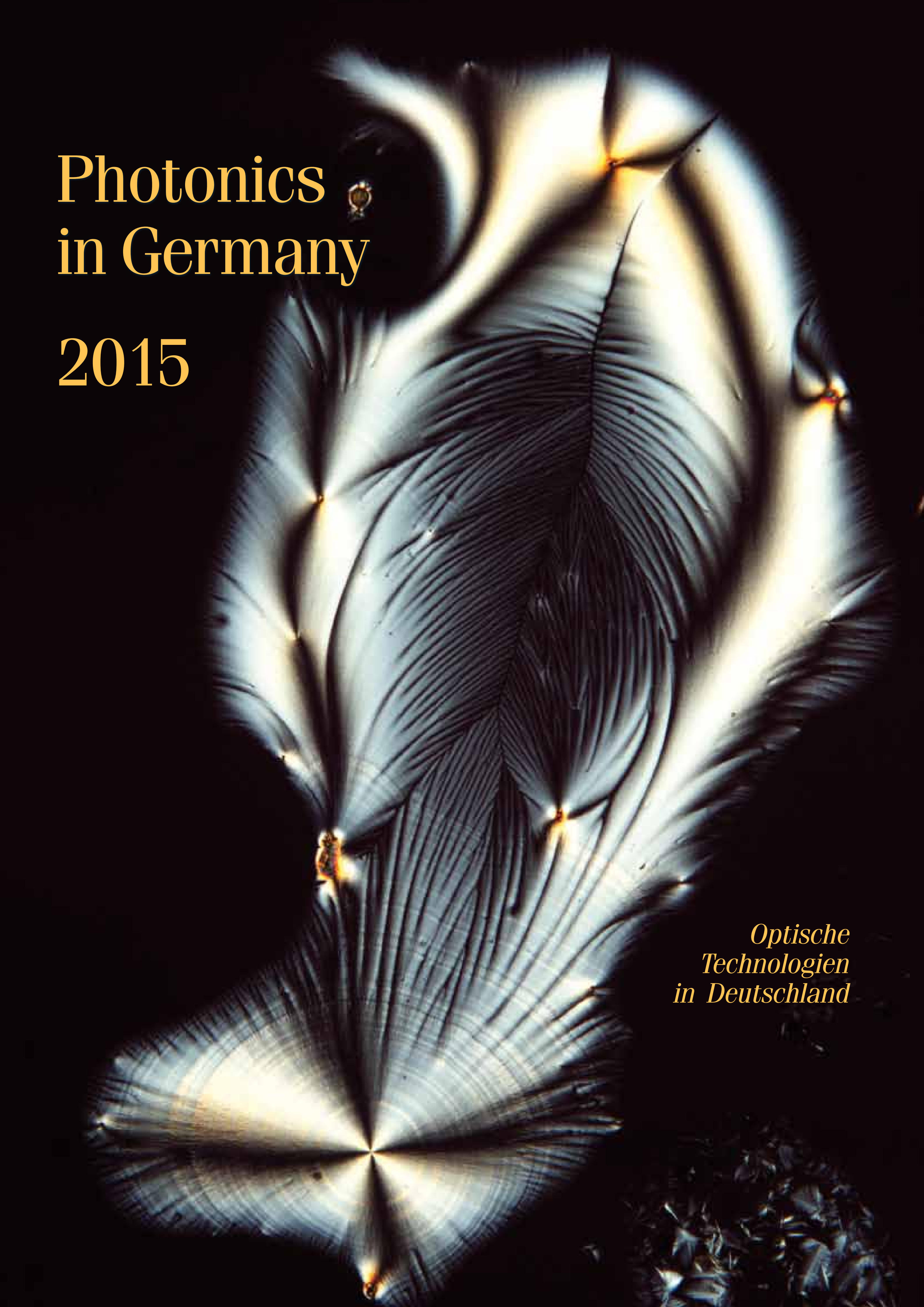
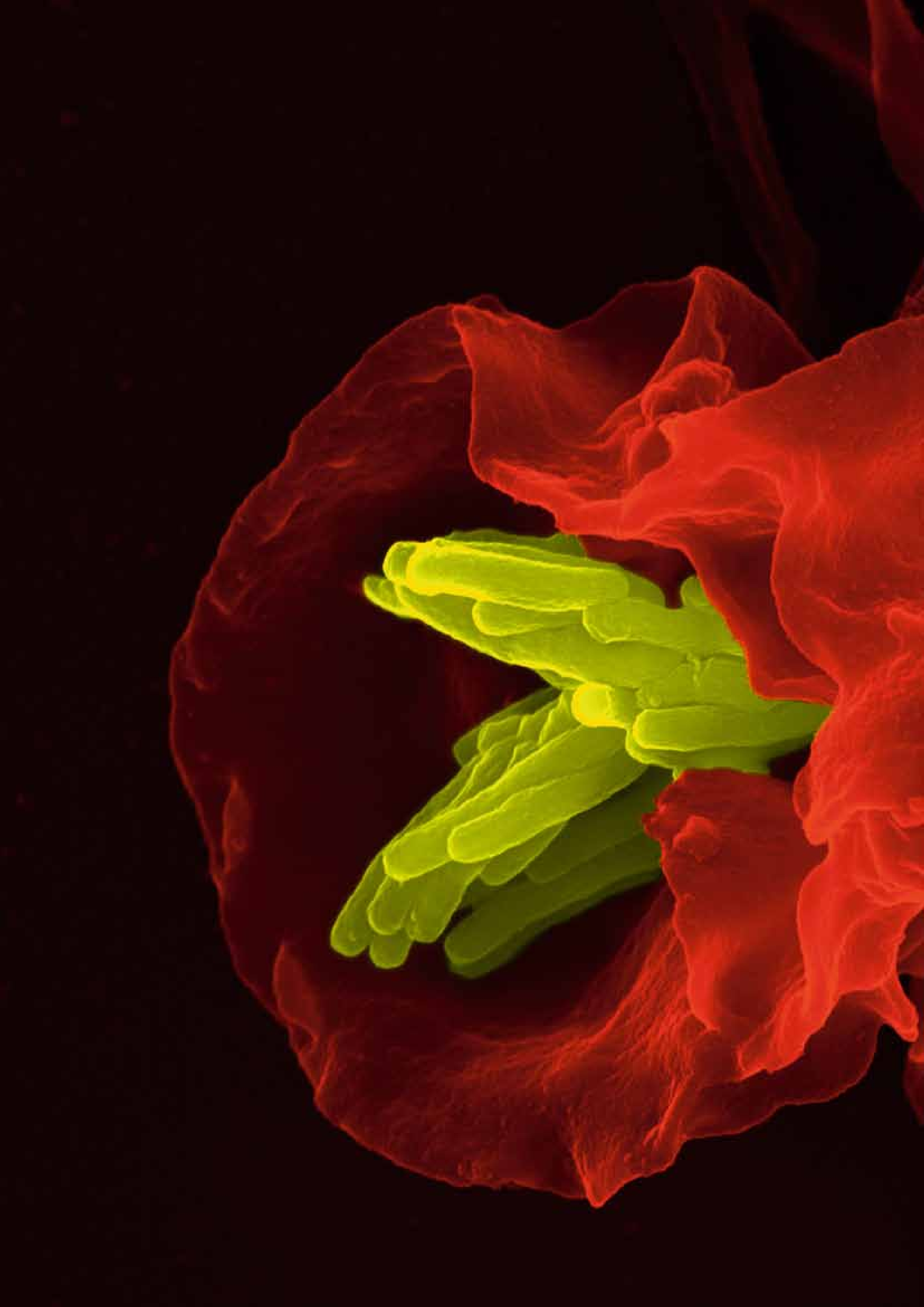
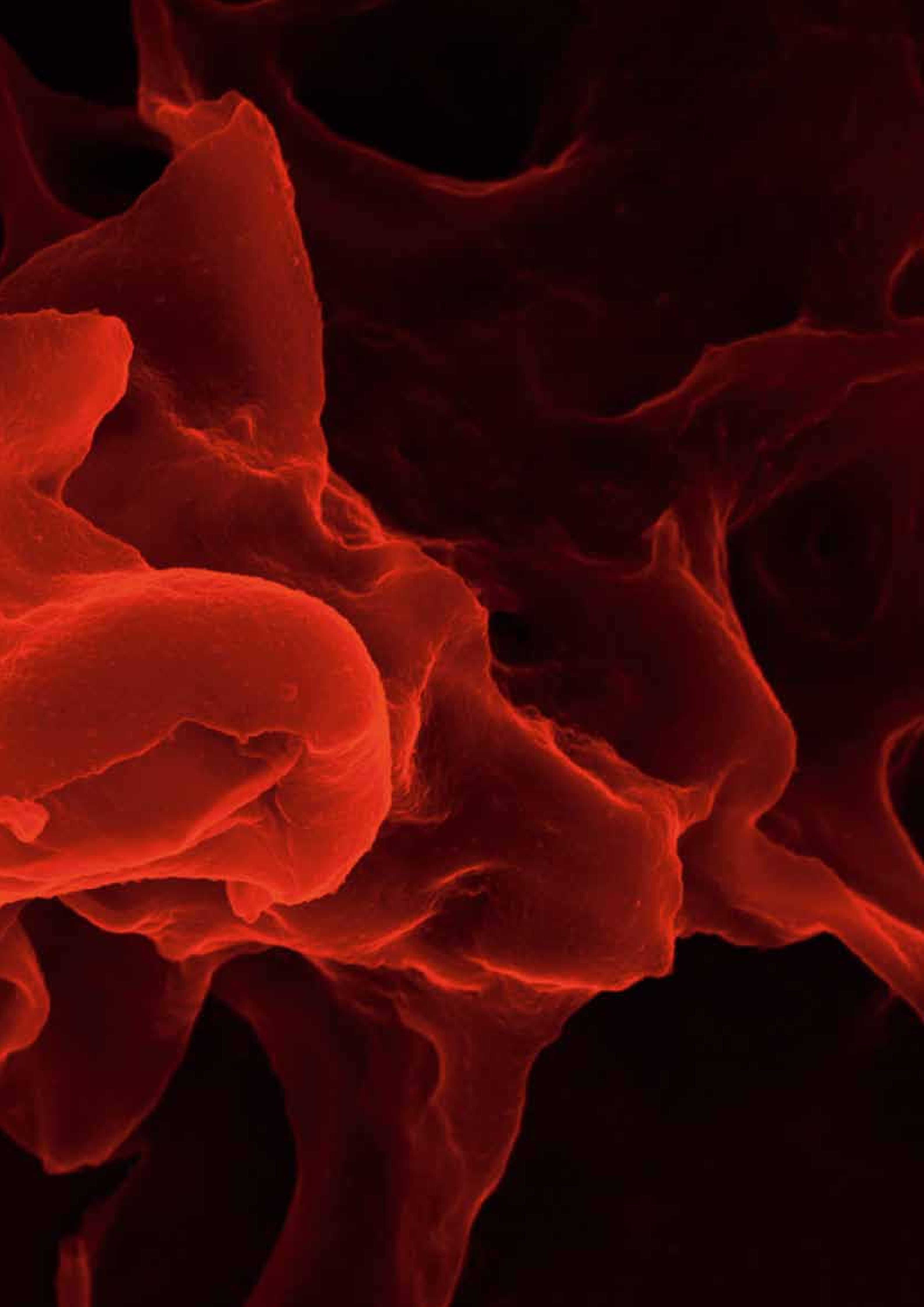


