrass Institute (WIAS) and the Zuse Institute Berlin (ZIB). Since June 2014, it has been funded by the Einstein Foundation Berlin, functioning under the name Einstein Center for Mathematics Berlin (ECMath).

www.matheon.de

On an initiative by Werner von Siemens and Hermann von Helmholtz, the Physical and Technical Institute of the German Reich (Physikalisch-Technische Reichsanstalt, or PTR) was founded in Berlin-Charlottenburg in 1887. Now renamed **The National Metrology Institute of Germany (PTB)**, it has offices in Braunschweig, Berlin-Charlottenburg and Berlin-Adlershof.

PTB Observatory in Charlottenburg
© PTB

The PTB consists of 9 scientific-technical divisions, two of which are located in Berlin, subdivided into approximately 60 departments with more than 200 working groups.

The two PTB divisions at the “Berlin Institute” deal with thermometry, radiometry, medical physics, mathematics and metrological information technology. In Adlershof, PTB operates the MLS (Metrology Light Source) electron storage ring for calibrating infrared (THz) to extreme ultraviolet (EUV) light and also utilizes the electron storage ring BESSY II.

www.ptb.de/en[1]

The **Telekom Innovation Laboratories (T-Labs)** serve as a link between industry and research. They belong to the central research and development (R&D) unit of Deutsche Telekom. Together with Telekom’s operating units, T-Labs are mandated to offer new ideas and support in the development and implementation of innovative products, services and infrastructures for Telekom’s growth areas. In cooperation with TU Berlin and the University of the Arts Berlin (UdK), Telekom established five chairs in the fields of telecommunication:

- Quality and Usability Lab
- Security in Telecommunications
- Service-centric Networking
- Design Research
- Assessment of IP-based Applications

In addition, T-Labs maintain a network of start-ups in Germany, Israel and the Silicon Valley.

www.laboratories.telekom.com

Start-ups and Spin-offs in Charlottenburg

Campus Charlottenburg offers a diverse infrastructure for those interested in founding new companies. TU Berlin created the **Center for Entrepreneurship** for start-ups, to which both the start-up service and the Department of Entrepreneurship and Innovation Management are coupled. At the start-up service alone, there are two dozen consultants available to provide advice on a wide variety of issues ranging from the application process to mentorships.

www.entrepreneurship.tu-berlin.de

There are also a variety of services outside the university that are available to entrepreneurs in City West. The **Charlottenburg Innovation Center (CHIC)** is located in close proximity to the TU Berlin and the University of the Arts Berlin. In nearby Wedding, the Berlin Innovation and Start-up Center (BIG) became the first German center of its kind when it opened in 1983. In 1985, it was expanded to become the Technology and Innovation Park Berlin (TIB), the first technology park in Germany. More than 90 companies work in the renovated AEG machine factory complex (built in 1887-1905), in close proximity to the 14 research institutes of the TU Berlin and the Fraunhofer Gesellschaft. Humboldt-Universität zu Berlin and Charité are also within walking distance. These start-up centers were organized by Innovations-Zentrum Berlin Management GmbH (IZBM), a subsidiary of the state-owned WISTA-MANAGEMENT GMBH.

www.campus-charlottenburg.org[2] | www.izbm.de/english

1 www.ptb.de/cms/en/about-us-careers/about-us/sites-in-berlin.html
2 www.campus-charlottenburg.org/index.php?id=157

4.4 The Southwest Berlin Technology Hub

Southwest Berlin is an internationally recognized research hub. It is where the "Kaiser Wilhelm Society for the Advancement of Science" (Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften), renamed the Max Planck Society in 1948, had its start. And it was here that Otto Hahn and Fritz Strassmann, working in their chemical institute in Dahlem, first demonstrated nuclear fission in 1938. The rich history represented by the city's many museums, historic as well as contemporary architecture, and the very landscape of Berlin-Potsdam itself (listed as a UNESCO World Heritage Site) mark the rich cultural life found in this area.

The academic landscape includes the internationally renowned Freie Universität Berlin, with its 29,000 students, which, together with Humboldt-Universität Berlin, operates the Charité – Universitätsmedizin Berlin, the largest medical school and university hospital in Europe

Other world-class institutions, such as the Helmholtz-Zentrum Berlin for Materials and Energy, the Bundesanstalt for Materials Research and Testing as well as the Aspen Institute and the Secret State Archives Prussian Cultural Heritage Foundation, likewise contribute to the location's international reputation.

www.rm-berlin-sw.de

University Research

Following the war and the partitioning of Berlin, the western part of the city no longer had a university of its own, since the former Friedrich-Wilhelms-Universität was located in the Soviet sector. This led to the founding of the "Free University of Berlin", **Freie Universität Berlin (FU Berlin)** in 1948.

In the wake of German reunification in 1990, the FU Berlin sought to remake itself and increased its research activities. The number of graduates, successful doctoral candidates and publications also grew significantly.

As a comprehensive university, the FU Berlin covers a wide range of subjects with more than 150 study programs in 12 departments and three central institutes.

In 2007, FU Berlin was singled out for special recognition by the Excellence Initiative launched by federal and state governments. It was one of nine universities in Germany receiving recognition in all three funding programs. In 2012, it again demonstrated its achievements as part of the Excellence Initiative and is now ranked as one of Germany's eleven "Universities of Excellence."

www.fu-berlin.de/en

The **Department of Physics** at the **FU Berlin** traditionally focuses on basic research. Among the department's current interests are solid-state and cluster physics, biophysics, and theoretical physics. This includes physical surfaces and their structures, the study of biologically significant molecules, investigating chemical reactions with rapid laser pulses, the application of mathematical models and the development of methods for multi-particle physics. The department has been focused for some time now on LIDAR, light detecting and ranging measurement of aerosols, ozone and summer smog.

The research conducted by the working groups is overseen by 17 professors in experimental physics (11), theoretical physics (5) and physics education (1). Four special professorships, together with the HZB (formerly HMI) and/or the Max Born Institute, serve to broaden the range of topics under investigation to include nuclear physics, solar energy, and fast nonlinear processes on surfaces and solids.

www.physik.fu-berlin.de/en

The **Department of Veterinary Medicine** at the **FU Berlin** is one of five institutions in Germany offering training to veterinarians. It is a well-known center of research in veterinary medicine. Founded in 1790, it is also the oldest veterinary institute.

www.vetmed.fu-berlin.de/en

In 1958, a decision was made to erect a large hospital comIn 1958, a decision was made to erect a large hospital complex in this part of Berlin. The result was the "Steglitz Clinic" (Klinikum Steglitz), constructed in southern Berlin between 1959 and 1969. It was the first major hospital complex in Europe to incorporate all institutes, clinics, and lecture halls under one roof. For space reasons, however, individual institutes moved over time into old villas or new buildings located nearby. In honor of American support, the clinic was renamed "Universitätsklinikum Benja-

Campus Benjamin Franklin (Charité)
© Charité Universitätsklinikum Berlin

min Franklin" (UKBF, Benjamin Franklin University Clinic). It had about 1200 beds and 36 scientific facilities. In 2003, UKBF merged with **Charité – Universitätsmedizin Berlin (Charité)** and is now known as **Campus Benjamin Franklin (CBF)**. Charité is a joint medical department of the Freie Universität Berlin and the Humboldt-Universität zu Berlin.

www.charite.de/en[1]

BerlinProtonen, the center for proton eye tumor therapy at Charité, is among the special institutes located at CBF. Proton irradiation is carried out in cooperation with Helmholtz-Zentrum Berlin at the latter's proton accelerator in Berlin-Wannsee. BerlinProtonen is a member of the Charité Comprehensive Cancer Center (CCCC).

www.berlinprotonen.de/en

Charité also includes the **Research Institutes for Experimental Medicine (FEM)**. The institutes have multiple roles, such as serving as the central site for breeding lab animals and for organizing animal imports and exports, overseeing animal welfare and providing veterinary services. They also have responsibilities with respect to genetic engineering, large animal surgery, transgenic techniques as well as training and education in the fields of laboratory animal science and animal welfare.

The services provided by the FEM are available both to the Charité as well as to a limited extent to external users such as other universities and companies.

web-fem.charite.de/en

Non-University Research

By virtue of its historical development, the Southwest Berlin technology hub also serves as home to a wide variety of non-university research institutes. In addition to the four Max Planck Society institutes, there are also several federal institutes, the Zuse Institute Berlin (ZIB), as well as BAM and part of the Helmholtz Center Berlin (HZB, formerly the Hahn-Meitner Institute).

Among the institutes associated with the Max Planck Society, the **Fritz-Haber Institute (FHI)** is the oldest. Dedicated to basic research, this institute was formed from the former Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry in Berlin-Dahlem. Research here is focused on understanding catalytic processes at the molecular level as well as on molecular physics. The Institute currently consists of five departments (Inorganic Chemistry, Chemical Physics, Molecular Physics, Physical Chemistry and Theory). In 2013 the FHI acquired its own Free Electron Laser (FEL) where work can be carried out at 6 workstations at wavelengths ranging between 4 and 48 microns.

www.fhi-berlin.mpg.de

Research at the **Max Planck Institute for Molecular Genetics (MPIMG)** concentrates on genome analysis of human beings and other organisms. The goal is to contribute to a better understanding of the biological processes in living organisms and to investigate the mechanisms associated with many human diseases. Together, MPIMG research groups attempt to gain new insights into the development of diseases at the molecular level, thus contributing to the development of new, disease-specific treatments.

www.molgen.mpg.de

1 www.charite.de/en/the_charite/campuses/campus_benjamin_franklin_cbf

New Max Planck Institute for Molecular Genetics building
© Andreas Muhs

Federal Institute for Materials Research and Testing (BAM)
© BAM

The **Federal Institute for Risk Assessment (BfR)** is an independent scientific institution that assesses health risks for consumers and draws up recommendations for risk reduction.

BfR results and recommendations serve as an aid to all interested parties in planning and choosing specific measures. Key activities include:

- Developing sensitive, state-of-the-art detection methods
- Compiling data for the purpose of risk analysis for exposure assessments
- Identifying, detecting and mitigating risks
- Evaluating, developing and validating alternative and complementary methods to animal testing
- Communicating and perceiving risks

www.bfr.bund.de/en

The second national Institute in Southwest Berlin is the **Julius Kühn Institute (JKI)**. The JKI is the national research center for cultivated plants in Germany and an autonomous primary federal authority directly accountable to the Federal Ministry of Food and Agriculture (BMEL). JKI specializes in issues relating to genetics and breeding research, as well as the protection and health of cultivated plants.

www.jki.bund.de/en

One Berlin institution able to look back a long history is the **Federal Institute for Materials Research and Testing (BAM)**. Materials research and testing are carried out at BAM with the objective of promoting the development of safety in technology and chemistry. Within the interconnected fields of materials, chemistry, environment and safety, BAM focuses in particular on:

- Regulatory functions relating to technical safety in the public domain, especially as regards dangerous materials and substances
- Collaboration in developing statutory regulations, for example with respect to safety standards and threshold values
- Advising the Federal Government, industry as well as domestic and international organizations on materials technology and chemistry
- Developing and providing reference materials and methods, in particular for chemical analysis and materials testing
- Assisting in the development of standards and technical regulations for the evaluation of substances, materials, structures and processes with reference to damage prediction and preservation of national economic values

At BAM, a variety of analytical methods are employed, drawn in particular from the fields of materials testing and analytical chemistry.

www.bam.de/en

The **Helmholtz Center Berlin for Materials and Energy (HZB)** operates two separate large-scale research facilities in Wannsee and Adlershof – the neutron source **BER II** and the synchrotron radiation source BESSY II (see Chapter 4.1) – both for basic research in physics. BER II is the core of the institute, which was founded in

1959 as the Hahn-Meitner Institute in Berlin-Wannsee. On January 1 2009, it was merged with the Berlin Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY) to form HZB. The synchrotron radiation source BESSY II allows for material analysis using brilliant, coherent light from the terahertz to the X-ray range. Each year, this research infrastructure is used by approx. 3000 visiting scientists.

Each of the institutes and departments within the different HZB research areas is headed by a professor appointed jointly by the universities in Berlin and Brandenburg. The research areas are complemented by work groups made up of junior researchers as well as joint HZB-university research groups and "Joint Laboratories."

The research reactor BER II supplies neutron radiation for a wide range of scientific investigations, in particular in materials science. Both thermal and cold neutrons are available. These pass through several neutron guide tubes to a total of 24 measuring stations. What makes the HZB special in this respect are the unique specimen environments it provides. Positioned in the world's most powerful magnets, specimens can be exposed to extreme low temperatures at the same time they are being irradiated with neutrons.

www.helmholtz-berlin.de[2]

Start-ups and Spin-offs in Berlin Southwest

Those interested in forming their own companies can draw on an extensive range of options available at the Southwest Berlin technology hub. In addition to the programs provided by the FU Berlin and Charité, there is also a local start-up center. **Profund Innovation,** the FU Berlin business incubator, has received numerous awards. It offers comprehensive consulting services to FU Berlin scientists and alumni up to 5 years after they leave the university. There are three business incubators on the university campus with a total of 100 workstations. Starting in 2009, FU Berlin began working with Charité to promote start-ups. Under the auspices of the "Entrepreneurial Network University," this collaborative effort is expected to achieve a new level of quality and be extended to include additional partners. The two institutions are partners in the EXIST-IV project entitled "Entrepreneurial Network University." With 2.8 million euros in funding, the goal is to implement this project through 2018.

www.fu-berlin.de/profund

The many start-ups overseen by Profund Innovation will soon get a new address. The new **Business and Innovation Center next to the Freie Universität Berlin** (FUBIC) is slated to be built on the 5-hectare site of the former American hospital at Fabeckstr. 62, in close proximity to the FU Berlin campus in Dahlem. Additional space will be available in the area around the TGZ SW for companies in the post start-up phase (growth phase). According to SÜDWEST regional management, it is expected that work at the center will be mainly geared around the specializations of the resident university or research institutions as well local research priorities in mathematics/computer science, ICT, healthcare and new materials. Overall, the site can accommodate 60 to 80 companies with about 900 employees.

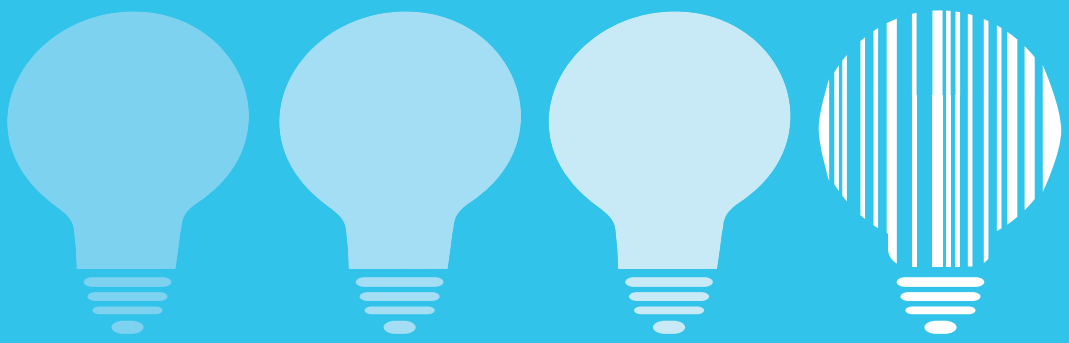
www.rm-berlin-sw.de[3]

Industry: Focusing on Medical Technology

Various companies in the fields of medical technology and analytics have taken up residence in the areas adjacent to the FU Berlin and Charité-Campus Benjamin Franklin. These companies include, for example, Berlin Heart GmbH, Knauer Wissenschaftliche Geräte GmbH and Laser- und Medizin-Technologie GmbH, Berlin. Southwest Berlin is also home to a network for RNA technologies unrivaled anywhere in the world.

www.rm-berlin-sw.de[4]

2 www.helmholtz-berlin.de/quellen/ber/index_en.html
3 www.rm-berlin-sw.de/projekte/technologie-und-gruendungszentrum-suedwest-fubic.html
4 www.rm-berlin-sw.de/rmsw/partner-netzwerke.html



5 Research and Industry

5.1 Process Measurement Technology

Introduction

It seems rather clear what the conditions must be to promote next-generation industrial processes and related trends in the development of cyber-physical systems meant to ensure an intelligent production environment for the "factory of the future" (smart factory): complete and accurate measurement of all relevant industrial production parameters. This applies to quantities of raw materials as well as process parameters and final product characteristics. Whether these parameters are measured before, during or after a certain stage of production – they all allow for efficient production at the highest levels of quality and with the lowest defect rate. This only increases the importance of process measurement technology, e.g. in the chemical/pharmaceutical industry, in production engineering, agriculture or environmental protection. It provides a better understanding of observed processes, which then serves as the basis for optimizing the design of those processes (quality by design) while also opening up the possibility for continuous quality and safety monitoring of products and materials.