Photonics in Germany

2015

Optische Technologien in Deutschland





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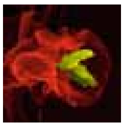

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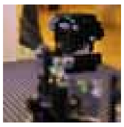

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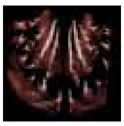

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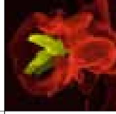

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Preface

Prof. Dr. Johanna Wanka
Federal Minister of Education
and Research
Bundesministerin für Bildung und Forschung

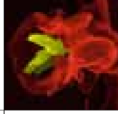
Photonics made in Germany is a global success: German-made LEDs now illuminate the Sistine Chapel while Stefan Hell at Göttingen's Max Planck Institute was awarded the Nobel Prize in Chemistry 2014 for super-resolved fluorescence microscopy. The German photonics industry has generated groundbreaking scientific findings and award-worthy innovations over and over again. The progress made in Germany is based on strong partnerships between science and industry and on close networks which focus on the new lead markets.

The Federal Government attaches great importance to enhancing the fertile ground for these partnerships. This is why we launched the new High-Tech Strategy in September 2014. With this tool in our hands, we are giving fresh impetus to the cooperation between businesses and research institutions as well as between future users and researchers in different disciplines. Not only is new knowledge generated in this way, but ideas can be turned into innovations more quickly too. Our goal is also to increase the involvement of citizens in research and innovation. To achieve this aim, we are developing new formats of public dialogue and working to make research funding more transparent.

The great innovative ability of photonics is playing an important role in making our economy more resource-efficient, and we are among the global leaders in this respect. In particular technologies that deal with light are helping to build the foundation on which we can accomplish the tasks set in the High-Tech Strategy. We need these technologies in the fields of digital economy, energy, health, mobility and security.

The publication "Photonics in Germany 2015" provides valuable information on research and development in optical technologies. Furthermore, it demonstrates Germany's strong research performance and offers an overview of potential points of contact. Together we must meet the challenges of the future. I firmly believe that our country's openness to new ideas and innovative thinking will continue to make it a prominent location for photonics.

Prof. Dr. Johanna Wanka
Federal Minister of Education and Research



Grußwort

Photonik aus Deutschland feiert international Erfolge: LEDs aus Deutschland erleuchten seit kurzem die Sixtinische Kapelle und für die Lichtmikroskopie mit ungekannter Schärfe erhielt Stefan Hell vom Max-Planck-Institut in Göttingen den Nobelpreis für Chemie 2014. Immer wieder bringt die Photonik in Deutschland bahnbrechende Erkenntnisse und preiswürdige Innovationen hervor. Die in Deutschland erzielten Fortschritte basieren auf starken Netzwerken von Wissenschaft und Wirtschaft und auf engen Partnerschaften, die neue Leitmärkte in den Blick genommen haben.

Der Bundesregierung ist es ein wichtiges Anliegen, den Nährboden für diese Partnerschaften weiter auszubauen. Dazu haben wir im September 2014 die neue Hightech-Strategie verabschiedet. Mit ihr geben wir Impulse für die Zusammenarbeit von Unternehmen und wissenschaftlichen Einrichtungen, von künftigen Nutzern und Forschern unterschiedlicher Disziplinen. So entsteht nicht nur neues Wissen. Auf diese Weise sollen auch Ideen schneller zu Innovationen werden. Unser Ziel ist es dabei auch, die Bürgerinnen und Bürger an Forschung und Innovation zu beteiligen. Dazu entwickeln wir neue Formate für Bürgerdialoge und wir gestalten die Forschungsförderung transparenter.

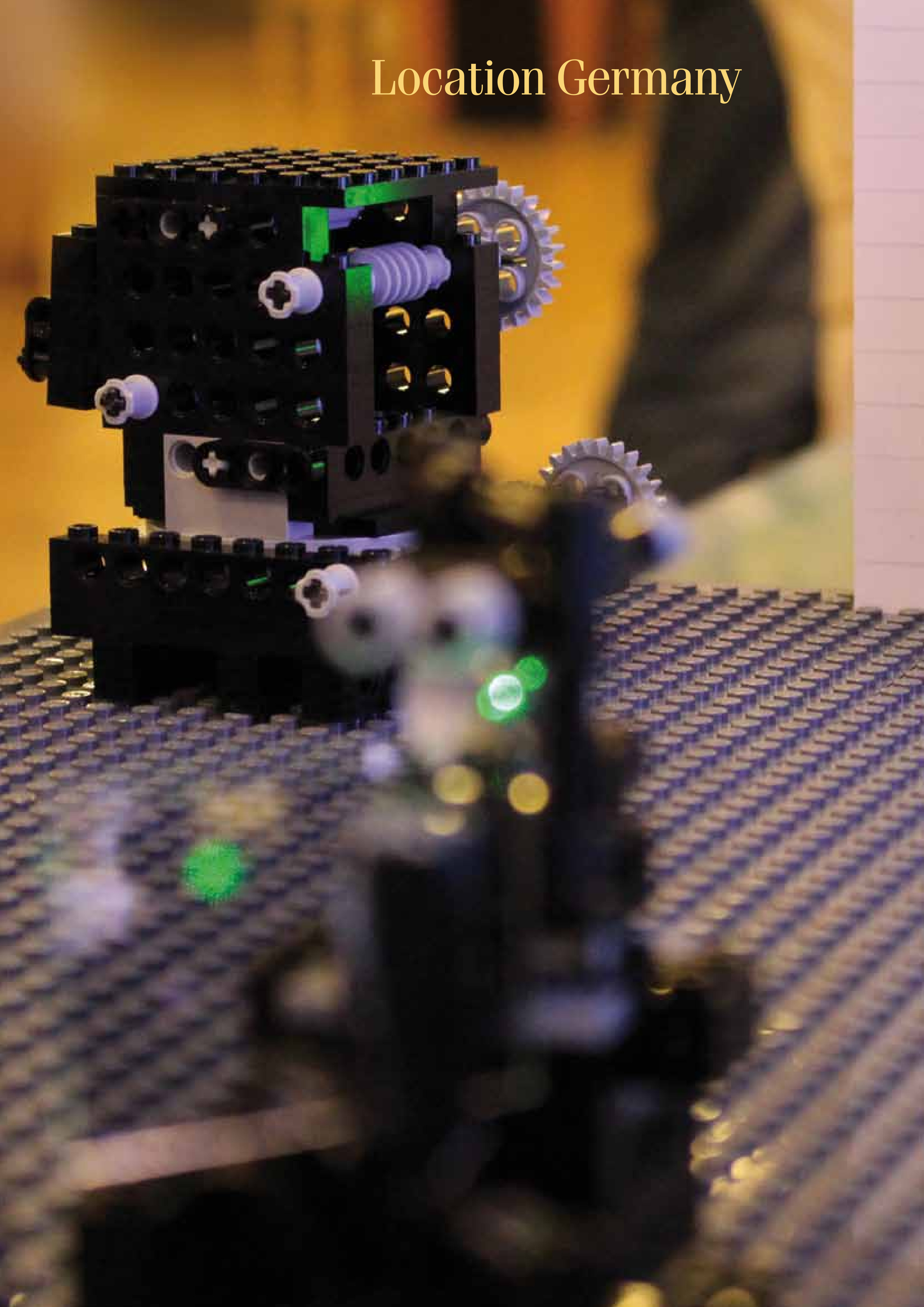
Die innovationsstarke Photonik leistet insbesondere einen wichtigen Beitrag, um unsere Wirtschaft ressourcenschonend zu gestalten. Wir stehen hier international mit an der Spitze. Gerade die Technologien rund um das Licht schaffen vielfach die Grundlage, um die Zukunftsaufgaben der Hightech-Strategie anzugehen. Wir brauchen sie für die Themenfelder digitale Wirtschaft, Energie, Gesundheit, Mobilität und Sicherheit.