Process analytical technologies require a high degree of reliability in terms of technical functionality, analytical precision, robustness and safety. This reliability must be guaranteed. According to the Federal Institute for Materials Research and Testing (BAM), process analytics will have a significant impact in the coming years, in particular on chemical and pharmaceutical production as well as manufacturing technology, thereby heavily influencing the market.

The historical relationship between research and industry in Berlin and Brandenburg has given rise to the development of many small, medium and large companies that offer highly specialized solutions for process measurement technology services. SMEs in particular have often drawn on their founders' core expertise to develop a number of methods and instruments that are among world's topranking technologies. They are supported by numerous research institutions with closely related applications that continuously develop and commercialize new technologies at the highest levels of quality. The range of topics is considerable. The following overview can, by its very nature, only provide an initial glimpse into a constantly changing landscape of companies and institutes at various locations in Berlin and Brandenburg.

Process Analytical Technology

The focus of the **BAM Division "Process Analysis Technology"** is on the development and application of process analytical technologies. This includes the development and validation of analytical on-line and at-line methods. The PAT Division supports BAM through research, development and public discussion in the:

- development of on-line analytical measurement and sensor technology with a focus on improvement of measuring capability
- generation of robust process data analysis tools for verifying process capability
- determination of "non-chemical" quantities as empirical quality parameters

This allows BAM to handle the following topics:

- Gas Analysis
- Inorganic Process Analysis – X-ray Fluorescence Analysis
- Optical Spectroscopy
- Chemometrics; Metrology

The following methods are employed:

- (Process)-Raman spectroscopy
- Process gas analysis
- X-ray fluorescence spectroscopy (XRF)
- Quantitative Process NMR spectroscopy
- Process-UV/VIS and NIR-spectroscopy

www.bam.de/en[1]

JP-ProteQ concerns itself with the analytical collection of production data as a basis for reliable process controls without identifying specific technologies or manufacturers. The focus is instead placed on the task itself, which is addressed, wherever possible, through modifications made to existing technologies. This is the fastest and most cost-effective way to approach the problem. In doing so, JP-ProteQ collaborates with partners such as the University of Potsdam, Optikexpertisen Dr. Volker Raab, Astro- und Feinwerktechnik Adlershof GmbH, among others, who apply their specific expertise to each respective project.

www.jp-proteq.com

1 www.bam.de/en/kompetenzen/fachabteilungen/abteilung_1/fg14

Multidimensional Methods for Industrial Quality Assurance

Interview with Dr. Uwe Beck, Federal Institute for Materials Research and Testing (BAM)

Dr. Beck, as head of the Surface Modification and Metrology Division at the Federal Institute for Materials Research and Testing (BAM), you work on behalf of the Federal Ministry of Economics on applications, in particular for private industry. What technical subjects are your primary concern?

The division is divided into three areas of expertise in the fields of surface modification and surface metrology with the following priorities: 1. mechanical and technological, 2. optical and 3. chemical-microstructural surface and layer quantities.

Analysis, measurement and testing methods as well as application-related optical methods are particularly relevant. They work quickly, usually non-destructively and non-invasively, require only small amounts of analyte, and can be used multi-spectrally in different wavelength ranges (from EUV to FIR).

The division is currently working on about 10 projects with funding from a variety of sponsors (EU, BMBF, BMWi, AiF, DFG). Projects in the field of optical metrology currently deal with such diverse topics as film characterization of energy conversion systems, monitoring hazardous gases using new photonic sensors, as well as optical detection of residual dirt, impurities and contamination on surfaces.

Three optical methodology groups deserve special mention: firstly, ellipsometry for non-destructive material and layer analysis; secondly, the scanning probe method for evaluating surface topography; and thirdly, the microstructural/chemical method.

This combination of multi-probe methods is so crucially important because BAM's research is not directed at standard products, materials or applications but rather at the entire spectrum of materials and applications. With increasing miniaturization, probe artifacts must always be taken into consideration. The multi-probe approach therefore provides a fundamental opportunity to validate hitherto uncharted ways of solving a problem.

What sorts of prospective projects can companies approach you about? What does a collaboration look like in actual practice?

There are no fundamental restrictions, just plenty of options: starting with testing reports, on through R&D preliminary studies, grant-based or externally- funded projects, comparative tests, quality assurance measurements, handling damage cases, as well as developing customized reference materials or work in pre-normative research.

In thin film analysis, there is a major trend towards optical measuring methods. They are contact-free and simple. What developments do you expect in this area in the coming years?

That's pretty obvious: continued miniaturization, nano-technology is on the rise. At the same time, however, there is also a need to evaluate larger surfaces, quantities of substances and batch sizes with cycle times as required by industrial quality assurance, where one second (per analysis, measurement, test) is often the benchmark. On the other hand, the product, material, charge must often be qualified in square meters, tons, 10M units. For this, multi-dimensional methods, such as, for instance, the transition from mapping to imaging, are essential.

Moreover, quality assurance often implies at-line, on-line and in-situ applicability of methodologies, of which optical far-field methods, including ellipsometry, are of elemental importance. As is the case in microelectronics, miniaturization will continue in microsystems technologies. The transition from MEMS to MOEMS is already underway. Semiconductor lasers and LEDs make hand-held analytical, testing and measuring systems a possibility, something that was unthinkable a few years ago. High intensity miniaturized light sources, integrated waveguides, laser-resistant layer systems, multi-modal techniques and the exploitation of quantum effects are some of the other buzzwords involved. All analyses, measurements, tests should be carried out with as high a lateral resolution (2D pixel) as possible, even using tomography (3D voxel).

Dr. Uwe Beck
Bundesanstalt für Materialforschung und -prüfung (BAM)
Federal Institute for Materials Research and Testing, Division 6.7, Surface Modification and Metrology
Unter den Eichen 44 – 46
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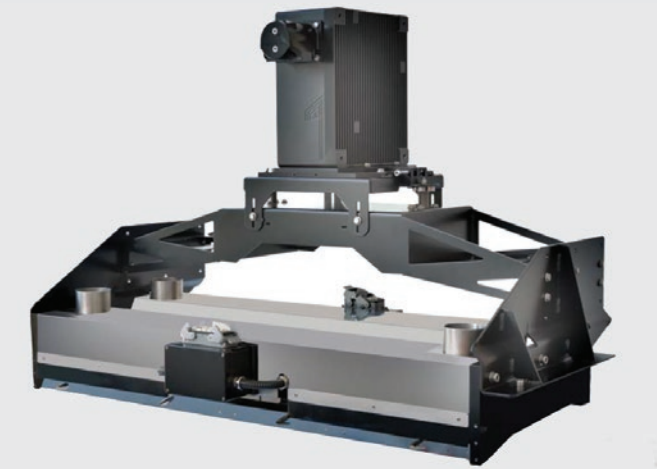
Email: info@bam.de
www.bam.de/en

Dr. Uwe Beck studied physics at TU Dresden. His dissertation focused on corrosion research. From 1980-1991 he worked at the research center in Teltow. After postgraduate studies at the Berlin Academy of Sciences, Dr. Beck received his PhD from the HU Berlin in 1990 in film systems for EL displays. Since 1991, he has been working at BAM Berlin where he was appointed Head of the "Surface Modification and Measurement Technique". Division in 2012. Together with Prof. Dr. A. Lunk (University of Stuttgart), he also founded the Arbeitskreis Ellipsometrie (AKE) – Paul Drude e. V. (the German association on ellipsometry) in 1999.

Measuring head prismagic®
© Bi-Ber GmbH & Co. KG



Multispectral KUSTAx.xMSI camera for sorting plastics
© LLA Instruments GmbH

Image Processing for Quality Control

The principal concern of **Bi-Ber** is the development and production of imaging systems for monitoring quality during production. The company focuses on implementing optical measurement systems for inspecting electronic and mechanical components in belt/testing/programming/assembly machinery for use by the medical device, automotive supply and electronics industries. The company provides standard quality assurance solutions to the confectionery industry, e.g. imaging systems for zero check monitoring as well as multi-view 3D applications (e.g. PRISMAGIC®, either as an all-in-one system or as components). Examples of suitable applications include the visual inspection of starter strip ceramics, radioactive seeds in medical technology, empty bottles, or other cylindrical components.

www.bilderkennung.de

CHRONOS VISION also offers solutions for industrial imaging (machine vision). Whether you are looking for suitable camera hardware or a turnkey solution – the experts at CHRONOS VISION will assist you in choosing the right camera model through consultation or complimentary testing. They also offer individualized know-how transfer through targeted training sessions and by providing support during the development phase. Applications range from the automotive industry to the food industry.

www.chronos-vision.de

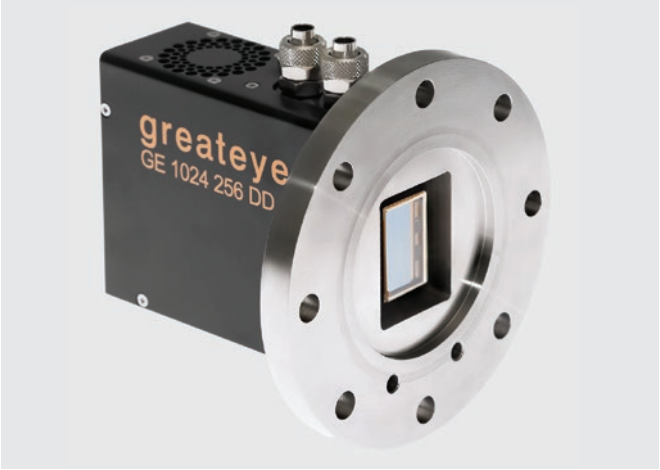
Berlin-based **pi4_robotics** is one of the leading manufacturers of imaging systems, automatic inspection systems and robots. In the photovoltaics sector, pi4_robotics is setting the standard with quality inspection systems based on electroluminescent technology.

Currently, its system solutions are used in particular in industry sectors like photovoltaics, automotive, glass, medicine and pharmaceuticals, fuel cell manufacturing as well as in the field of ceramics. The main revenue drivers at pi4_robotics include inspection systems for flat glass. pi4_robotics invented the product identification system PV-IDent. Using electroluminescence images of solar panels, this system detects inherent product characteristics and uses them for product recognition.

www.pi4.de/english

Imaging Spectroscopy

For more than 20 years, **LLA Instruments (LLA)** has been developing and manufacturing analytical technology for chemical imaging for use during processing and in the laboratory. NIR spectrometers by LLA are utilized worldwide to analyze and sort material streams, e.g. waste separation in recycling. LLA technology makes it possible to quickly and easily identify PVC during PET-flake sorting and to identify extraneous material in paper recycling. In addition, imaging



Full-frame CCD cameras for VUV, EUV, X-ray imaging and spectroscopy
© greateyes GmbH

Optris GmbH IR cameras and pyrometer
© Optris GmbH

NIR spectrometers are also used in C & D recycling, minerals and food sorting. The NIR portfolio includes multi- and hyperspectral cameras as well as multiplexed NIR spectrometers. An extensive range of accessories, such as illumination units, software packages, RGB cameras and comprehensive technical support services round out the NIR portfolio at LLA. The high-resolution Echelle spectrometer ESA 4000 was developed for in-situ analysis of inorganic matter such as metal and glass.

www.lla-instruments.com

Super-sensitive CCD Cameras for Spectroscopy and Imaging

greateyes offers a series of high performance cooled full-frame CCD cameras for imaging and spectroscopy with ranges from X-Ray to near infrared (NIR). The cameras combine scientific CCD sensors and low-noise readout electronics for optimal detection of weak signals. These properties make them ideal detectors for use in a broad range of applications in the industrial and scientific community, e.g. to inspect solar cells and modules. Solar cells and solar modules may suffer from a variety of invisible defects which reduce their output power and long-term stability. The highly sensitive inspection systems from greateyes are able to uncover these defects. The instruments are employed in R&D, production control and optimization, inbound & out-bound quality checks, defect analysis, as well as in the inspection of solar power equipment. As a result, these systems contribute to significantly reducing costs and increasing the quality of photovoltaic products.

www.greateyes.de

IR Sensors and Cameras

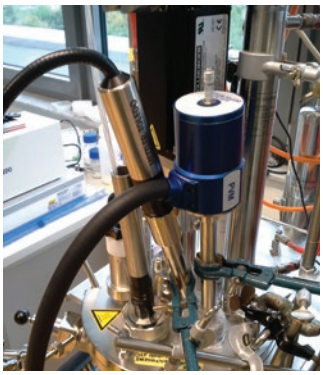
For over ten years now, **Optris** has been developing and manufacturing innovative infrared measurement devices for non-contact temperature measurement, including handheld thermometers, stationary industrial thermometers and infrared cameras for point and area measurement. Together with its free thermal analysis software, its devices enable constant monitoring and control of virtually every manufacturing process, providing for reductions in production costs through specific process optimization.

The fields in which its equipment is being applied include the automotive industry, plastics processing, temperature control in medicine, life sciences, the metalworking industry, the solar and semiconductor industry, the glass industry, the pulp, paper and textile industry, and, not least, laser processes.

www.optris.com

Fiber Sensing and Multi-channel Spectroscopy

innoFSPEC Potsdam is a joint undertaking of the Leibniz Institute for Astrophysics Potsdam (AIP) and the University of Potsdam (UP). The mission of innoFSPEC Potsdam is to conduct fundamental research and develop innovative technological solutions for fiber sensor systems and multi-channel spectroscopy in astronomy and physical chemistry. In doing so, it brings together the capabilities offered by new chemical analysis methods with high-performance multi-object and multi-channel spectroscopy. For example, the project entitled "Fiber-optical Process Sensing" applies numerous complementary fiber-optical sensors to a high-performance model reactor in order to develop innovative methods for on- and in-line analysis of chemical reactions and demonstrates the enormous potential of Process Analytical Technology (PAT).



Fermenters with (fiber)-optical in-line sensors
© Sandmann

www.innofspec.de/en

Color Analysis

ColVisTec specializes in integrating color analysis into process control. The aim is to increase efficiency through continuous process monitoring and quality control. This involves the early detection and prevention of defects and incidents occurring during the production process. Probes of various designs provide solutions for many applications on both transparent and opaque materials. Fields of application include: polymers (extruder application), powder (powder coating, other powder media), mixing processes, paste media, paints and coatings, printing inks, pharmaceuticals (as PAT for hot melt extrusion), chemicals, paper, foodstuffs, beverages and other liquid media.

www.colvistec.de

Optical Sensors and MEMS Technology

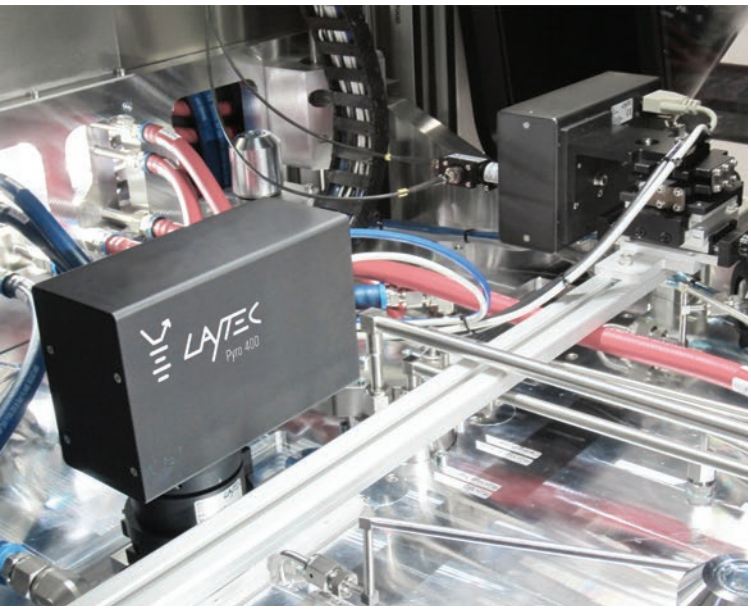
First Sensor is the one-stop developer and manufacturer of high-precision optical and opto-electronic sensor solutions and is able to provide long term continuity of supply. This includes component development and production in semiconductor plant cleanrooms, the packaging of integrated circuits and opto-electronic hybrid integration, as well as full system development. Available as components, modules or system solutions, First Sensor's products are an integrated part of many applications, such as pressure sensors, flow sensors, level sensors, radiation sensors (alpha-, beta- and gamma- as well as X-rays) and special sensors.

www.first-sensor.com/en

AEMtec, a member company of exceet Group, has been developing and producing highly miniaturized electronic components and systems for over ten years at the Berlin-Adlershof science and technology hub. Evaluation electronics often need to be directly connected to sensor components within a very limited space. Whether the needs are in the field of optical, magnetic or pressure sensors – AEMtec has wide-ranging experience with the relevant technologies and the special challenges associated with them. In the pressure sensor field, for example, calibration is a significant concern. AEMtec also develops and produces rotary angle sensors, optical sensors and MEMS systems. In addition, it provides specially developed high-precision testing equipment for the validation of highly complex optical assembly groups. An integral part of AEMtec's engineering team includes a group dedicated to developing product-specific (opto-) electronic test systems.

www.aemtec.com/en

CP – Color Probe
© COLVISTEC GmbH



Pyro 400: All real-time growth parameters
© LayTec GmbH

ALD Real Time Monitor
© Sentech Instruments

Monitoring of Thin Film Processes

LayTec is the world's leading manufacturer of process-integrated optical metrology for thin film processes. LayTec measuring instruments provide real-time information on coating process parameters – either in-situ (directly during the process) or in-line (during the substrate transfer between coating steps).