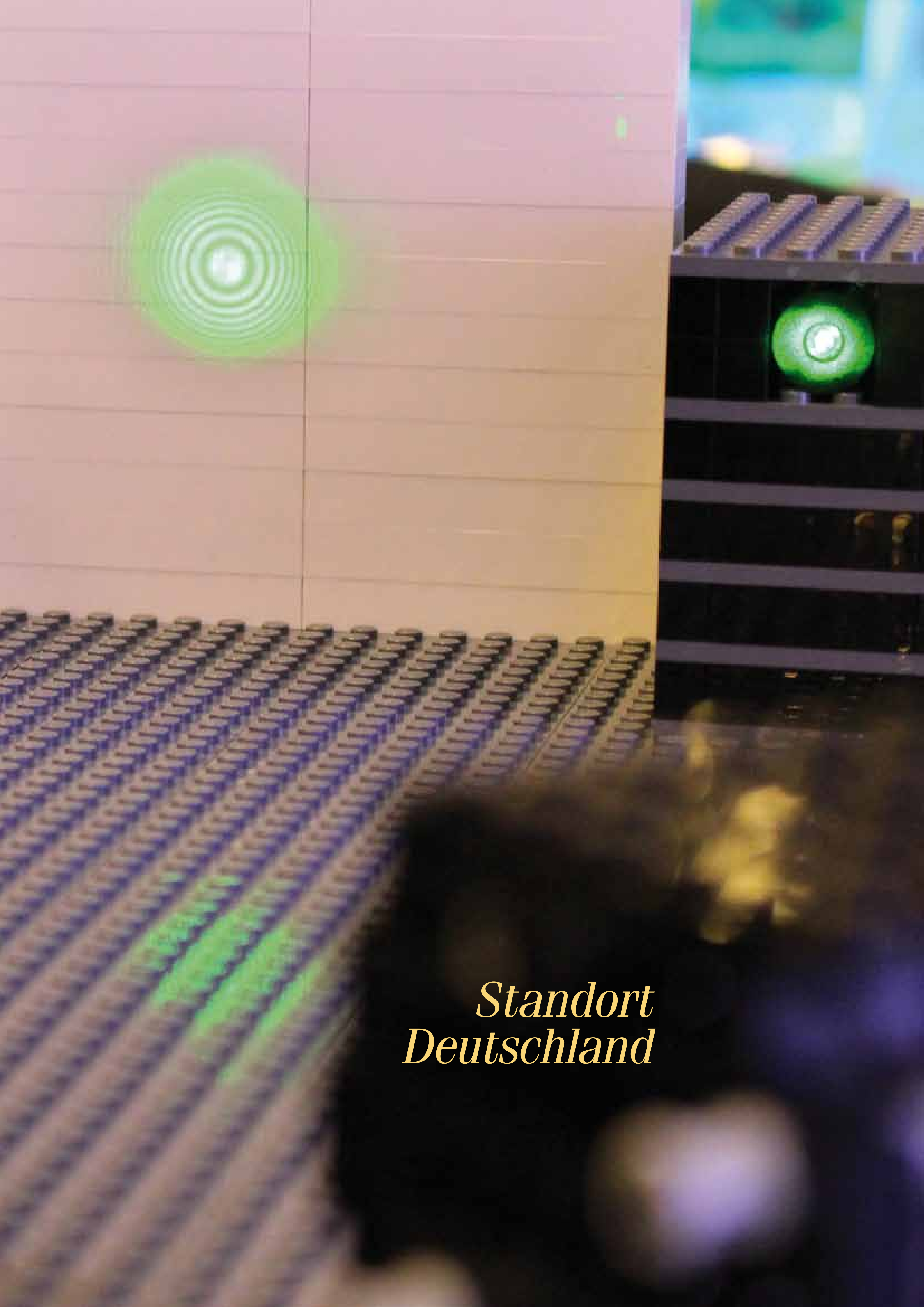
Die Publikation „Photonics in Germany 2015" gibt wertvolle Informationen zu Forschung und Entwicklung in den Optischen Technologien. Sie zeigt zudem die deutsche Forschungsstärke auf und bietet eine Zusammenschau möglicher Ansprechpartner. Wir wollen die Herausforderungen der Zukunft gemeinsam angehen. Ich bin überzeugt, dass mit Aufgeschlossenheit für Neues und Ideenreichtum unser Land auch in Zukunft ein herausgehobener Standort für Photonik bleiben wird.

Prof. Dr. Johanna Wanka
Bundesministerin für Bildung und Forschung

Bundesministerium
für Bildung
und Forschung

Location Germany





Standort Deutschland

Strengths of the Location Germany

Close links between excellent science, a powerful economy, and targeted funding policies form the basis for innovation and growth

Photonics is indispensable – not only to our society, but also to innovations and growth in Germany. After an initial niche existence, it has evolved into one of the most important key technologies in Germany and Europe with a considerable potential for growth. German companies rank among the world market leaders in many sub-segments of photonics and, together with the research landscape, have contributed about eight per cent towards consolidating a powerful position on the world market and safeguarding this over the years. The world market share is even significantly higher in the sub-segments of photonics belonging to the powerful core sectors in Germany (production technology, image processing and measurement technology, optical components and systems, and medical technology).

The success of the German photonics industry and the location Germany is the fruit of an effective and consistent development in the sector. Over the years, close cooperation has emerged between the institutional landscape, outstanding scientists, and the economy, supported by targeted funding policies. Several factors have contributed to this. On the one hand, technical and regional alliances have been forged that promote interdisciplinary dialogue between industry, science, and costumers and hence supplement the highly dedicated activities of the leading trade associations. Over time, an extensive knowledge infrastructure has grown that is benefiting the whole network. At the same time, cooperation projects between research institutes and businesses raise the political visibility of the photonics industry on both the national and regional levels. For the high tech industries, the sensible use of funding has become an indispensable element towards realising sound basic research or projects of priority interest with closer ties to the market. These serve to support the companies' own R&D applications that, at nine to ten per cent, are far higher than the processing industry's average. Only long-term supporting measures can help to create innovations in key technologies and tap into new markets at an early stage. At the same time, this combination of supporting measures acting over a broad front and targeted project grants is unique in the international arena and a strength of the German location. By introducing their expertise and needs into the dialogue with politics, the photonics industry and science provide the power needed to drive ahead projects that promise pioneering potential for Germany's economy. In this respect, the advantages of these supporting measures extend far beyond financial aid. Cooperation

Experts from industry, science and politics discuss about the future of photonics in Germany at the Photonics Congress 2014 in Berlin. Source: VDI-Technologiezentrum GmbH/ Frank Nürnberger

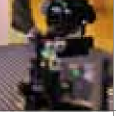
Annika Löffler,
VDMA Photonics Forum

projects give rise to professional networks that can enrich each other and forge new contacts and project potential. It is of particular importance to the location Germany that the photonics sectors here have continued to form over recent years, that they present themselves as a united front, and that they define together innovative themes. An effective supplement to this has proved to be measures that have been initiated across all sectors by the industrial associations and the Federal Ministry for Education and Research in support of a "family brand strategy for photonics" for Germany. The "Photonics Business and Finance Forum" elaborates strategies and contents serving the capital market as a continuous and early communication of commitment opportunities in the photonics segment. This supports primarily the SMEs in effectively communicating Germany as a location for photonics investments to the finance sector, in gaining deeper insights into the structures and potential, and hence improving their chances of implementing research findings successfully. Germany, too, promotes a highly effective dialogue with the public and young new recruits for the purpose of raising the visibility of photonics, communicating career and training opportunities, and hence simplifying the companies' search for qualified young talent. This is an important step if Germany is to safeguard its innovative capacity in future as well.

Summing up, Germany can boast excellent conditions for further growth and innovation in the photonics sector. Not only the highly competent networks and the creation of value on a powerful knowledge base, but also the high export ratio in excess of 66 per cent testifies to the international competitive strength of the location Germany. Especially in its powerful core sectors of photonics, Germany will continue its dynamic growth on the global market level in the years to come. The German industry and research landscape enjoys an excellent position to maintain and target the expansion of their technological core competences in photonics. New technologies such as e.g. ultrashort pulse lasers, photonic process chains, Industry 4.0, and additive manufacturing are opening up new fields of applications, serving to boost competitiveness in other, highly relevant branches of industry as well. As a key technology, photonics provides crucial ideas towards mastering the challenges that society will have to face in future and, to boot, will sustain the need for R&D and highly qualified workers over years to come. It opens up new opportunities for new future markets and new prospects for the production location Germany. Here, it is important to tap into the established and successful interaction of science, economy, and politics.

Spectacular impressions of photonics: Bach's Toccata played on a laser harp. Source: VDI-Technologiezentrum GmbH/Frank Nürnberger

VDMA – German Engineering Federation
Verband Deutscher Maschinen- und Anlagenbau e. V.
Forum Photonik
Corneliusstraße 4
D – 60325 Frankfurt am Main
Phone +49 (0)69-756081-22
Fax +49 (0)69-756081-11
Mail a.loeffler@vdw.de
Web http://photonik.vdma.org



Make Light – Photonics Innovation Made in Germany

Collaborative research
Federal President Gauck awarding the German Future Prize 2013 for the project „Ultra short pulse laser for industrial mass production“ to the research team of the University of Jena and the companies Bosch and Trumpf
Source:
German Future Prize / Eventbild-Service / Stephanie Pilick

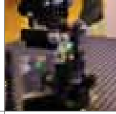
open Innovation
Make Light-exhibition booth at the Maker Faire 2014:
„Lego Photonics“ by the University of Osnabrück with Michelson-interference pattern.
Source:
VDI Technologiezentrum GmbH

Besides beer, dirndl and sauerkraut there is a special German tradition also in R&D. It is a special kind of long-lasting, dedicated R&D cooperation between partners from academia and industry. They won´t grant a patent for it, but it is nevertheless an asset to be able to really do research together although your background is different and your affiliation is to competing companies and institutes. It is not about who will prevail – academia or industry. It is all about how everybody follows their own rules and yet they make a difference by working closely together.

This culture of „joint“ R&D plays an important role for the rapid transfer from inventions to products in photonics. The claim of Zeiss and Abbe was „calculate, don´t just try out“. So modern industrial optics has been that way from the beginning. When lasers were invented about 50 years ago, this scientific marvel has been made an industrial workhorse by close and trustful cooperation between scientific and industrial pioneers. The German innovation prize 2014 was awarded to a team of researchers from Jena university, Bosch and Trumpf for pioneering short pulse lasers as an industrial tool. All in all, they worked hard for 15 years – and eventually, they succeeded. And they still go on inventing new types of application for short pulse lasers.

Sometimes there is doubt about the pace of innovation in Germany. But sometimes patience and dedication is required for innovation, and that you can find in Germany. Germany has slightly over 1 % of the world population, more than 7% of the global scientific publications and 11% of r&d-intensive world exports. And also cooperation can be exported: German science and industry have been able to grow together with new partners in the rising economies.

The federal German government has invested heavily in science and innovation lately. Under it´s High Tech Strategy federal agencies have joined forces with science and industry to adress innovation needs like health, energy and security.



MinR Dr. Frank Schlie-Roosen
Bundesministerium
für Bildung und Forschung

Broad application
Competition by the Federal Ministry of Education and Research „Communities in new light": Citizen dialogue for new lighting applications in schools. The school center located at the Mäusheckerweg in Trier-Ehrang is the first school in Germany that was completely equipped with LED lighting. In the meantime about 100 further schools were converted to LED lighting.

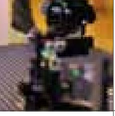
Source:
VDI Technologiezentrum GmbH

One example for joining forces is solid state lighting. 10 model projects have been selected at the outset in order to be able to devise guidance for a sub-sequent roll-out to various public lighting applications. Today, many hundreds of lighting projects have been started or have already been finished. Legislation has made solid state lighting the baseline technology for federal building projects.

There are many other examples, where photonics today is a key technology, driving innovation. Among them are 3d printing, photovoltaics and microscopy. Overall, the industrial R&D budget in photonics is about 9% of sales. If you do the math, this is somewhere between 2 and 3 bn € annually. Public funding for photonics projects is a little over 100 mn €. So, photonics in Germany means innovation lead by industry, with the public sector being a trustful and patient partner for selected high-risk projects.

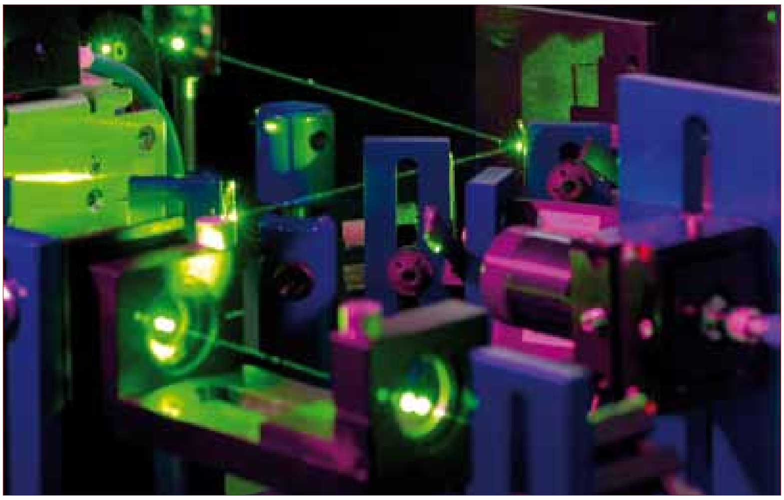
In the end, innovation always is about people. People dream and aspire certain goals for their education and their professional career. This is why science, industry and the federal government also invite everybody to do photonics for themselves. Many photonics technologies and components today have become affordable. You can build a laser interferometer with Lego or build and program your own 3D scanner. You can do things together with friends from the other side of the world, or even things nobody else has thought about. So it is time to open up innovation and invite people to join in with their own ideas and experience. Make light.