LayTec products are used in industry and research around the world. They significantly shorten the development cycles of new thin film materials and processes. When integrated into production lines, LayTec products also provide for highly efficient quality control and an automated process control system, which can significantly increase both the process yield and the effective system run time.

www.laytec.de

SENTECH Instruments is one of the leading suppliers of plasma process technology systems for coating and etching using atomic layer deposition (ALD) and plasma-enhanced chemical vapor deposition (PECVD); it also offers ellipsometers for thin film measurement. The new ALD Real Time Monitor complements SENTECH's ALD systems with in-situ measuring technology. The Real Time Monitor makes it possible to resolve adsorption and desorption during the ALD process. This serves particularly to optimize ALD process parameters. The advantage over traditional methods is that the optical method takes measurements on the actual sample surface.

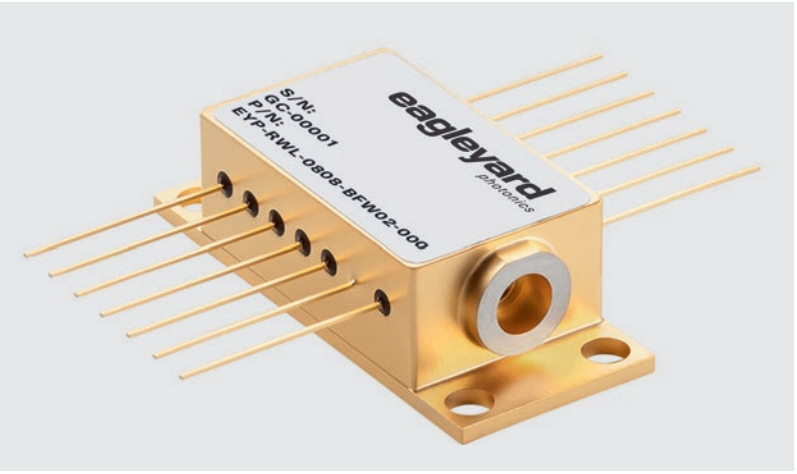
www.sentech.com

Ultrasonic Technology for Manufacturing Semiconductors

In Potsdam, **F&K Physiktechnik** develops and manufactures state-of-the-art ultrasonic components for use in wire & flip-chip die bonders used for assembly and connection technology in semiconductor production (chip bonding).

In addition, it also offers test systems for ultrasonic transducers as well as consulting for ultrasonic bonding processes, bonding capability investigations and on-site displacement investigations using laser interferometry.

www.fkphysiktechnik.com



Butterfly Ridge Waveguide Laser
© eagleyard Photonics GmbH

Single Particle Explorer (SPE)
© rap.ID Particle Systems GmbH

Laser Sources in Process Measurement Technology

With ridge waveguide lasers (RWL) from **eagleyard photonics** and with the aid of diffractive optical elements, it is possible to generate a variety of beam patterns – which are necessary in order to precisely measure 3D surfaces with CCD sensors. Due to their excellent beam characteristics, lasers are the ideal source for large-area measurements as used in the automotive industry, as well as for contactless measurement of speeds from a distance in a variety of industrial applications.

www.eagleyard.com[2]

Foreign Particle Analysis

In carrying out foreign particular analysis, **rap.ID** applies particle image analysis systems with automated Raman identification in combination with other methods, such as EDX, IR spectroscopy and laser induced breakdown spectroscopy (LIBS – **metal.ID**). These innovative systems and services are used throughout the world to detect contamination in production processes. rap.ID can provide information on the number, size and chemical composition of the particles.By working closely with customers, it's possible to carry out foreign particle tests on products in order to develop specific methods for routine foreign particle testing and characterization. If required, the methods can be validated in accordance with the demanding standards of the pharmaceutical industry.

www.rap-id.com | www.metal-id.com

Measuring Optical Assemblies

Developing new optical assemblies requires the highest levels of precision. **Berliner Glas** has been developing expertise in this area for decades. It not only manufactures assemblies, but also characterizes them. It writes its own software to analyze measurement data for customized specifications. Selected measurement technologies include:

- Wavefront measurements
- Measurements of size, shape and position
- Angle measurements of optical components
- Micro-roughness
- Spectral reflection and transmission measurement
- (Cylinder lens) centering
- Imaging performance
- Metrology developments

www.berlinerglas.com[3]

2 www.eagleyard.com/markets/industryinstruments/metrology
3 www.berlinerglas.com/engineering-expertise

5.2 Environmental Analysis

Introduction

How clean is our water? And what will the ozone levels be this summer? What sorts of contamination must be taken into account before a former industrial site can be developed? To answer questions like these, environmental analysis must first undertake a qualitative and quantitative examination of substances in the environment. Berlin and Brandenburg have developed tightly networked structures for this purpose, bringing together large, medium and small research institutes into close collaboration with a variety of mainly medium-sized companies. An extract of these structures is found in the following.

Trace Analysis

BAM Department 1 comprises several divisions that deal with the various aspects of environmental analysis. These include, for example, inorganic and organic trace analysis, environmental analysis as well as a division for chemical and optical sensor technology.

Special fields of competence include inorganic trace elements, element speciation and isotopic analysis, especially of pure substances, environmental, biological and medical materials, along with the development of suitable analysis procedures and instruments. While in part focusing on analyzing pollutants in soil, air and water, the department also develops analytical methods to determine the presence of ethyl glucuronide (ETG) in hair, for example, which serves as a biomarker for the classification of alcohol consumption. Environmental analysis is also concerned with antibodies and their analytical use – which is another area that BAM is working on, in collaboration with a variety of companies and research institutes.

www.bam.de/en[1]

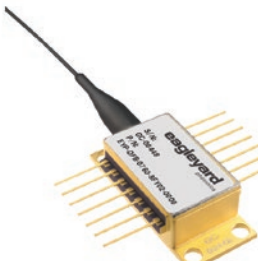
Water Analysis

Hach Lange's company portfolio encompasses a variety of applications and products in the field of water analysis. Using a luminescence measuring process, for instance, it's possible to measure the period between the time a light pulse is emitted and the time it is reflected back. Measuring the oxygen-dependent interval makes the method resistant to interference of any kind. Years of practice have shown that this method overcomes the disadvantages of traditional electrochemical measurement techniques. The minimal maintenance required by the sensor make it inexpensive to operate. The long-term stability of measured values increase process reliability and help produce savings, for instance, in terms of the aeration energy required in municipal and industrial wastewater treatment plants.

www.hach-lange.de

Oxygen Measurements

In absorption spectroscopy, lasers provide for non-contact and remote measurement of oxygen. **eagleyard photonics** provides DFB laser diodes (DFB-760, DFB-764) that achieve the greatest oxygen absorption lines. Due to their significantly higher output power compared with other lasers (e.g. VCSEL), they are ideally suited for industrial applications under difficult measuring conditions. Excellent long-term wavelength stability makes regular recalibration cycles obsolete, which can significantly reduce the customer's operating expenses.



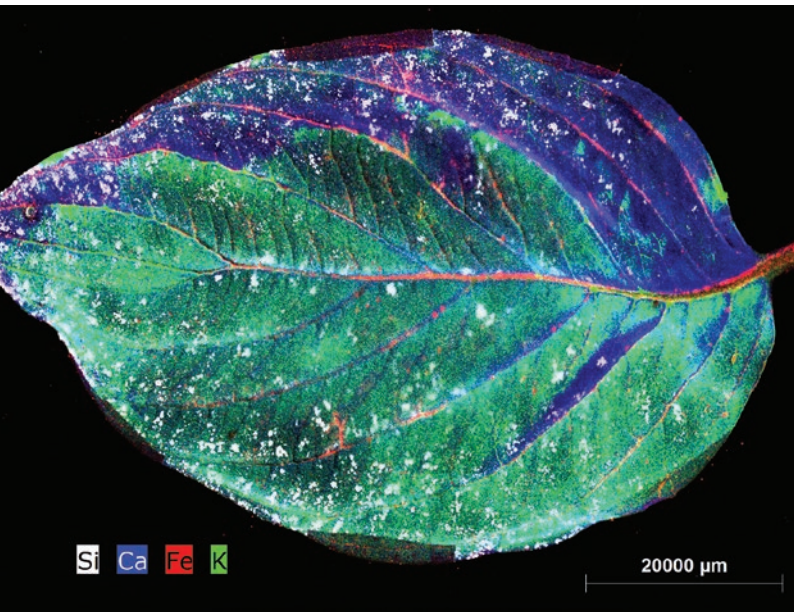
Fiber coupled DFB laser diodes
© eagleyard Photonics

www.eagleyard.com[2]

X-ray Analysis

X-ray fluorescence analysis (XRF) is an established method for measuring the concentration of individual elements in biological samples. **Bruker Nano** offers a variety of XRF devices that make it possible to examine the metabolism

1 www.bam.de/en/kompetenzen/fachabteilungen/abteilung_1/index.htm
2 www.eagleyard.com/markets/industryinstruments/analytics



Element map of an autumn leaf taken with the M4 TORNADO micro-XRF system from Bruker
© Bruker Nano GmbH

of biological samples quickly and with minimal sample preparation. They provide valuable information about environmental influences. In addition, they are also used to analyze building materials, conduct geological research, as well as in forensics and archeometry. Moreover, Bruker is the first company able to offer all commonly used X-ray analysis procedures (EDS, WDS, EBSD, Micro-XRF and micro-CT) from a single source.

www.bruker-nano.de

Rapid Detection of Organic Contaminations

The **Leibniz Institute for Agricultural Engineering Potsdam-Bornim e.V.** investigates optical methods for the rapid detection of organic contamination. The focus is on the use of optical technologies to non-destructively determine the quality parameters of plant products. The methods investigated include:

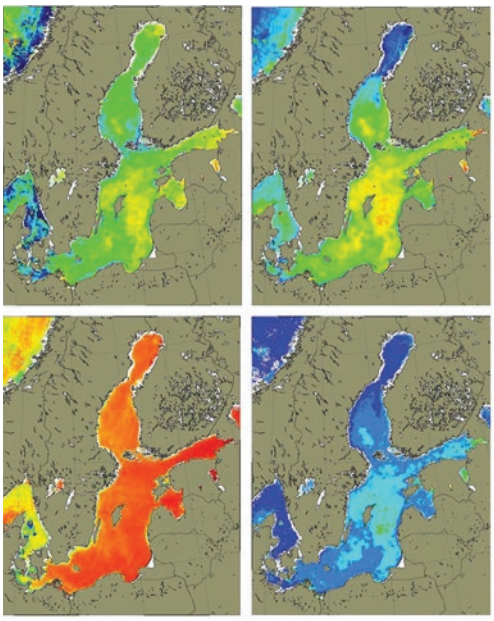
- Hyperspectral analysis
- Chlorophyll – fluorescence – intensity measurements
- Portable spectrophotometer
- Raman spectroscopy

In addition, flow cytometry, fluorescence and UV spectroscopy methods are used to develop rapid tests to identify microorganisms.

www.atb-potsdam.de/en

Optical Marine Remote Sensing

The working group on “Marine Remote Sensing” within the **Earth Observation Center (EOC)** at DLR is also represented at the Adlershof site. This working group focuses on using optical methods to (remotely) detect components in variously sized water bodies. Whereas non-imaging sensors are employed on board ships or in the water itself, so-called imaging spectrometers are used on aircraft and satellites. The latter can also provide spatial images for each spectral band. Remote sensing is the only technology that can be employed to monitor the high spatial and temporal dynamics of water bodies since it provides synoptic and repeatable overviews over large areas. The MOS-IRS imaging spectrometer developed by DLR (and flown on the IRS-P3 satellite from 1996 to 2005) was, as the first instrument of its kind, primarily used



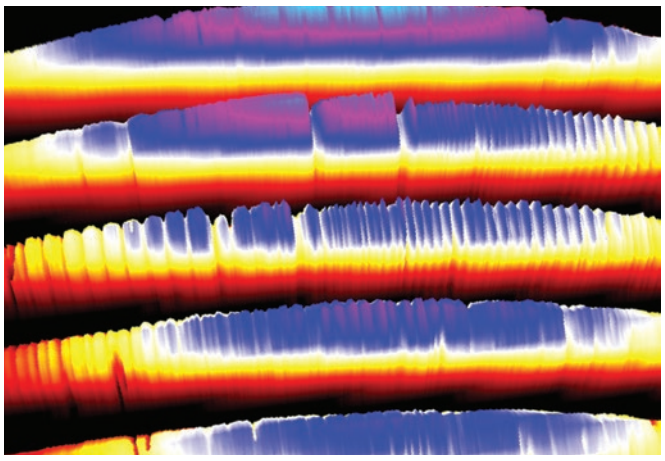
Concentrations of chlorophyll (u.l.), suspended matter (u.r.), yellow substance (l.l.) and the resulting water transparency (l.r.) in the Baltic Sea, derived from MERIS data, July 1, decade 2008
© DLR

for basic research and to demonstrate the feasibility of quantitative satellite remote sensing. It was followed by the imaging spectrometer MERIS on board the ESA environmental satellite ENVISAT, which marked the transition to regular delivery of data for environmental monitoring by government authorities and aimed at confirming adherence to European guidelines as part of the COPERNICUS program. Through the launch of Sentinel-3 in early 2016 a new more powerful successor of MERIS will be in orbit for furthermore detailed mapping of water bodies.

www.dlr.de/eoc/en

Plasma Spectroscopy

At the **Leibniz-Institute for Analytical Sciences – ISAS - e.V. (ISAS)** in Dortmund, a miniaturized plasma with a liquid electrode, has been developed which can be operated in continuous flow operation requiring only small sample volumes. This system allows the determination of chemical elements diluted in the liquid electrode using optical emission spectroscopy. Trace elements in very small sample amounts can also be detected with the high-resolution absorption spectroscopy developed at **ISAS Berlin** that uses a continuous plasma source as background emitter. With both analytical techniques, the extremely fine-structured spectra must be measured with high-spectral resolution, sensitivity and accuracy.



Echelle absorption spectrum of a phosphorus oxide sample to determine the concentration of phosphorus
© ISAS

To this end, ISAS Berlin developed an Echelle Spectrograph equipped with a **greateyes** Peltier-cooled CCD surface receiver. This makes it possible, for instance, to determine important plasma parameters such as the temperature of different species or electron density. The latter can be used for characterization and further development of the plasma source.

www.isas.de/en | www.greateyes.de

Particle Identification

Under the project entitled “Photon Density Wave (PDW) Spectroscopy,” **innoFSPEC** Potsdam is developing a unique fiber-optical method to analyze e.g. particle sizes in strongly light-scattering, opaque materials. In close cooperation with scientific and industrial partners, PDW technology is being applied in fields such as foodstuffs and polymer chemistry, nanotechnology, and biomedicine. In 2014 this technology was awarded with the Bunsen-Kirchhoff Prize funded by the GDCh (Gesellschaft Deutscher Chemiker).