MinR. Dr. Frank Schlie-Roosen
Bundesministerium für Bildung und Forschung
Referat 513
Heinemannstrasse 2
D – 53175 Bonn
Phone +49 (0)228-9957-3259
Mail frank.schlie-roosen@bmbf.bund.de



Getting to the Top – Remaining at the Top

German photonics has climbed a steep path upwards during the last decades. Today, the rising star photonics is acknowledged to be one of the top high-tech industries in the country. The market volume of the German photonics industry has reached economic significance with more than 30 billion Euro. Each "photonic" Euro has a typical leverage factor of 50, resulting in a trillion Euro market of photonics-enabled products which range from optical networks, intelligent automobile lighting, and medical diagnostic systems to the now omnipresent smartphones - to name just a few.



Source: LDT Laser Display Technology GmbH – Jena

In the political arena, photonics has become one of the acknowledged key enabling technologies (KET) in Germany, in Europe and worldwide.

In Germany, this success story rests on three pillars:

- Entrepreneurship by dedicated individuals materializing the many bright ideas continuously generated in research institutions and companies. In total, there are over 1,000 entities in Germany that are active in photonics.
- Bottom-up: Strong initiatives by committed researchers and company leaders to define and implement the photonics roadmap. The most prominent outcome is the European technology platform Photonics21 which has made photonics one of Europe's key enabling technologies.
- Top-down: Successful commitment by the government to support photonics over an extended period of time; to foster the excitement for lasers, LEDs and optics among school kids, undergraduates and graduate students; to support the brightest research groups in academia in and beyond universities.

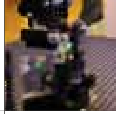
Only this combination of factors has put us in the strong position, German photonics is in today. With some 43% share of the European photonics market, Germany is the light house of the continent. Today, more than 130,000 highly skilled German engineers, technicians, and operators are employed in the photonics industry.

Research continues to prove excellence too – most prominently visible in the 2014 Nobel prize in Chemistry for Stephan Hell of the Max Planck Institute of Biochemistry in Goettingen for his invention of the microscopic imaging below the Abbe limit.

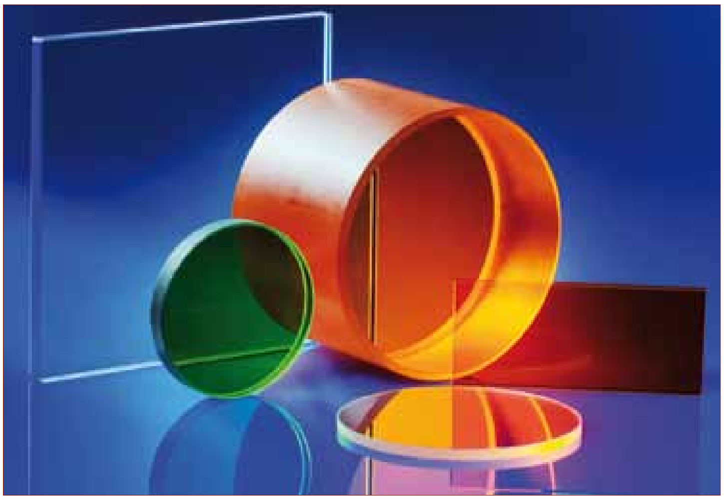
Now the challenge is to keep up this momentum! The photonics community in Germany is been asked to provide that steady flow of innovative products that will allow photonics to stay in the premier league of technologies.

This way we will ensure further significant support for our industry and attract the most talented people who have the means to master the scientific, technical and economic challenges of the world of tomorrow.

But the photonics community needs to be aware of risks, too: Surprisingly, disruptive action could come from the European Union - just from the same institutions which



Dr. Wenko Süptitz
Head of Photonics Division
SPECTARIS

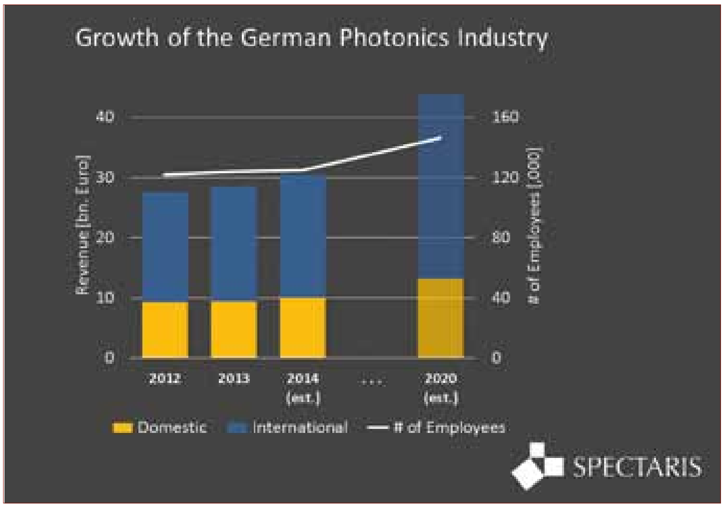


Source: Schott AG

A characteristic of photonics is that it builds on special materials like leaded glass, cadmium-containing filters and gallium arsenide semiconductors. Only with those well-engineered and environmentally strictly controlled materials photonics can accomplish the performance parameters which make the optical technologies so outstanding. With the current risk that essential optical materials might get banned from European production floors - or that their further use requires uneconomically high implementation costs – there are very serious concerns that the globally operating photonics industry will prefer other locations in the world to grow its business in the future.

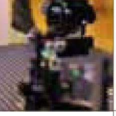
have strongly supported photonics during the last couple of years. The Restriction of Hazardous Substances directive (RoHS) and the regulation of Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) - two in principle well intended measures - have the means to do significant "collateral damage" to the photonics industry in Europe and to all the subsequent beneficiaries.

The industry association SPECTARIS, their corporate members and other leading German and European associations are currently fighting for a fact-based reasoning why the photonics industry should get the permanent permission to use the full variety of optical materials, and this without any risks of undercutting the environmental goals of RoHS and REACH.



Maintaining the strong position of German photonics might be as challenging as it was to get to the top in the first place. But today's strength of German photonics is an excellent base to be very successful in the future.

SPECTARIS
German Industry Association for Optical, Medical and Mechatronical Technologies
Dr. Wenko Süptitz
Werderscher Markt 15
D – 10117 Berlin
Phone +49 (0)30-4140 21-25
Fax +49 (0)30-4140 21-33
Mail sueptitz@spectaris.de
Web www.spectaris.de



International Investment in Germany's Photonics Industry

The photonics industry will play a central role in the development of a number of German economic sectors in the coming years, driven by strong German companies, internationally renowned R&D institutes, and generous government support.

But just how attractive is Germany's photonic sector for international investors? Which fields are foreign companies investing in in Germany? And are foreign direct investment (FDI) projects being carried out in areas where the domestic industry has existing strengths?

The data suggest that the lion's share of FDI projects were a result of a boom in international investment in photovoltaics in Germany between 2008 and 2012 due to the country's progressive Energiewende policy. However, investment in this segment has stalled recently due to a rapid drop in prices caused by international competition. Somewhat surprisingly, displays and light sources also came in the top three sectors. Let's examine these latter categories in more detail.

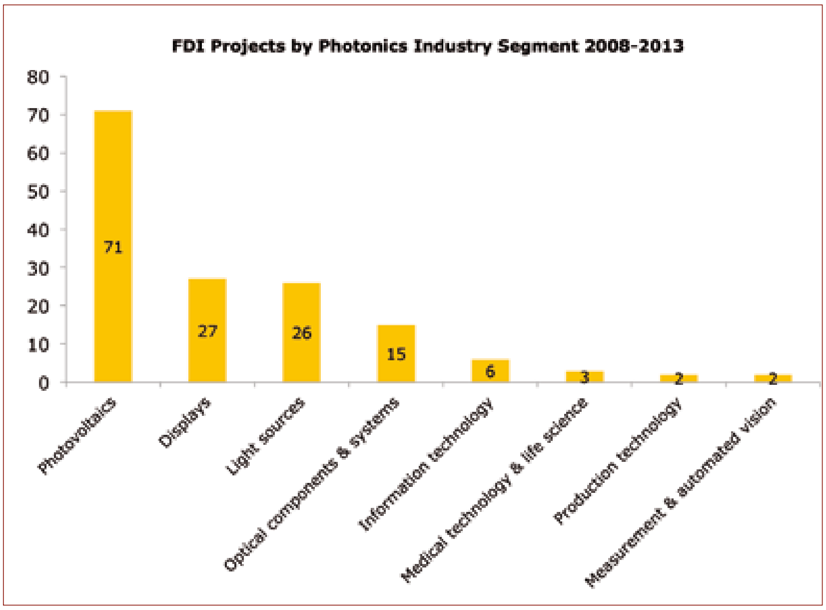
In the PV sector, roughly half of all projects were established for the purpose of sales, marketing, support, or distribution activities. About a fifth were manufacturing projects. However, there is a clear downward trend toward the end of the recorded period with the last recorded investment by an international company in PV manufacturing taking place in January 2012.

In the light sources and display segments, most of the projects carried out were in the areas of sales and marketing, support, or distribution activities. It is noteworthy that no foreign companies invested in display manufacturing projects between 2008 and 2013. This is hardly surprising: Display production and a large part of the corresponding value chain moved to Asia long before the period examined here. The relatively large number of FDI projects can be explained by Germany's large domestic market and role as the world's fourth-largest and Europe's leading economy. Most of the new investments were in sales and marketing offices for young and relatively unknown Asian companies looking to gain a foothold in Europe.

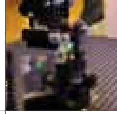
Germany has seen some manufacturing of light sources. Both displays and light sources are mostly destined for business-to-consumer markets. Thus it can be seen that most of the FDI projects were attracted to the large German consumer market and not to serving world markets from a manufacturing base in Germany.

It is striking that 6 out of a total of 15 foreign investments in the optical components and systems sector were manufacturing projects. This may be due to suppliers seeking proximity to Germany's particularly strong industrial presence in the sector.

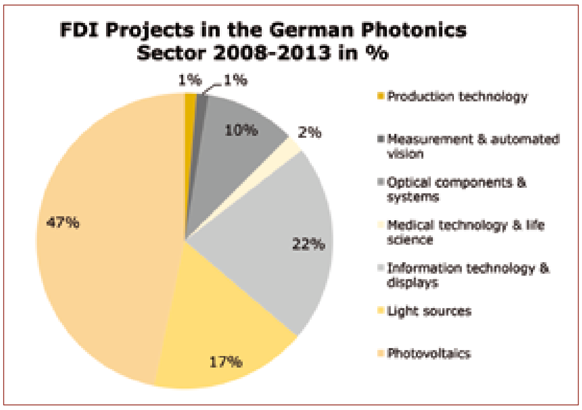
Production technology, medical technology and life science, and measurement and automated vision, have seen relatively few international investment projects compared to the levels of domestic production. Pos-

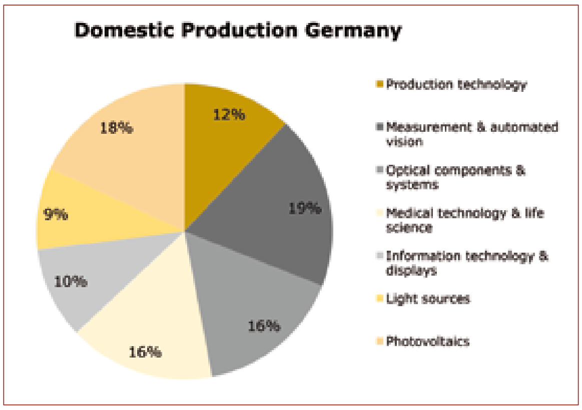


Source: GTAI analysis based on fDi Markets 2014*



Max Milbredt
Manager Investor Consulting
Electronics & Microtechnology
Germany Trade and Invest





Source: Photonics Industry Report 2014, GTAI analysis based on fDi Markets

sible reasons include barriers to entry such as rigid regulations, e.g. in life science, or specific strengths of the German industry making these segments unattractive to new entrants.

One particularly interesting example of an investment in photonics technologies in the period examined was Samsung's investment in Novaled in 2013. Novaled, which is based in the eastern German city of Dresden, is a manufacturer of OLED materials. These materials are used in novel applications such as OLED TVs or OLED lighting. The investment was one of Germany's most successful VC exits ever. It is a prime example of how new technologies developed in Germany's photonics sector trigger the interest and commitment of international investors.

Returning to the initial questions, it is clear from examples like these that Germany's photonics sector is attractive to investors from abroad. The German consumer market for lighting and displays remains especially attractive for foreign investors. Germany's inherent strengths in medical technologies and life science, production technology, and measurement and automated vision, mean the country still has the potential to attract foreign investment in its manufacturing sector. Germany Trade & Invest is actively approaching international companies to encourage investment in all of these segments of the photonics industry in Germany.