In addition, young scientists founded the spin-off company **PDW Analytics** to explore commercial opportunities for the technology.

www.pdw-analytics.de | www.innofspec.de/en

rap.ID. is following a somewhat more general approach to particle identification. It uses its technology to identify foreign particles from parenterals or injectables as well as to determine the particle material in implants and to carry out studies on technical cleanliness.

To do so, the particles are mainly isolated using membrane filtration. Special methods optimized for material characterization of micron particles (FT/IR, REM/EDX, Raman and LIBS spectroscopy) make it possible to then identify practically all materials. A complete microscopic documentation of the particles is included.

www.rap-id.com | www.particle-identification.com

5.3 Bioanalytics

Introduction

The accurate analysis of chemical compounds, biological macromolecules as well as cells and microorganisms is currently an important problem being investigated in a variety of scientific, industrial and medical fields. Microscopic and spectroscopic procedures are the technologies commonly used in these investigations. Favorite approaches, especially with a number of biological specimens, are high-performance liquid chromatography (HPLC) with UV or fluorescence detectors and Raman spectroscopy. Berlin and Brandenburg have developed an industrial or industry-oriented infrastructure that makes available technologies for the analysis of biological compounds as well as other devices. Problems such as diagnosing skin cancer demonstrate how biological diagnostics can bring about advances in clinical diagnostics.

Fluorescence and Raman Spectroscopy

Mobile analysis technology for fluorescence and Raman spectroscopy is being developed at the **Fraunhofer Institute for Reliability and Microintegration (Fraunhofer IZM)**. By virtue of the variety of radiation wavelengths it employs, the RF-KombiSCAN not only can detect the quantity of different substances, but their composition as well. This innovative, portable, hand-held optical meter simplifies and expedites the process of making measurements through the integration of fluorescence and Raman spectroscopy.

The mobile scanner can be used as a laboratory research device as well as in industrial applications. The technical innovation and mobility of the RF-KombiSCAN is currently unsurpassed and could be applied to other areas as well, such as food monitoring, medical sciences, police investigations, border protection measures, forensics as well as in inorganic material analysis.

www.izm.fraunhofer.de/en

The **Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH)** develops laser emitters for Ra- man spectroscopy. This includes diode lasers that emit light with two wavelengths at a fixed distance of about 1 nm from a single chip, which makes them ideal for “shiftedexcitation Raman difference spectroscopy” (SERDS).

SERDS makes it possible to clearly separate Raman signals from interfering background fluorescence or ambient light. Use of micro-optics means the laser can be kept compact, which is essential for mobile use. FBH uses this technology in order, among other things, to provide beam sources in the yellow wavelength range.

www.fbh-berlin.com

RF-KombiSCAN as laboratory device
© Fraunhofer IZM

Miniaturized two wavelengths diode laser module for Raman spectroscopy
© FBH/Schurian

Imaging Raman Spectroscopy

Imaging Raman spectrometers are multichannel ("multiplex") devices that are not yet available as industrial products. Due to the extremely high demands placed on modern large telescopes, imaging multiplex spectrographs have existed in astrophysics for about 25 years. The goal of the RIA project being carried out jointly by the **Laser- und Medizin-Technologie GmbH, Berlin (LMTB), the Leibniz Institute for Astrophysics Potsdam (AIP)** and the companies **Berliner Glas** and **eagleyard photonics** is to develop such a multichannel Raman spectroscopy system.

The following areas were addressed as pilot applications for this project:

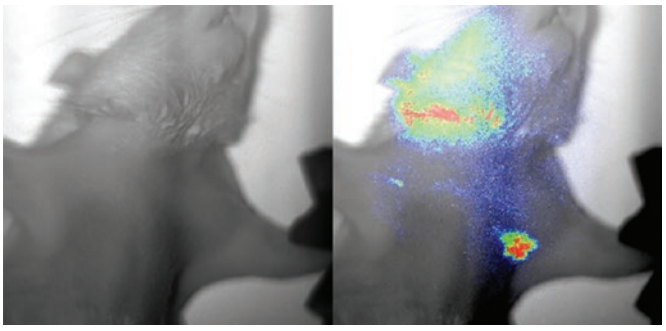
- Analysis in microtiterplates: endpoint and kinetics in microtiter
- Process analytics/recycling: identification of substances and their transformation during processing.
- Security: identifying substances and liquids at access control, e.g. at airports.

www.lmtb.de | www.aip.de/en

www.berlinerglas.com | www.eagleyard.com

Fluorescence In Vivo Imaging

The principle of fluorescence in vivo imaging is based on the properties of fluorochromes, which respond to an external light source by emitting light of a different wavelength. **greateyes** supplies a camera capable of detecting in the near-infrared range that is able capture the emissions. Fluorescence in vivo imaging can be applied, for example, to detect cancer cells in lymph nodes. In the example above, a fluorescence labelled dye was applied intravenously into rats, which then concentrated in lymph node tissues. The detection of the weak fluorescence, which permeates the tissue, requires a highly sensitive camera together with a special filter.



Overlay picture of a light scatter image (left) and fluorescence detection (right) using the camera GE 1024 1024 DD NIR
© greateyes GmbH

www.greateyes.de

Time-resolved Optical Microscopy

Studies in bioenergetics in the **Department of Chemistry** at **TU Berlin** employ microscopy and spectroscopy and electrophysiological methodologies, combining them with optical methodologies in examining living cells. Wide-field fluorescence microscopy with high spacial- and time-resolution single photon detectors for multichannel FLIM measurements provide for spatial resolution microscopy of dynamic processes and simultaneous fluorescence correlation spectroscopy in each pixel with 100 ps resolution along with a measurement period of 10 microseconds.

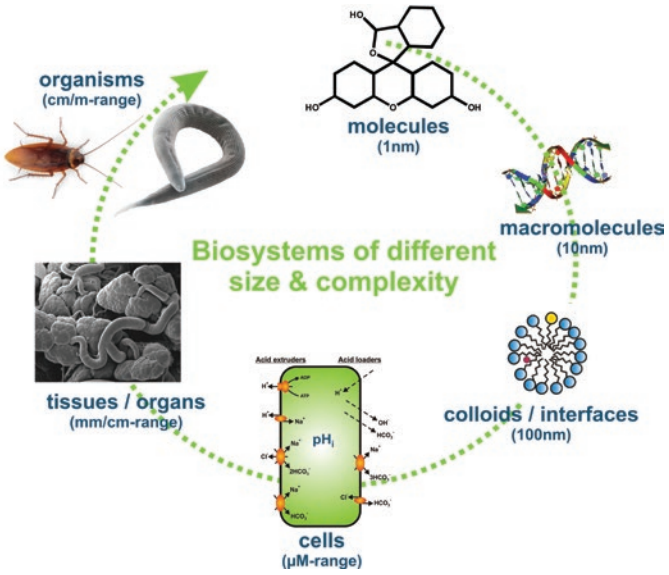
These technologies go beyond previous limits in terms of precision, parallelization and speed and have a particularly high potential for applications in industrial projects. This applies in particular to applications in the field of pharmaceutical active ingredient research and cell-based diagnostics.

This makes it possible, for example, to detect with unprecedented precision the fluorescence lifetime distribution of photosynthetically active proteins in unicellular organisms in order to investigate important regulatory processes in photosynthesis. Biological or chemical reference structures will help in determining to what extent the technology can overcome the diffraction limit of spatial resolution in optical microscopy procedures.

www.bioenergetik.tu-berlin.de

Applied Laser Sensing in Complex Biosystems

The ALS ComBi group at the Department of Physical Chemistry at the University of Potsdam pursues the realization of laser-based sensing techniques and their application in the life sciences. Thereby, bio-targets of different size and complexity will be characterized.



Hierarchy of complex Biosystems ranging from nm- to cm-scales.
© Uni Potsdam

The central infrastructural development was the establishment of a microscopy application lab. Here, multiplexing concepts using spatial, spectral or time-resolved separation (e.g. 1P/2P-excitation, FLIM/PLIM) and single molecule detection (e.g. FCS) provide information about spatio-temporal interactions of cellular parameters. For cell-manipulation, fluorescence microscopy can be combined with a nanofluidics-AFM (FluidFM) for delivering fL-volumes with high spatial accuracy. For studying the subcellular architecture, super-resolution microscopy techniques (easy-STED, dSTORM) with diffraction-unlimited resolution down to 40 nm are established. In addition, ALS ComBi focusses on the development of two complementary optical biosensor concepts based on SOI-technology with waveguides and photonic crystals or on optical fibers with inscribed fiber Bragg gratings. The biosensors will be adapted for label-free detection with high sensitivity and multiplexing capabilities in small sample volumes without extensive sample preparation.

www.uni-potsdam.de/en/alscombi

Non-invasive Measuring and Imaging

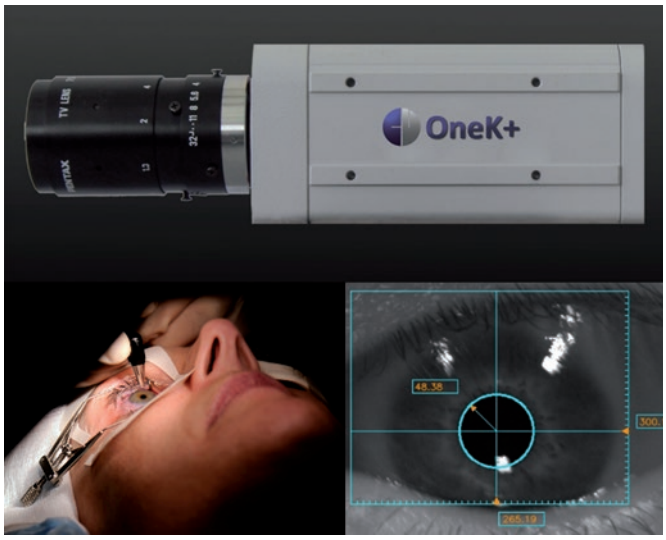
As age-related illnesses such as cancer, cardiovascu-lar and neurodegenerative diseases become more and more relevant, new approaches and improved methods for medical diagnosis and therapy are required. Quantitative and differential-diagnostical methods help to determine early, precise and individual treatment decisions by enabling accurate and reliable identification of disease-specific parameters. Optical measurement and imaging techniques provide valuable contributions to this end.

Non-invasive optical medical imaging
© PTB

At the department “Biomedical Optics” of the **National Metrology Institute of Germany (PTB)** measurement procedures in this field are developed, examined and tested, in cooperation with clinical partners. Flow-cytometry, microscopic measurement techniques and quantitative nucleic acid diagnostics of cells and (bio-) molecules underpin metrology to support laboratory diagnostics. One goal of this work is the development of reference measurement procedures and values, to enable & support the federally mandated quality assur-ance of tests in laboratory medicine. Non-invasive quantitative determination of important biomarkers (e.g. concentration of haemoglobin, oxygen saturation) in tissue, as well as in-vivo imaging of pathological changes using fluorescencelabelled probes, round out the tasks of the department. For this purpose, opto-spectroscopic measurement and imaging techniques are developed and examined.

www.ptp.de/en[1]

1 www.ptb.de/cms/en/ptb/fachabteilungen/abt8/fb-83.html



OneK+ Eye Tracker
© CHRONOS VISION

Ophthalmology

The examination and diagnosis of eye movements and related disorders provides important information on a variety of diseases above and beyond the field of ophthalmology. The Chronos Eye Tracker (C-ETD) from **CHRONOS VISION** makes it possible to conduct a comprehensive examination of three-dimensional eye movement. Also, refractive surgery (e.g. Lasik procedure) demands precise real-time measurement of the position of the eye. During each laser operation, the position of the eye is measured by the Eye Tracker and relayed to the laser guidance control. Thus, the laser firing pattern compensates for any changes in eye position. Rapid tracking optimizes treatment outcome and shortens treatment time to the benefit of patients. As original equipment manufacturer, CHRONOS VISION currently supplies an OneK+ Eye Tracker with a real-time tracking rate of more than 1000 Hz together rate and an extremely short latency period. In addition, the software solution DeyeRECTOR® provides modules that complete robust and precise eye tracking during ophthalmic surgery.

www.chronos-vision.de[2]

Mobile Foodstuff Analysis

JTL-BioTec.Analytics develops and manufactures innovative instruments for milk analysis. Its NIR spectrometers ascertain the fat and sodium content of raw milk and check for mastiti during processing. In addition, the company also supplies automatic freezing-point osmometers to determine osmolality.

www.biotec-analytics.de

Automated Sample Handling

Automation plays an important role in medical technology and the pharmaceutical industry. This includes, for example, pipetting or optical analysis of biological samples. The CytoFa analysis system by **pi4_robotics** combines robot-based liquid handling with automated image acquisition of biological samples in a compact laboratory instrument.

Laboratory instrument CytoFa
© pi4_robotics GmbH

CytoFa uses a motorized microscope with a high-resolution camera and a 3-axis robot, along with an additional axis of rotation for handling liquids. Its spatial isolation and integrated temperature control make CytoFa particularly well suited for handling light- and temperature-sensitive materials. The microscope images can be presented and stored either manually or automatically in different layers (z-stack). A variety of lighting and contrast methods can be set in the control software depending on the configuration of the microscope; these settings are then integrated into the automated process. This makes possible, for instance, fluorescence imaging of biological samples.

www.pi4.de

2 http://chronos-vision.de/en/medical-engineering-development.html

5.4 Thin Film Analysis

Introduction

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 is found in key diagnostics for nanotechnologies, semiconductor technologies and materials science, where it accelerates the development of innovative complex material systems.

The many technological challenges include, for example, the development of miniaturized optical systems, light sources, highly sensitive detectors, algorithms for data analysis, image processing and pattern recognition, as well as optimization of cost-effective systems for specific applications in materials technology.

The region is home to component developers and manufacturers working along the entire innovation and value chain. In addition, strong research partners with complementary technologies at large-scale facilities can also be found in the region as well as a strong potential user community in the field of materials science.

Reflectometry on Large Samples

The **BESTEC** product portfolio includes measurement systems for light-in / light-out technologies in the energy range from UV to soft X-rays, which are used, for instance, in reflectometry, ellipsometry or Raman spectroscopy. They are suitable for applications such as measuring large surfaces in the optics industry, for basic research at XFEL sources, or for materials research at synchrotron radiation sources.

All Bestec systems feature precise in-vacuum manipulators for samples and detectors, which enable highly reproducible movements in several degrees of freedom over broad areas. Their robust, lubricant-free design, with special attention given to ensuring they are particle-free, guarantees safe and reliable operation. Fully automated variants as well as models tailored to the specific detector type and sample size can be produced on request.

www.bestec.de

Spectroscopic Ellipsometry

SENTECH Instruments, based in the Adlershof Technology Park, offers a wide range of reflectometers as well as laser and spectroscopic ellipsometers in its product portfolio with innovative thin-film metrology. SENTECH continuously develops new applications. The Müller matrix can now be measured using the 2C-option for the spectroscopic ellipsometer SENresearch. This makes it possible to measure all 16 Müller Matrix elements with an accuracy of +/- 0.005. This option expands the areas of application of the SENresearch ellipsometer to include in particular anisotropic, depolarizing and structured samples. Furthermore, this innovative ellipsometer can now determine the exact refractive index, absorption coefficient and

Reflectometers for large samples and investigations with monochromatic light in the wavelength range of 10 nm – 20 nm
© BESTEC GmbH

Spectroscopic ellipsometer SENresearch 4.0
© SENTECH Instruments GmbH

film thickness by applying the Step Scan Analyzer (SSA) principle. The motorized goniometer allows independent movements of analyzer and compensator, which allows it to perform angle-dependent scattering measurements in order to analyze periodic structures.

www.sentech.com 

In Situ Spectroscopy

The In Situ Spectroscopy group at the **Leibniz-Institute for Analytical Sciences – ISAS – e.V. (ISAS)** in Berlin-Adlershof aims to develop strategies for in situ spectroscopic investigations of functional organic surfaces and hybrid films, with a special emphasis on vibrational spectroscopy.

The group develops methods in the areas of optical models, evaluation procedures and experimental equipment for the in situ study of surfaces in liquid environments (Reflection-Anisotropy-Spectroscopy, Ellipsometry, Raman and IR spectroscopy, IR Microscopy, IR mapping ellipsometry at BESSY II).

Combined lab and synchrotron measurements focus on functional films and molecule adsorption on functional surfaces, e.g. stimuli responsive polymer brushes or specific linkers for bio- and solar cell applications. Measurement concepts are being continuously improved in order to analyze more quickly, with higher sensitivity and at higher lateral resolution.

www.isas.de/en[1] 

Imaging Spectroscopy of Optical Layers

In optical applications, thin layers/coatings are utilized to customize the reflection or transmission performance of surfaces and optical components for UV-, VIS- and IR radiation. Common uses include the production of reflective elements (e.g. mirrors) or as anti-reflective coating for optical surfaces (e.g. lenses, prisms, displays, panels and OLEDs). For these purposes, metals with high absorption- or reflection capacity as well as dielectric materials with high transparency are utilized. The imaging NIR hyperspectral cameras uniSPECx.xHSI from **LLA Instruments** make it possible to spacially measure the spectral processes of the transmittance or reflectance factors of optical components at wavelengths ranging from 350 nm to 2200 nm. A common application is in automatic full-surface material control of glasses or filter lenses in UV-, VIS or NIR spectral range immediately after the dielectric coating process.

www.lla-instruments.com 

Infrared Thermography

During the production of solar cells, temperature distribution on the wafers is recorded during string brazing. This assures a reliable and efficient assembling process. Temperature measurement takes place on the silicon surface, which is connected to the braze point. This is how the quality of the homogeneity of the brazing is measured. Challenges posed to brazing process monitoring are: adequate local resolution and temporal resolution, since the heating of the braze points can take place in less than a second. The optris PI infrared camera from **Optris** has established itself as a suitable measurement device given its resolution of 160x120 pixels as well as a frame rate of 120 Hz for the whole image. Contact-free infrared thermography is an essential tool for checking the performance of solar cells. One option for performance checking is periodical modulated illumination of solar cells while simultaneous observing the process with an infrared camera – so-called Illuminated Lock-In Thermography.

www.optris.com[2] 

Optical Measuring as a Service

Optotransmitter-Umweltschutz-Technologie e.V. (OUT e.V.) provides the optical measurement of plane coatings and surfaces as a technical service. This includes wavelength-dependent transmission, absorption and reflection

1 www.isas.de/en/institute/departments/interface-analytics/in-situ-spectroscopy
2 www.optris.co.uk/temperature-measurement-solar-industry

measurements from 0.2 µm up to 1.25 mm (terahertz) as well as the identification of optical constants n(λ), k(λ). In addition, OUT eV. offers a variety of photometric measurements of LEDs and small radiation resources:

- luminous flux (lm), radiant flux (W)
- luminous intensity (cd) and radiant intensity (W/sr)
- angle of radiation, directional characteristics
- luminous flux distribution body
- color temperature distribution body
- color rendering index (CRI, Ra, ...)
- color temperature (CRT)
- color coordinates x, y (CIE 1931) or Luv (CIE 1976)
- spectral resolved measurements of the bidirectional scatter function (BSDF) of solid surfaces between 198 and 1115 nm
- reflection spectrogram for azimuth and elongation -90° till +90° between 198 and 1115 nm

www.out-ev.de/english

X-Ray Fluorescence Scanning Electron Microscope

A new wavelength-dispersive X-ray spectrometer (WDS) for scanning electron microscopy (SEM) was developed at the **Institute for Nanometer Optics and Technology (INT) at the Helmholtz Center Berlin** in cooperation with the **Insti-**

Unraveling the Mysteries of Paintings

Using Bruker's M6 JETSTREAM Micro-XRF scanner

Micro X-ray fluorescence analysis (micro-XRF) has proven a valuable tool in archaeometry and restoration. This technique helps us to better understand artistic processes, discover hidden works, and supports restorers as they preserve important works of art.

"Pentimenti" (Italian, plural of "remorse") are traces of alterations to paintings. They are commonly analyzed with ultraviolet light or X-ray radiography to discover what is now covered with new layers of paint. However, using micro-XRF for this purpose provides a wealth of additional information: the opportunity to do element analysis not makes it possible to see the original hidden beneath subsequently altered areas, but also to determine the composition of all the inorganic pigments that were used. Learning about the pigments used during a given time period sheds light on the ones used later in the areas that were covered with new layers of paint.

An impressive example is provided to Bruker Nano by Prof. Koen Janssens, Professor of Analytical Chemistry, and Dr. Geert van der Snickt of the University of Antwerp, Belgium. It shows the analysis of the right panel of a triptych painted by Hans Memling for the Moreels, an influential family from Bruges. Here, Mrs. Moreel kneels next to St. Barbara. Behind her are 11 of her daughters. The analysis of the upper half of the right panel using the M6 JETSTREAM provides some remarkable findings. The lower part of the image below shows a map of the top half of the right panel of the triptych. It is an overlay of the copper (green), mercury (red) and scattered primary radiation (white) maps. The copper distribution shows that the original version of the panel contained only four of her daughters. The others were obviously added later and painted on top of the landscape in the background.

Also, alterations were made to the clothes worn by Mrs. Moreel and her eldest daughter. This information can be taken from the scattered radiation map; the décolleté of both mother and daughter appears darker. A red without mercury was used to paint St. Barbara's skirt. The vermillion (containing mercury and therefore red) used on the left arm and bodice was probably added during a later restoration phase.

Bruker's M6 JETSTREAM large object Micro XRF scaner in front of the right panel of the Moreel triptych. Courtesy University of Antwerp, Belgium.

tute for Scientific Instruments (IfG) and the Institute for Applied Photonics e.V. (IAP) in Adlershof. With an array of 17 reflection zone plates, this spectrometer covers an energy range of 50 eV to 1,120 eV. This makes it possible to measure X-ray emission spectra from light elements in the soft X-ray range. A version with 200 reflection zone plates was used as a multi-channel analyzer for quasi-continuous spectra measurements in the energy range of 100-1000 eV. The expected energy resolution of $E/\Delta E \sim 100$ was achieved across the entire energy range.

www.helmholtz-berlin.de[3]

www.ifg-adlershof.de | www.iap-adlershof.de

New X-ray Analytical Methods

For the investigation of nano-structured material, such as solar cells, depth resolution in the nm-range is necessary. For this purpose, new synchrotron-based techniques such as reference-free grazing incidence XRF (GIXRF) and near edge X-ray absorption spectroscopy (NEXAFS) are currently being developed by the **Analytical X-ray spectroscopy group at the TU Berlin** in close cooperation with The National Metrology Institute of Germany (PTB) at the electron storage facility BESSY II.

www.axp.tu-berlin.de

3 www.helmholtz-berlin.de/forschung/oe/fg/nanometeroptik

(Left) Upper half of the right panel of the Moreel triptych. (Right) Composite elemental image showing the distributions of copper (green), mercury (red) and the total scattering intensity (the more tube radiation that is scattered, the brighter the area appears).

X Link®: Cross-linking control in the blink of an eye
© LayTec GmbH

Metrology for Thin-film Processes

LayTec measuring instruments provide real-time information on coating process parameters – either in-situ (directly during the process) or in-line (during the substrate transfer between coating steps). The technologies used by LayTec metrology include:

- Multiple wavelength reflectance
- Reflectance and transmittance metrology
- Infrared and UV pyrometry
- Deflectometry
- Photoluminescence
- Conductivity
- Reflection Anisotropy Spectroscopy (RAS)
- Cross-linking degree control

LayTec supplies these measurement technologies for the production of semiconductors, solar cells, electronic and opto-electronic components, as well as for use in ambitious research projects

www.laytec.de

Certified Testing of Layer Systems and Surfaces

BAM Division "Surface Modification and Measurement Technique," deals with the characterization of thin films and functional surfaces such as hard coatings (e.g. wear protection), optical layer systems (e.g. UV protection) and metallic coatings (e.g. corrosion protection or as electro-magnetic shielding).

Various testing procedures accredited under DIN EN ISO/IEC 17025 enable the determination of mechanical, optical, micro-structural and electrical surface and layer quantities, common substrate and layer properties such as surface topography as well as energy, thickness and adhesion.

Depending on material and layer thickness, different non-destructive and destructive techniques can be applied with supplementary or overlapping fields of application:

- Spectroscopic ellipsometry (SE)
- X-ray fluorescence spectroscopy (XRF)
- X-ray reflectometry (XRR)
- Light microscopy / Metallography
- Eddy current-/ magnetic field probe
- White light interference microscopy (WLIM)
- Atomic force microscopy (AFM)
- Fringe projection (FP)
- Light microscopy / Metallography
- Mechanical profilometry (stylus)
- Instumented indentation testing (IIT)
- Micro hardness measurement per Vickers / Knoop
- FTIR spectroscopy / imaging (FTIR)
- X-ray fluorescence spectroscopy (XRF)
- X-ray diffractometry (XRD, GIXD)
- Spectroscopic ellipsometry (SE)
- Color measurement
- Tensiometry: plate method, drop method
- Centrifuge adhesion test
- Scratch test
- Peel test

www.bam.de/en[4]

4 www.bam.de/en/kompetenzen/fachabteilungen/abteilung_6/fb67/index.htm

Overcoming the Turbulences in the Photovoltaics Market

Interview with Dr. Albrecht Krüger, SENTECH Instruments GmbH

SENTECH's main market is in research and development with a focus on thin film analysis. How is the field developing internationally?

After the worldwide fall in demand for measurement technology for photovoltaics, the market for thin film analysis has re-stabilized. In order to generate new growth potential, SENTECH is also looking for other fields of application. For example, SENTECH uses high speed, low-noise ellipsometers in in-line and in-situ applications.

With in-situ applications, there are synergies between thin film measurement and plasma process technology – our second business segment. The best example is the latest product, the ALD Real Time Monitor, which detects cyclic layer growth of atomic layer deposition in real time by SENTECH ALD reactors.

As a result of the sales crisis, numerous investments in the photovoltaic market have been put aside. This market was very important for SENTECH – how do you assess the current and future market situation?

SENTECH was able to position itself well in the photovoltaic market and its SE 400 PV laser ellipsometer is the worldwide standard for measuring individual antireflective coatings. It's true that investment-related new acquisitions are, indeed, rare. But we see a trend and new opportunities in the development of solar cells through the use of complex multi-layer systems for passivation and antireflective coatings.

SENTECH can supply spectroscopic ellipsometers used in this process. Judging from prior sales to research institutes, these devices are now increasingly used by cell manufacturers in Taiwan, which we see as an indication that the PV market in Asia is growing once again.

Does your company currently work with the Berlin branch? What advantages does the Berlin site offer you?

SENTECH benefits in many ways from the Adlershof site, because it facilitates intensive cooperation with universities, institutions of higher education and research institutes in the Berlin area. For example, SENTECH is working closely with the Ferdinand-Braun-Institut as a competence center for III/V-compound semiconductors in the fields of microwave technologies and opto-electronics. The Fraunhofer Institutes in the Greater Berlin area are always good partners in developing and improving applications. The number of successful partnerships that lead to new products is what makes Berlin attractive to us.

What new projects are you currently working on in the field of research and development?

Projects are important for SENTECH for a variety of reasons. Most importantly, it promotes the continued development of our application spectrum and range of products. Sponsored projects support our development objectives.

In order to expand our position in the photovoltaic market of the future, we are, for example, involved in developing passivation and anti-reflection coatings for solar cells. In addition to measurements of highly scattering samples for photovoltaics, SENTECH focuses on developments in micro- and nano-structuring.

Scattering measurements can be used to characterize regular structures in 3D. SENTECH and its partners have received funding to develop this technology. Projects and partnerships play a very important role for SENTECH because they allow us to advance application-oriented development and promote innovation.

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CEO
SENTECH Instruments GmbH
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Email: info@sentech.de
www.sentech.com

Dr. Albrecht Krüger studied and received his doctorate in Physics from the Martin-Luther-Universität in Halle. In September 1990, he and Dr. Helmut Witek founded SENTECH Instruments in Berlin. The company's core interest lies in the development, manufacture and marketing of thin film measurement and plasma process technology.

Nanotribology and Nanostructuring of Surfaces

BAM Division "Nanotribology and Nanostructuring of Surfaces", focuses on the development and application of analytical techniques for tribology, mechanical, electrical and optical properties on the sub-micron scale. One topic of research has to do with the structure-property relationships of complex polymer systems. The investigation of a variety of failure and damage mechanisms in composites, inner and outer surfaces and interfaces of polymeric solids to organic, inorganic and metallic solids is another focus of the division.

www.bam.de/en[5]

Optical Coatings

Berliner Glas provides coatings on a wide variety of substrates and for wavelengths between DUV up to near-infrared. Years of experience with various types of thin film coatings allow the development team to find the best possible solutions, from coating design to series production. Customer specified thin film coating development and production includes:

- Anti-reflection coatings (V-Coat and broadband)
- Polarizing and unpolarizing beam splitters
- Narrow-band filters and band-pass filters
- Laser coatings (HR; AR) with a high damage threshold
- Transparent and electrically conductive coatings
- Chrome and black chrome coatings
- Wear-protection, bondable and solderable coatings

www.berlinerglas.com

The **Coating Laboratory of the Institute for Optics and Atomic Physics** at TU Berlin has a long tradition of working with optical fibers, glasses, crystals, wafers and other substrates. Oxides, metals and polymers are applied by ion-assisted electron beam evaporation, thermal evaporation, magnetron sputtering or dip coating. Tailored layer systems are used as laser mirrors, narrow-band Fabry-Perot filters or for the anti-reflection treatment of interfaces. A special focus is coating and preparation of fiber-optic end-facings as well as heat-sensitive plastics. The coating laboratory is highly adaptable and is an excellent R&D partner for prototypes and small batch production.

www.ioap.tu-berlin.de[6]

Thin-Film Technologies for Photovoltaics

At the **PVcomB** Competence Center Thin-Film- and Nanotechnology for Photovoltaics Berlin, thin-film photovoltaic technologies and products are being developed in cooperation with industry partners. Technology and knowledge transfer occur via research projects with industrial partners as well as through the training of highly skilled professionals.

PVcomB assists industrial partners in initiating production as well as with the continuous development of industrial processes. It facilitates the development of promising high-risk concepts and drives the transfer and upscaling of results from fundamental research conducted by HZB and TU Berlin to a PVcomB standard module size of 30 cm x 30 cm. Industrial partners can use the PVcomB reference lines as benchmarks, e.g. for new or alternative materials, analytical tools and process controls.

Working in close collaboration with the Helmholtz Center Berlin for Materials and Energy (HZB), TU Berlin (TUB), the University of Applied Sciences Berlin (HTW) and other partners, PVcomB serves as a means of training qualified engineers and academics.

www.pvcomb.de

5 www.bam.de/en/kompetenzen/fachabteilungen/abteilung_6/fb66/index.htm
6 www.ioap.tu-berlin.de/menue/arbeitsgruppen/ag_wo/beschichtungslaborosimsp

5.5 Safety Technology

Introduction

The demands being made of modern safety technology are significant and constantly changing. On the one hand, they have to reliably detect individual deviations within a large population of standard conditions (e.g. baggage screening). On the other hand, large amounts of data need to be quickly processed and compiled in the event of a disaster. In other instances, easily verifiable and difficult to reproduce security elements need to be developed at the lowest possible cost. Solving these complex problems requires a highly developed research and development infrastructure that can provide highly reliable customized products and services. Berlin and Brandenburg are able to provide the kind of close cooperation between institutions and private enterprise to develop the specific solutions needed at the highest level technical standards.

Sensor Technology for Baggage Inspection

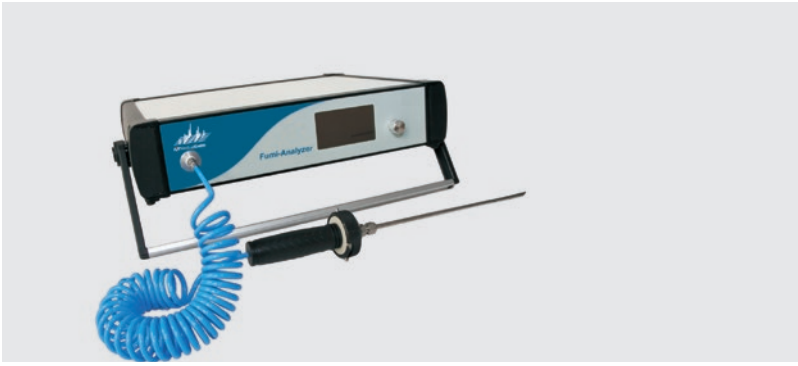
Baggage inspection equipped with sensors of First Sensor
© First Sensor AG

Light of different wavelengths is used, for example, to monitor hazard areas or screen items of luggage. In this field, **First Sensor** offers optimized, highly sensitive sensor solutions that are able to detect visible and infrared light as well as X-rays and ionizing radiation (radioactivity), e.g. photodiode arrays for non-destructive X-ray analysis and inspection. These photodiode arrays are optimized for the exclusive detection of X-ray radiation by scintillator luminescence in the blue and green spectral range. Due to the minimal edge spacing of the photodiode elements, the arrays are particularly suitable for a seamless linear arrangement of multiple components with a constant photodiode pitch.

www.first-sensor.com/en

Sensor Technology for Container Inspection

The Fumi-Analyzer is a mobile multi-gas/multi-sensor detector developed at **IUT Medical** for high-sensitivity detection of toxic gases in import containers. It can be used to detect and identify fumigation and other toxic gases within the required concentration range without requiring any on-site absorption.



Fumi-Analyzer for the inspection of import containers
© IUT Medical

Due to the sensor extension, it can measure fumigation gases such as sulfuryl difluoride (SO_2F_2) and formaldehyde (CH_2O). The Fumi-Analyzer is therefore the first mobile device able to detect and identify all relevant fumigation gases at the required level of sensitivity. The device is composed of an ion mobility spectrometer (IMS), a photo ionization detector (PID) coupled with a gas-chromatographic column (GC column), an infrared (IR) detector and electrochemical cells (EC).

www.iut-medical.de

Detection of Safety-relevant Gases

BAM Division "Surface Modification and Measurement Technique" is developing optical safety technology. They are investigating the use of ellipsometry in combination with surface plasmon resonance on 40 – 50 nm gold layers to produce a sensor system for safety-relevant gases. The method was tested with a variety of gases: flammable gases such as hydrocarbons and hydrogen, oxidizing gases such as oxygen and ozone, toxic gases such as carbon monox- ide, as well as inert gases such as helium and nitrogen. As a result, a special measurement procedure was developed that can quickly

determine certain gas concentrations in explosion-proof environments.

www.bam.de/en[1]

Optical Security Technologies

The Network Optical Security Technologies (nost), founded in 2102, is funded by the Federal Ministry for Economic Affairs and Energy via the Central Innovation Program SME (Zentrales Innovationsprogramm Mittelstand – ZIM). The network is dedicated to the goal of bringing about the technical fusion of various sensor technologies as well as system integration. nost brings together medium-sized companies and research institutes from the field of optical security technologies and related technology fields and supplements their expertise with a sales platform for security systems that have yet to establish themselves in the marketplace. This makes it possible to create competitive synergies for the international market.

nost-project.org

Passenger Counting

iris-GmbH offers sensors for automatic passenger counting which can be used to provide cheap, reliable and continuous data on the utilization of public transport systems. The count data acquired by the sensors will be used for operation optimisation, capacity planning or for revenue sharing.

Ever since the early nineties, when the first electronic counting systems appeared, the InfraRed Motion Analyzer (IRMA) by iris has been the principal system in use around the world for passenger counting. The most recent product family IRMA MATRIX counts with 3D industrial vision. This enables reliable detection at all environmental conditions and accurate counting also in crowded situations. The sensors are in operation for example at BVG Berlin and German regional trains, also in Munich, Geneva, Los Angeles, Houston, Montreal, Shanghai, Abu Dhabi and at further more than 250 transport operators worldwide.

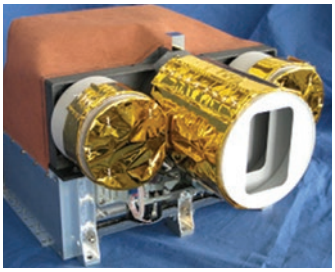
www.irisgmbh.de

Remote Fire Detection via IR Sensors

For several years now, satellite data have been used to assess a variety of forest fire parameters. A major limitation of existing sensors is that they have a relatively poor spatial resolution of 1 km per pixel at best. Typically, only fires with an energy output of more than 10 megawatts (= flaming vegetation fire of approximately 200m^2) can be reliably detected. This means that up to 50% of all fires are not covered by currently available satellite systems.

The **German Aerospace Center's (DLR)** FIREBIRD mission based on the satellites TET-1 and BIROS is designed to help significantly reduce existing uncertainties and gaps in detection. Together with systems that are already in orbit, TET-1 and BIROS are to act as "fire scopes." On the one hand, this will close the significant observation gap with respect to the high number of small fires (with an upward energy output between 1 and 10 MW) so that many more fires can be detected. On the other hand, the TET-1 / BIROS mission will be used to validate and fine-tune emission assessment from spatially less well-defined data that are obtained, for instance, with geostationary satellites at short intervals. Both satellites are based on the technological experience that DLR was able to obtain during the BIRD mission from

IRMA Matrix automatic passenger counting device
© iris GmbH



BIROS-Sensors
© DLR

1 www.bam.de/en/kompetenzen/fachabteilungen/abteilung_6/fb67/index.htm

2001 to 2004. The smallest burn zone recorded with BIRD was 12 m². The heart of the TET-1 and BIROS payload is the same as that of the BIRD satellites: a bi-spectral infrared sensor developed at the DLR Institute of Robotics and Mechatronics and the DLR Institute of Optical Sensor Systems that can record signals in the central and thermal spectral range. Another three-channel camera covers the range of visible light and near-infrared. The entire electronic system was redeveloped for this purpose.

TET-1 / BIROS can provide data on fires at a much higher spatial resolution (approx. 200 m compared to the more than 1 km per pixel available up until now). Another unique feature is the real-time adjustment of sensor integration time: If the data recorded and processed onboard is suspected of saturating the signal, then a second exposure with a shorter integration time is triggered. This smart technology resolves the problem of saturation encountered with extremely hot fires.

www.dlr.de/en[2]

Linking Aerial Photographs and Ground-Based Data for Disaster Situations

Large scale events and disasters place significant demands on public authorities and organizations with security responsibilities. Within a short period of time, they have to make decisions and manage the event in a safe and efficient manner. At the same time, they have to minimize the consequences for the general public. This is why powerful tools are being developed in the VABENE++ project at the **DLR Institute of Transportation Systems.**

For instance, as part of a Medical Task Force exercise a high-resolution 4k camera system was used on a DLR research helicopter to provide precise pictures of the mission area. The data obtained were processed on board and transmitted via microwave data link directly to the operation control. In combination with ground-based sensor systems for traffic monitoring the camera data provided additional information for the position detection and visualization of the “bigger picture”.

Airborne observation of the patient transfer with the 4K camera system developed in the VABENE++ project
© DLR

www.dlr.de/vabene/en

Terahertz Technology

Terahertz (THz) radiation has long proved difficult to generate. It has numerous applications, however, such as in detecting non-metallic weapons and explosives or for use in food inspection. THz radiation is also now being used in many studies in the fields of solid state physics, astronomy, biology as well as in environmental monitoring. To facilitate the generation of THz radiation and promote commercial applications, several Berlin institutes and companies have joined together in the project entitled “Terahertz Quantum Cascade Lasers for Spectroscopic Applications.” The **Paul-Drude-Institut (PDI)** and the **HU Berlin** have been investigating semiconductor theory and working with semiconductor wafers. Grids were added at **Ferdinand-Braun-Institute**, while micro-assembly and testing of the quantum cascade laser (QCL) took place at **eagleyard photonics**. The main advantage of the new product is that it does not require a liquid helium cooling system for the QCL since its working temperature is between 40 and 80 K, which makes sterling or nitrogen-based cooling possible.

www.eagleyard.com | www.pdi-berlin.de[3]
www.fbh-berlin.com[4] | www.dlr.de/en[5]

2 www.dlr.de/os/en/desktopdefault.aspx/tabid-10185/17350_read-41682
3 www.pdi-berlin.de/research/core-research-areas/intersubband-emitters
4 www.fbh-berlin.com/research/iii-v-electronics
5 www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10419

5.6 Astronomy and Aerospace

Introduction

When a new planetary mission reaches its objective, the whole world joins in the excitement via TV or the Internet. It is easy to forget the years spent in transit and, especially, the long period of development and testing of the extremely robust and high-performance technology on board the craft that preceded this milestone. Not only are many components for the aerospace industry being developed in Berlin and Brandenburg, there is also a sophisticated testing infrastructure here to qualify the hardware for space conditions. With the development of adaptive optics, astronomy has made considerable progress in the 21st century and overcome many limitations of ground-based observation – and in doing so has literally opened up new worlds. But here, too, the advanced technology developed by specialized institutions and networks in Berlin and Brandenburg often ends up in the background. As is so often the case in the astronomy and aerospace sectors, the technologies developed for these pursuits are transferred over to completely different fields where they help bring about technological advances.

Astrophysical Research and Equipment Development

The **Leibniz-Institute for Astrophysics Potsdam (AIP)** is dedicated to astrophysical inquiries ranging from the exploration of our sun to the evolution of the cosmos. The key areas of research are cosmic magnetic fields and extragalactic astrophysics as well as the development of research technology in the fields of spectroscopy, robotic telescopes, and e-science. A considerable part of the institute's efforts are aimed at developing research technology in the fields of spectroscopy, robotic telescopes, and e-science. AIP is the successor to the Berlin Observatory, founded in 1700, and to the Astrophysical Observatory of Potsdam, founded in 1874. The latter was the world's first observatory explicitly dedicated to the study of astrophysics. AIP has been a member of the Leibniz Association since 1992. Current projects include the Potsdam Echelle Polarimetric and Spectroscopic Instrument (PEPESI) for the Large Bionocular Telescope (LBT) in Arizona, USA as well as the automatic 1.2-m telescopes STELLA-I and STELLA-II at the Izana Observatory in Tenerife, Spain.

www.aip.de/en

Fiber Optic Sensor Technology

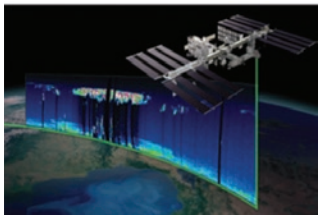
At **innoFSPEC** Potsdam, the project on "OH Emission Line Filters" for infrared night sky observation is concerned with the application of Fiber Bragg Gratings (FBGs). FBGs are complex gratings stamped into fibers which can be used to construct highly specialized line filters to suppress unwanted atmospheric oxygen and hydrogen lines in astronomical observations. This technology will play a fundamental role in the instrumentation used in the next generation of extremely large telescopes (ELT). innoFSPEC Potsdam is a joint undertaking of the Leibniz Institute for Astrophysics Potsdam (AIP) and the University of Potsdam (UP). Established as a center of innovative competence, innoFSPEC conducts research in "fiber optical spectroscopy and sensing". In March 2015, innoFSPEC received an additional five years' funding from BMBF.

www.innofspec.de/en | www.uni-potsdam.de/en

Lasers for the Aerospace Industry

The SpaceX delivery to the International Space Station (ISS) on January 10, 2015 also included several DFB lasers from **eagleyard photonics**. The fiber coupled laser diodes will be used there as a seed source component for a LiDAR system as part of the CATS (Cloud Aerosol Transport System) project. The laser diode produces beams at 1064 nm, 532 nm and 355 nm to determine the properties of cloud and aerosol layers. eagleyard photonics offers customized solutions for use in space. Laser diodes are the ideal light source for harsh operating conditions. Compact and robust,

The two 1.2m telescopes STELLA-I and STELLA-II at the Izana Observatory on Tenerife, Spain.
© AIP



eagleyard lasers in LiDAR systems
© NASA/eagleyard Photonics GmbH

Cross-Innovation at its best!

Interview with Prof. Dr. Martin Roth, Leibnitz Institute for Astrophysics Potsdam (AIP)

Optical technologies are clearly key technologies in astrophysics – what technologies and developments are of particular importance at the moment?

A special challenge for the next generation of ground-based Extra Large Telescopes (ELTs) involves the production of segmented mirrors for primary mirrors with diameters of more than 30 m – like for instance those in the European astronomy flagship project, 39-m E-ELT.

It is not simply a matter of the industrial production of precision optics, but of serial production and integration into a hitherto unknown, highly complex system.

We are likewise entering new territory with the production of extremely thin, deformable (adaptive) mirrors for the adaptive optics of the E-ELT.

As for the development of focal instruments, increased telescope diameter means larger components will be required, so new solutions must be found for reflective and refractive optics, diffraction gratings and prisms, as well as for detector systems. A whole new area that we have only just begun to develop for use in astrophysics is astrophotonics, which involves the use of fiber optics and integrated optics for focal instruments.

Together with the University of Potsdam, Charité and LMTB Laser- und Medizin-Technologie GmbH from Berlin, your institute has solved a technological problem in multiplex spectroscopy with applications in cancer research. How does astrophysics provide support to this medical project?

Physicians have, in principle, found in Raman spectroscopy a new minimally invasive optical method to diagnose cancer which can prevent the stress of a biopsy and the risk of metastasis. However, imaging is not possible with current state-of-the-art single-channel spectrographs, so this method is not really suitable for use in actual practice.

Through knowledge and technology transfer, we have found a way to produce an imaging capability with multiplex spectrographs used in astrophysics. This is a big step forward.

How did this unusual collaboration come about?

The idea for a partnership between Charité – Universitätsmedizin, LMTB GmbH and AIP came about in the OptecBB network, specifically in the working group for Biomedical Optics.

Since October 2013, thanks to funding from the BMBF VIP program, this interdisciplinary line-up has been working on validating the concept of "multiplex Raman spectroscopy from astrophysics for medicine."

Multidimensional spectroscopy is a special focus of the master plan for the photonics cluster. What topics in the master plan continue to play a role at your institute?

In the field of "optical analytics" topics like "imaging and multi-dimensional data analysis" as well as "optical sensors and fiber optics" constitute important issues for the Center for Innovative Capacities, innoFSPEC Potsdam.

With respect to "optics for communication and sensors", topics such as "photonic systems integration" and "optical sensors" show special promise for cross innovation in connection with our research in the field of astrophotonics.

Prof. Dr. Martin M. Roth
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www.innofspec.de/en

After studying physics at LMU Munich, Prof. Dr. Martin Roth earned his PhD in astrophysics from the University Observatory in Munich (1993). This was followed by activities at the Wendelstein Observatory and at the European Southern Observatory (ESO) in Garching. Since 1994, he has been a researcher at the Leibniz Institute for Astrophysics Potsdam (AIP). In 2009, he initiated innoFSPEC Potsdam and was appointed professor at the University of Potsdam in 2011.

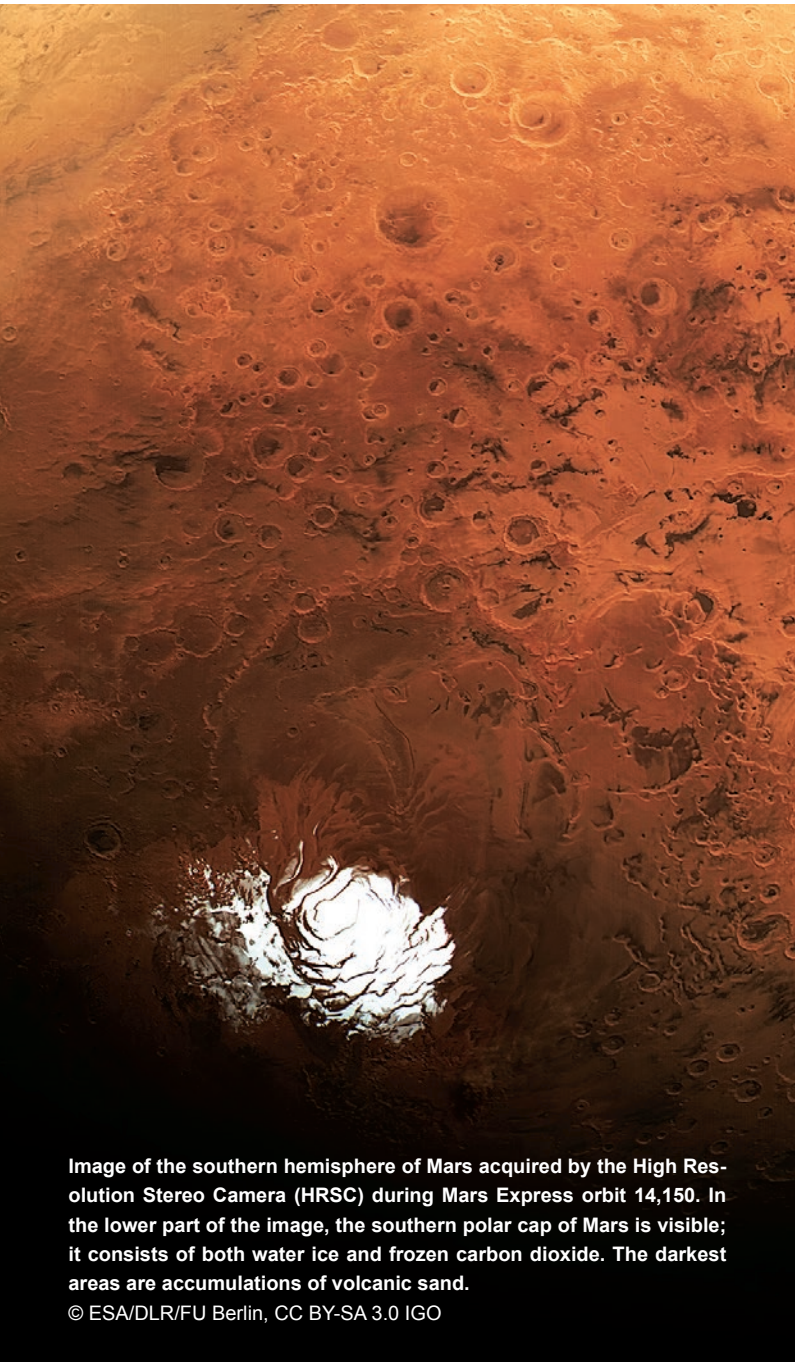


Image of the southern hemisphere of Mars acquired by the High Resolution Stereo Camera (HRSC) during Mars Express orbit 14,150. In the lower part of the image, the southern polar cap of Mars is visible; it consists of both water ice and frozen carbon dioxide. The darkest areas are accumulations of volcanic sand.

they can withstand even extreme environmental conditions. DFB lasers have been successfully used in NASA and ESA aerospace programs where they have been subjected to extensive qualification tests according to the MIL and other standards.

www.eagleyard.com

Camera Electronics

First Sensor has successfully participated in a variety of projects in the aerospace industry. Often these have involved highly specialized solutions that must undergo an optimization process requiring a number of design cycles pursued in close cooperation with the customer. Such projects at First Sensor have included such things as:

- Mars camera
- Laser guidance systems
- Simulation tools
- Nuclear radiation sensors

The launch of the first European mission to Mars, Mars Express, was a particular highlight. Among the instruments on board Mars Express was the HRSC (High Resolution Stereo Camera) whose electronic system was completely designed and manufactured by First Sensor Lewicki GmbH. The HRSC is scheduled to map the entire surface of Mars in three dimensions. To do so, this camera can make out details measuring only two meters from an altitude of 250 kilometers.

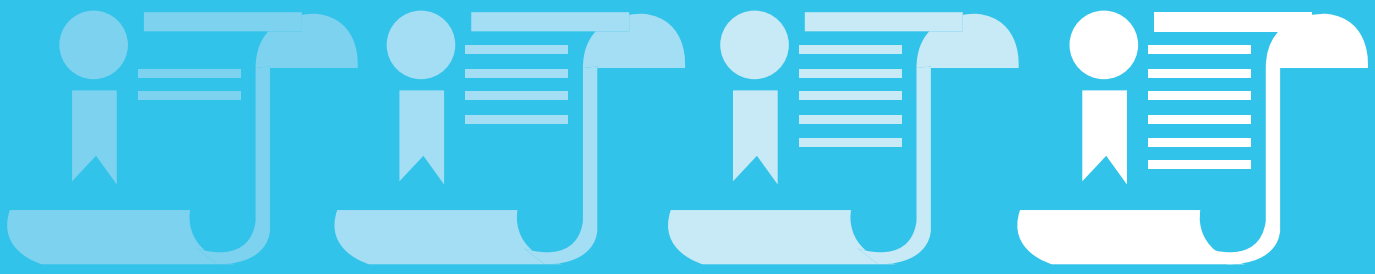
www.first-sensor.com/en

Aerospace Systems

Fascinating three-dimensional images of Mars were taken with the HRSC stereo camera developed in Berlin-Adlershof. The **German Aerospace Center's (DLR) Institute for Planetary Research** operates the camera and analyses the image data. The extension of ESA's oldest planetary mission through 2018 attests to the quality of this camera. Also the Philae lander from the Rosetta space probe that set down on the comet "Churyumov–Gerasimenko" in November 2014 was outfitted with instruments developed in Berlin: the ROLIS camera for multispectral imaging and the MUPUS thermal probe, which will measure the thermal conductivity of the comet. Moreover, the **DLR Institute of Space Systems** operates the System Conditioning department's Space Simulation Chamber in Berlin-Adlershof. Their task is to test hardware for use in space. The DLR scientists from Berlin are not only involved in planning and preparing space missions, but also in executing those missions and in evaluating their scientific results.

www.dlr.de/irs/en[1] | www.dlr.de/pf/en

1 www.dlr.de/irs/en/desktopdefault.aspx/tabid-3611/5027_read-8286



6 Training and Continuing Education Programs

6 Training and Continuing Education Programs

Introduction

An industrial infrastructure for optics and related high technologies emerged in Berlin and Brandenburg, starting in the early 19th century. Educational and training opportunities were also developed early on in order to ensure future generations of appropriately qualified employees. Today, the region offers a sustainable network with a wide variety of institutions and programs to provide vocational training from apprentice level to master certification, and university training from bachelor degrees to PhDs. In addition, there is also a wide range of other educational programs, including an introduction to the world of science in preschools and elementary schools as well as in-service training in a wide variety of specializations.

Studying in Berlin and Brandenburg

Post-secondary institutions in Berlin and Brandenburg offer excellent opportunities to study a wide variety of subjects related to optical analysis. This begins with physics and chemistry (FUB, HUB, TUB, Potsdam University and BTU Cottbus) and continues with specialized bachelor's and master's degree programs at a variety of institutions. These include stand-alone programs as well as specializations or modules for coursework in engineering or natural sciences. Joint appointments between post-secondary institutions and research institutions not affiliated with universities create strong networks and ensure direct access to current and applied research even outside the university. A comprehensive overview of the various vocational training opportunities can be found in the **Bildungsatlas Optische Technologien und Mikrosystemtechnik in Berlin und Brandenburg** (training atlas for optical technologies and microsystems technologies), which is in its 4th edition for 2016/17.

www.optecbb.de/en[1]

Graduate Schools

A number of graduate schools in Berlin and Brandenburg offer applied study and research programs for postgraduates, with substantively and organizationally structured courses of study. Participants often work as assistants or receive stipends. Most graduate schools are funded by DFG and their programs are limited to 9 years.

FUB, HUB and TUB each organize a dozen or so such interdisciplinary graduate schools. In addition to the DFG-funded programs, the universities in Berlin were able to establish several graduate programs to promote science and research at German post-secondary institutions as part of the German Universities Excellence Initiative. The **Berlin International Graduate School of Natural Sciences and Engineering (BIG-NSE)**, founded by TUB, has received funding since 2007 and serves as a key element of the Excellence Cluster **Unified Concepts in Catalysis (UniCat)** within the Excellence Initiative.

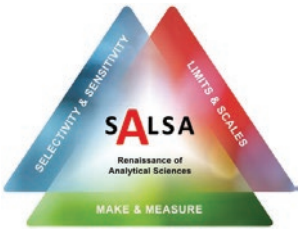
BIG NSE unicat

www.big-nse.tu-berlin.de

The **School of Analytical Sciences Adlershof (SALSA)**, established in Berlin in 2012, is also part of the Excellence program. SALSA is a graduate program of the

1 www.optecbb.de/lang/media/download/OpTecBB_Bildungsatlas_www.pdf

Humboldt-Universität zu Berlin offered at Adlershof's modern campus where doctoral candidates learn analytical problem-solving methods using an integrated and multidisciplinary approach.



www.salsa.hu-berlin.de

Adlershof is also home to the **Hybrid4Energy** graduate school, operated jointly by both HUB and HZB. Its focus is on promoting interdisciplinary education, training, and research on hybrid organic/inorganic systems for electronic, optoelectronic and photovoltaic devices with a view to predicting and controlling material properties. These novel materials are destined for use in the photovoltaic industry and next generation IT structures.

www.physik.hu-berlin.de/h4e

School Programs for Young Students

As part of effort to cultivate young talent in STEM professions, educational opportunities for school-age students have recently been created at many institutions. The **DLR_School_Lab**, for instance, offers about 20 different modules that allow children and teens to conduct experiments on a specific topic over the course of a day. At the Helmholtz Center Berlin for Materials and Energy (HZB), students are able use a school lab on special project days. Like the HZB, the school lab Insight into Matter has two locations: Berlin-Wannsee and Berlin-Adlershof (BESSY II). There, pupils aged 5-13 conduct experiments on topics relating to magnetism & superconductivity, solar energy research, interference, materials research as well as light & colors.

DLR_School_Lab

www.dlr.de/schoollab/en | www.helmholtz-berlin.de[2]

Teacher Education

Humboldt-ProMINT-Kolleg is a permanent university unit that covers a multitude of subjects and school levels. Since fall 2010, it has been working with all concerned players to develop pedagogical research, school teaching and teacher education in STEM subjects and to evaluate their activities. Program fellows place a particular emphasis on networking the fields of biology, chemistry, primary school education, computer science, mathematics and physics. Through its ProMINT-Kolleg concept, Humboldt-Universität zu Berlin became one of four universities in Germany to win the Deutsche Telekom Foundation's competition for excellence in STEM teacher education in 2009.

HUMBOLDT-
PROMINT-KOLLEG

www.promint.hu-berlin.de

Vocational Training

In addition to vocational training in primary occupational categories such as precision optician or microtechnologist, a number of other professions are also of high importance to the industry. Chemistry and physics lab technicians, with responsibilities for overseeing basic functions in high-tech laboratories, are as sought after as are precision engineering technicians for the production of high-precision components. Inter-company training centers and training associations that group together training providers in the interest of mutual support, help ensure the quality of vocational training. One example is the **Ausbildungsverbund Mikrotechnologie**

2 www.helmholtz-berlin.de/angebote/schuelerlabor/index_en.html

Berlin-Brandenburg (a micro-technology vocational training association). In addition to the broad training opportunities provided by vocational schools for secondary-level students, universities and institutes have also created their own vocational training programs. These are focused in particular on training the next generation of employees for scientific workshops and laboratories.

www.promano.net

Vocational Continuing Training Opportunities

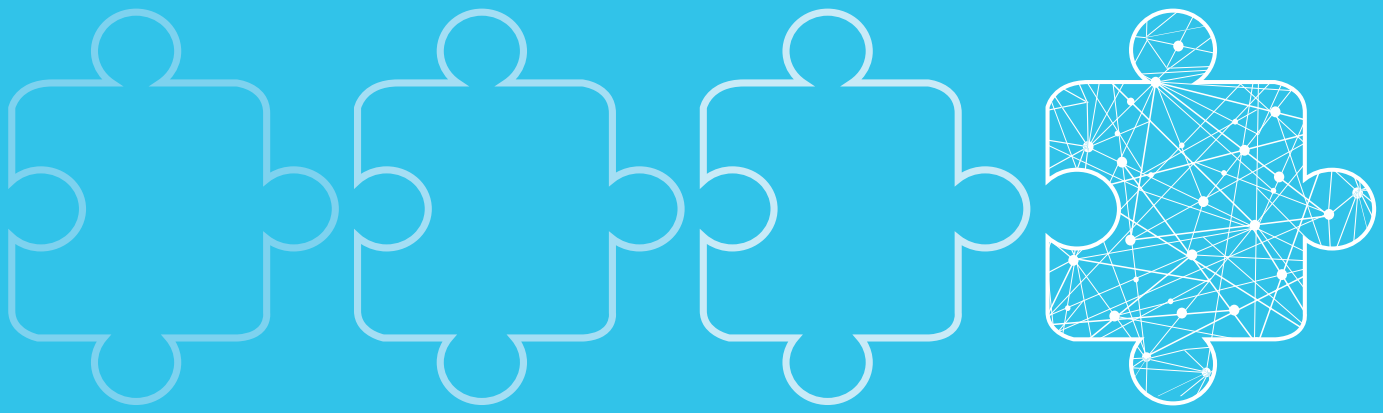
In the photonics / microsystems technologies cluster, the beQual project offers special continuing education programs for high-tech companies. The program arose out of a need on the part of these companies that was not being met by the qualification programs currently available from existing educational and training service providers for certain types of training of interest to only a few employees. A pilot project in Berlin being funded by the Senate Department for Economics, Technology and Research conducted model training sessions for employees from 6 companies in 2 institutes in the photonics' cluster between October 2014 and May 2015. As participants and organizers were highly satisfied with the results of this pilot, new training units will start from 2016 onwards.

www.fbh-berlin.com[3]

The goal of the **AlFaClu project (Altersgerechte und –übergreifende Fachkräfteentwicklung in Hochtechnologie-Clustern** - (age-appropriate and intergenerational professional development in high-tech clusters) in the optical technologies and microsystems technology cluster in Berlin and Brandenburg is to analyze age-related shifts with respect to the availability of skilled workers and develop comprehensive methods to address problems. The results will be made available as academically substantiated tools, best practice guides, checklists, templates, etc., and also be communicated directly via workshops while being integrated into a continuing education and training program in the cluster. The aim is to acquire and develop skills as well as provide skilled workers with ongoing training. The project involves OpTecBB working in collaboration with the Helmut Schmidt University, the Universität Hamburg, the Center for Microsystems Technology (ZEMI) in Berlin and ten other value partners from industry, science and administration.

www.alfaclu.net

3 www.fbh-berlin.com/about-us/talents-skilled-personnel



7 Industry Platforms

7 Industry Platforms

Berlin Partner for Business and Technology

Berlin Partner for Business and Technology offers business and technology promotion for companies, investors and science institutes in Berlin. With carefully tailored services and excellent links to research, our experts provide an outstanding range of services to help companies launch, innovate, expand and secure their economic future in Berlin.The Optics Cluster was established to promote technological development in the region. It provides companies and research institutions access to resources, such as knowledge and capital, at both the local and international level in the fields of:

- Laser technology
- Lighting technology
- Optics for communication and sensors
- Optical analytics
- Biomedical and ophthalmic optics
- Microsystems technology

The Photonics Cluster in Berlin and Brandenburg is especially distinguished by its strong scientific foundation (10 universities and 26 extra-university research institutions) and the high number of specialized small and medium-sized companies (more than 400 SMEs) with widely ranging know-how – making it the perfect basis for reciprocal transfer between science and industry leading to national and international cooperation.

Contact: Gerrit Rössler
gerrit.roessler@berlin-partner.de | www.berlin-partner.de/en
www.photonics-bb.com | www.businesslocationcenter.de/en

Center for Molecular Diagnostics and Bioanalytics

The Center for Molecular Diagnostics and Bioanalysis (ZMDB) is the technology transfer platform for the fields of in-vitro diagnostics and bioanalysis. It is located at Berlin Partner for Business and Technology GmbH. The goal of ZMDB is to support the development of innovative diagnostics in the Berlin-Brandenburg region by establishing joint R&D projects. ZMDB also provides all required information. In the course of developing cross-innovations, special emphasis is also given to optical technologies as well as bioelectronics. In addition, ZMDB has been representing Berlin-Brandenburg since 2010 as the only German region in the European Diagnostic Clusters Alliance (EDCA), which focuses on the development of new solutions for in-vitro diagnostics.

Contact: Dr. Günter Peine
peine@zmdb.de | www.zmdb.de/en

micro photonics – International Congress and Exhibition

The micro photonics International Congress and Exhibition will help reposition Berlin's laser optics industry in the marketplace starting October 2016. The first micro photonics is set to take place from October 11-13, 2016, at the Berlin ExpoCenter City. After that, the three-day conference will be held once a year. As Dr. Stefan Franzke, Managing Director of Berlin Partner for Business and Technology, points out, *"Optical technologies and closely related microsystems technologies are among the drivers of innovation in the region – with more than 400 companies and 36 academic institutions involved in research, development and production in and around Berlin. By raising the profile of micro photonics, we are providing the local photonics sector with a new international showcase that better reflects the strengths of this key Berlin industry."* The micro photonics is focused around an international congress organized by Messe Berlin GmbH in cooperation with K.I.T Group and Berlin Partner for Business and Technology GmbH, along with other highly-regarded partners.

Contact: Kerstin Kube-Erkens
kubeerkens@messe-berlin.de | www.micro-photonics.de/en

ZAB – Brandenburg Economic Development Board

The Brandenburg Economic Development Board (ZAB) is the primary point-of-contact for efforts aimed at promoting economic development in the state of Brandenburg. Its work focuses on attracting businesses to the area, the development of an innovative SME sector, including foreign trade promotion, support for technology-oriented start-ups, as well as providing energy consultation. ZAB is partnered with the Investitionsbank des Landes (ILB) and Brandenburg Capital GmbH. The Enterprise Europe Network (EEN) at ZAB provides advice specifically for European framework programs and fosters cross-border partnerships.

Contact: Dr. Anne Techen
anne.techen@zab-brandenburg.de
www.zab-brandenburg.de/en

OpTecBB e.V. – Optical Technologies from Berlin and Brandenburg

Optec-Berlin-Brandenburg e.V. (OpTecBB) is the competence network for optical and micro-system technologies in the Berlin-Brandenburg region. The association was founded in 2000 by companies and research institu- tions with support from relevant state ministries in Branden- burg and the Berlin Senate. Today, the association has more than 100 institutional members. Along with its partners ZAB Berlin Partner, OpTecBB assumes primary responsibility for shaping the substantive elements of cluster management in the optics cluster in Berlin and Brandenburg. Areas of activity are:

- Optics for communication and sensors
- Optical analytics
- Lighting technology
- Biomedical and ophthalmic optics
- Laser technology
- Microsystems technology

In addition, the association is also active in the following areas:

- Training next generation specialists
- Organizing trade fairs and events
- Internationalization
- Location marketing
- Support for start-ups

OpTecBB is a member of both OpecNet Deutschland e.V., a fusion of all German regional competence networks for optical technologies, as well as EPIC – European Photonics Industry Consortium and is also involved in the Photonics21 European technology platform.

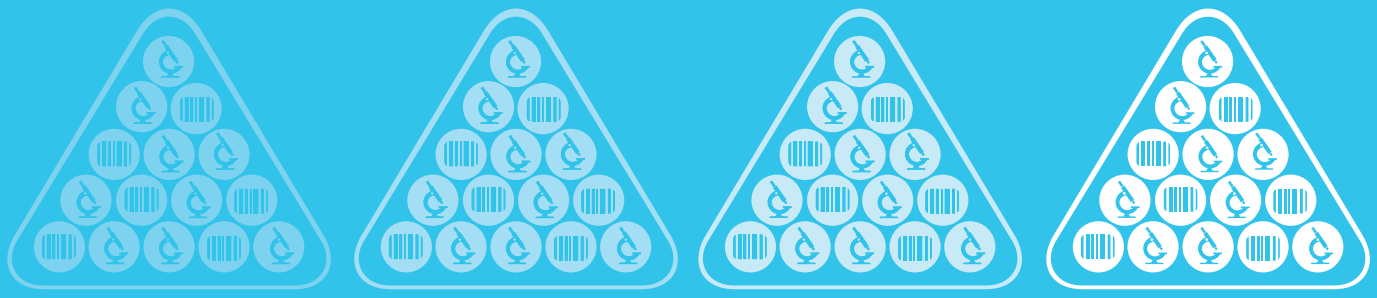
Contact: Dr. Frank Lerch
lerch@optecbb.de | www.optecbb.de/en

PRORA – Symposium on Process-Oriented X-Ray Analysis

The prestigious and nationally recognized symposium series PRORA (process-oriented x-ray analytics) was inaugurated in 2001 by the IAP (Institute for Applied Photonics e.V.). The symposium with its more than 100 participants has since been held every two years and is accompanied by an equipment fair at which both German as well as various foreign device manufacturers exhibit their latest products. In 2017, PRORA will again be opening its doors for its ninth time at the Science and Technology Park Berlin-Adlershof. All practitioners, developers and manufacturers in the field of process-oriented X-ray analysis, as well as all other interested parties, are invited to participate. The consolidation of this symposium and the growth in attendance demonstrate the value placed on the work of the IAP, both at home and abroad.

Contact: Dr. Reiner Wedell
wedell-iap@ifg-adlershof.de | www.adlershof.de[1]

1 www.iap-adlershof.de/fachtagungen



8 Companies & Research Institutions at a glance

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Companies	Website
5micron GmbH	www.5micron.de
ACI Analytical Control Instruments GmbH	www.aci-berlin.de
AEMtec GmbH	www.aemtec.com/en
art photonics GmbH	www.artphotonics.com
Becker & Hickl GmbH	www.becker-hickl.de
BERLINER GLAS KGaA - Herbert Kubatz GmbH & Co	www.berlinerglas.com
Berliner Nanotest und Design GmbH	www.nanotest.eu/en
BESTEC GmbH	www.bestec.de
Bi-Ber GmbH & Co.KG	www.bilderkennung.de
Bruker Nano GmbH	www.bruker-nano.de
Chronos Vision GmbH	www.chronos-vision.de
Colibri Photonics GmbH	www.colibri-photonics.com
ColVisTec AG	www.colvistec.de
Crystal Photonics GmbH	www.crystal-photonics.com
E.F.G., Elektrotechnische Fabrikations- und Großhandels-Gesellschaft mbH	www.efg-berlin.de
eagleyard Photonics GmbH	www.eagleyard.com
Entwicklungsbüro Stresing	www.stresing.de
EPIGAP Optronic GmbH	www.epigap-optronic.com
EuroPhoton GmbH für Optische Sensorik	www.europhoton.de
F&K Physiktechnik GmbH	www.fkphysiktechnik.com
First Sensor AG	www.first-sensor.de/en
FLEXIM Flexible Industriemesstechnik GmbH	www.flexim.com
greateyes GmbH	www.greateyes.de
HACH LANGE GmbH	www.hach-lange.com
IfG - Institute for Scientific Instruments GmbH	www.ifg-adlershof.de
IOM Innovative Optische Messtechnik GmbH	www.iom-berlin.de
iris-GmbH infrared & intelligent sensors	www.irisgmbh.de
IUT Institut für Umwelttechnologie GmbH	www.iut-berlin.info
IUT Medical GmbH	www.iut-medical.com
JP-ProteQ GmbH	www.jp-proteq.com
JTL-BioTec.Analytics	www.biotec-analytics.de
L.U.M. Gesellschaft für Labor-, Umweltdiagnostik und Medizintechnik mbH	www.lum-gmbh.com
Laser- und Medizin-Technologie GmbH Berlin (LMTB)	www.lmtb.de
LayTec AG	www.laytec.de
LLA Instruments GmbH	www.lla-instruments.com
LTB Lasertechnik Berlin GmbH	www.ltb-berlin.de
Mikroskop Technik Rathenow GmbH	www.askania.de
Optikexpertisen Dr. Volker Raab	www.raab-photonik.com/en

Companies	Website
Optris GmbH	www.optris.com
PDW Analytics	www.pdw-analytics.de
pi4-robotics GmbH	www.pi4.de/english
PicoQuant GmbH	www.picoquant.com
Pronova Analysentechnik GmbH & Co. KG	www.pronova.de/en
rap.ID Particle Systems GmbH	www.rap-id.com
Raytek GmbH	www.raytek.com
Robert Riele GmbH & Co. KG	www.riele.de
rtw Röntgen-Technik Dr. Warrikhoff GmbH & Co. KG	www.rtwxray.de
Schmidt + Haensch GmbH & Co.	www.schmidt-haensch.com
Secopta GmbH	www.secopta.com
SENTECH Instruments GmbH	www.sentech.com
sglux GmbH	www.sglux.de/en
SPECS Surface Nano Analysis GmbH	www.specs.de
TechnoLab Gesellschaft für Elektronikindustrie-Service mbH	www.technolab.de
TRIOPTICS Berlin GmbH	www.trioptics-berlin.com
Vistac GmbH	www.vistac.com
Wissenschaftliche Gerätebau Dr. Ing. Herbert Knauer GmbH	www.knauer.net

Research Institution	Website
Bundesanstalt für Materialforschung und -prüfung (BAM) *Federal Institute for Materials Research and Testing*	www.bam.de/en
Charité Universitätsmedizin Berlin (Charité) *Charité Universitätsmedizin Berlin*	www.charite.de/en
Deutsches Zentrum für Luft und Raumfahrt (DLR) *German Aerospace Center*	www.dlr.de/en
Forschungszentrum MATHEON - Mathematik für Schlüsseltechnologien *Research Center MATHEON - Mathematics for Key Technologies*	www.matheon.de
Fraunhofer-Institut für Angewandte Polymerforschung (Fraunhofer IAP) *Fraunhofer Institute for Applied Polymer Research*	www.iap.fraunhofer.de/en
Fraunhofer-Institut für Produktionsanlagen und Konstruktionstechnik (Fraunhofer IPK) *Fraunhofer Institute for Production Systems and Design Technology*	www.ipk.fraunhofer.de/en
Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut (Fraunhofer HHI) *Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute*	www.hhi.fraunhofer.de/en
Fraunhofer-Institut für Zelltherapie und Immunologie (Fraunhofer IZI) *Fraunhofer Institute for Cell Therapy and Immunology*	www.izi.fraunhofer.de
Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration (Fraunhofer IZM) *Fraunhofer Institute for Reliability and Microintegration*	www.izm.fraunhofer.de/en
Freie Universität Berlin (FU Berlin) *Freie Universität Berlin*	www.fu-berlin.de/en
Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) *Helmholtz Center for Materials and Energy*	www.helmholtz-berlin.de
Humboldt-Universität zu Berlin (HU Berlin) *Humboldt-Universität zu Berlin*	www.hu-berlin.de/en
Innovative faseroptische Spektroskopie und Sensorik (innoFSPEC)	www.innofspec.de/en

Research Institution	Website
Innovative fiber-optical Spectroscopy and Sensor Systems	
Institut für Angewandte Photonik e.V. (IAP eV) *Institute for Applied Photonics*	www.iap-adlershof.de
Institut für Dünnschichttechnologie und Mikrosensorik e.V. (IDM) *Institute for Thin Film Technology and Micro Sensor Systems*	www.idm-teltow.de/en
Integrative Research Institute for the Sciences (IRIS) *Integrative Research Institute for the Sciences*	www.iris-adlershof.de/en
Kompetenzzentrum Dünnschicht- und Nanotechnologie für Photovoltaik Berlin (PVcomB) *Competence Centre Thin-Film- and Nanotechnology for Photovoltaics*	www.pvcomb.com
Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V. (ATB) *Leibniz Institute for Agricultural Engineering Potsdam-Bornim*	www.atb-potsdam.de/en
Leibniz-Institut für Analytische Wissenschaften - ISAS - e.V. (ISAS) *Leibniz Institute for Analytical Sciences*	www.isas.de/en
Leibniz-Institut für Astrophysik Potsdam (AIP) *Leibniz Institute for Astrophysics Potsdam*	www.aip.de/en
Leibniz-Institut für Kristallzüchtung (IKZ) *Leibniz Institute for Crystal Growth*	www.ikz-berlin.de
Leibniz-Institut für Höchstfrequenztechnik - Ferdinand-Braun-Institut (FBH) *Leibnitz Institute for Radio-Frequency Engineering - Ferdinand Braun Institute*	www.fbh-berlin.com
Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (MBI) *Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy*	www.mbi-berlin.de/en
Max-Planck-Institut für Gravitationsphysik (Albert Einstein Institut) *Max Planck Institute for Gravitational Physics*	www.aei.mpg.de
Max-Planck-Institut für Kolloid- und Grenzflächenforschung (MPIKG) *Max Planck Institute of Colloids and Interfaces*	www.mpikg.mpg.de/en
Max-Planck-Institut für molekulare Genetik (MPIMG) *Max Planck Institute for Molecular Genetics*	www.molgen.mpg.de
Max-Planck-Institut für molekulare Pflanzenphysiologie (MPI-MP) *Max Planck Institute for Molecular Plant Physiology*	www.mpimp-golm.mpg.de
Optotransmitter Umweltschutz Technologie e.V. (OUT eV) *Optotransmitters Ecology Technology*	www.out-ev.de/english
Paul-Drude-Institut für Festkörperelektronik *Paul Drude Institut for Semiconductor Electronics*	www.pdi-berlin.de/en
Physikalisch Technische Bundesanstalt (PTB) *The National Metrology Institute of Germany*	www.ptb.de/en
Technische Hochschule Wildau (TH Wildau) *Technical University of Applied Sciences Wildau*	www.th-wildau.de/en
Technische Universität Berlin (TU Berlin) *Berlin Institute of Technology*	www.tu-berlin.de
Telekom Innovation Laboratories (T-Labs) *Telekom Innovation Laboratories*	www.laboratories.telekom.com
Universität Potsdam (UP) *University of Potsdam*	www.uni-potsdam.de/en

Networks & Cluster Organizations	Website
Berlin Partner für Wirtschaft und Technologie GmbH	www.berlin-partner.de/en
Cluster Photonics in Berlin and Brandenburg	www.photonics-bb.com
Initiative of Non-University Research Institutes in Adlershof e.V. (IGAFA)	www.igafa.de/en
Network Optical Security Technologies (nost)	www.nost-project.org/en
OpTecBB - Competence Network for Optical Technologies	www.optecbb.de/en
ZukunftsAgentur Brandenburg GmbH (ZAB)	www.zab-brandenburg.de/en

Entrepreneurial Services	Website
Centre for Entrepreneurship at the TU Berlin	www.entrepreneurship.tu-berlin.de
GO:INcubaror GmbH, Potsdam	www.gooincubator.de
Golm Innovation Center GO:IN, Potsdam	www.goin-potsdam.de
Humboldt-Innovation GmbH, Berlin	www.humboldt-innovation.de

Educational Programs / Graduate Schools	Website
Bildungsatlas / Training Atlas	www.optecbb.de (Download)
Berlin International Graduate School of Natural Sciences and Engineering (BIG-NSE)	www.big-nse.tu-berlin.de
Excellence Cluster "Unified Concepts in Catalysis (UniCat)"	www.unicat.tu-berlin.de
Humboldt-ProMINT-Kolleg	www.promint.hu-berlin.de
Hybrid4Energy Graduate School	www.physik.hu-berlin.de/h4e
School of Analytical Sciences Adlershof (SALSA)	www.salsa.hu-berlin.de

Locations	Website
Technology Park Adlershof / Analytic City Adlershof (WISTA Management GmbH)	www.adlershof.de/en
Science Park Potsdam-Golm (Standortmanagement Golm gGmbH)	www.wisspark.de/en
Campus Charlottenburg (Technische Universität Berlin)	www.campus-charlottenburg.org
Southwest Berlin Technology Hub (Regionalmanagement Berlin SÜDWEST)	www.rm-berlin-sw.de

9 Imprint

Optical Analytics

in the Capital Region Berlin-Brandenburg

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Errors and omissions excepted.

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Our aim: your success!

Berlin and Brandenburg support the focal area Optical Analytics with an economic policy developed across state borders in the Photonics cluster. The cluster is managed under the aegis of Berlin Partner for Business and Technology, the Brandenburg Economic Development Board (ZAB) and the network OpTecBB.
Our aim is to provide comprehensive support to companies and scientific institutions interested in inward investment or further development in the capital region.

We are ready to assist you with:

- **Finding a site**
- **Funding and financing**
- **Technology transfer and R&D cooperation**
- **Cooperating in networks**
- **Recruiting personnel**
- **Developing international markets**

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