About Germany Trade & Invest

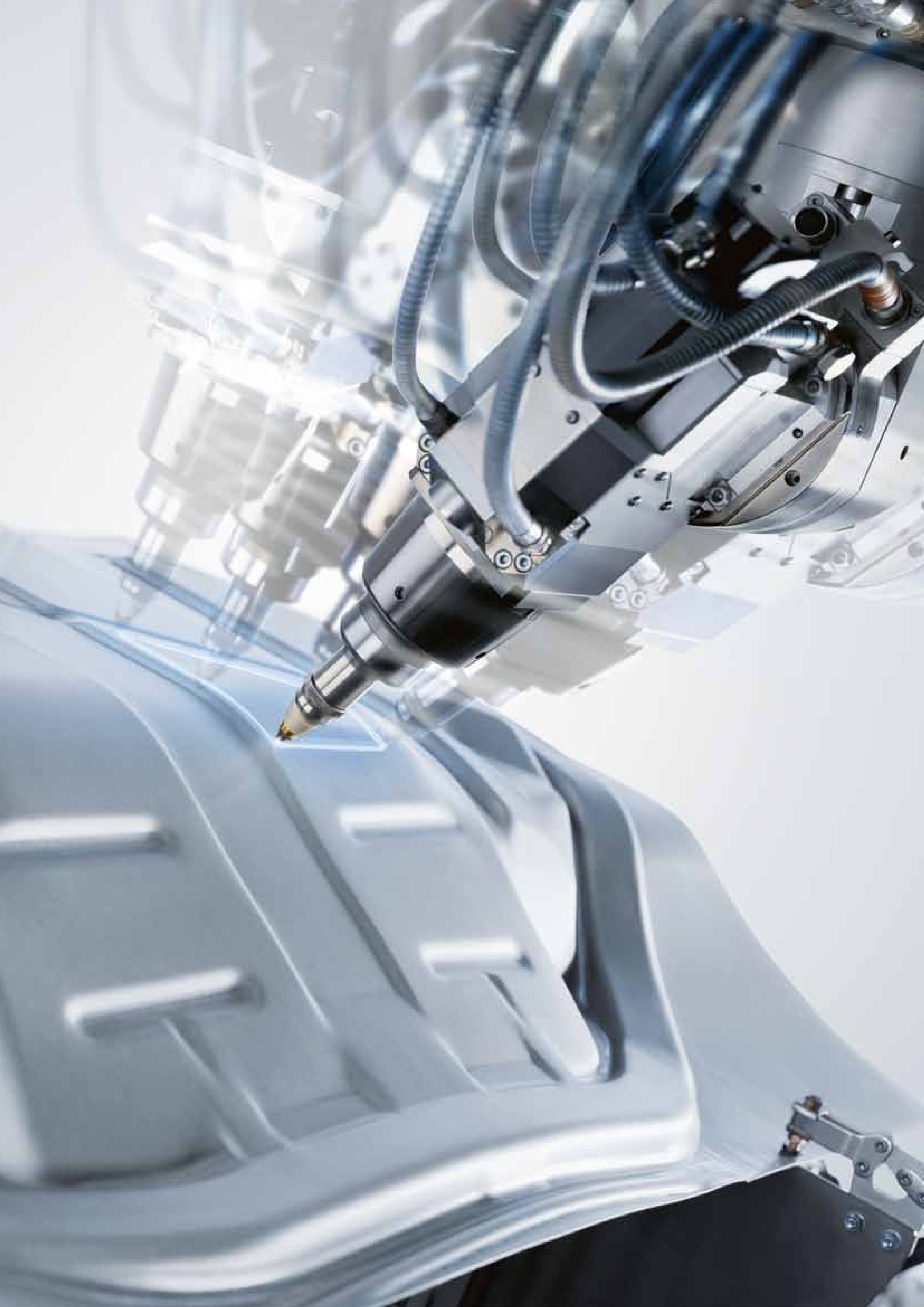
Germany Trade & Invest provides free-of-charge consulting services to photonics companies looking to invest in the country. We consult on all matters concerning the market from tax and legal issues and investment funding through to site identification. Germany Trade & Invest is funded by the Federal Ministry for Economic Affairs and Energy (BMWi).

* The Financial Times fDi Markets foreign direct investment database was used to derive the data for this article. The sector definitions are based on those used in the Photonics Industry Report 2013 (jointly published by the German Federal Ministry of Education and Research and the SPECTARIS, VDMA, and ZVEI German trade associations). 152 FDI projects were identified for the six-year period from January 2008 to December 2013.

Max Milbredt
Manager Electronics & Microtechnology
Germany Trade and Invest
Gesellschaft für Außenwirtschaft und Standortmarketing mbH
Friedrichstraße 60
D – 10117 Berlin
Phone +49 (0)30-200 099-408
Fax +49 (0)30-200 099-111
Mail max.milbredt@gtai.com
Web www.gtai.com

Innovations in Growth Markets

Innovationen in Wachstumsmärkten



Ultrafast Lasers for High Quality Microstructures

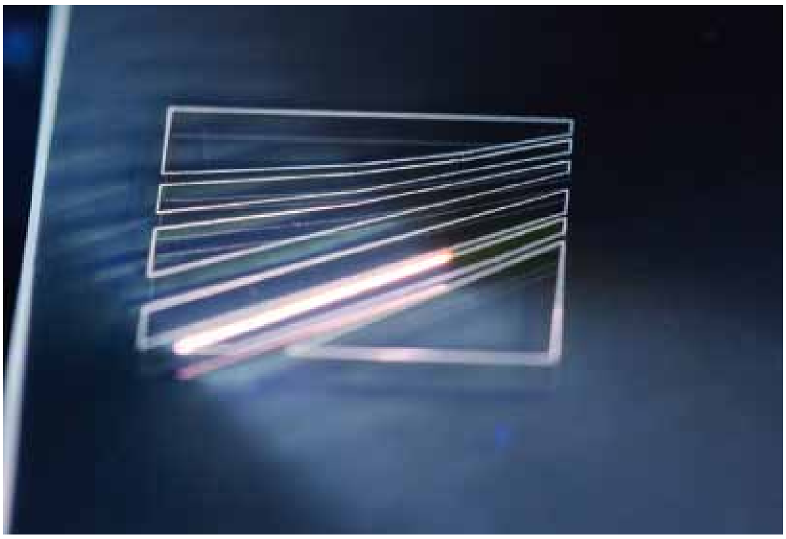
Ultrafast lasers are the key to ultra-precision processing in various areas of application, for example in electronics, sensor technology, medical technology, fine mechanics and microsystem technology, filter technology, lighting industry or solar technology. Thin coatings can be removed, fiber-reinforced plastics drilled, transparent material in-volume structured and various surfaces can be processed using ultrafast lasers.

Ultrafast lasers, i.e. lasers with pulse durations of less than ten picoseconds, have experienced a stormy development on the scientific front since their beginnings 40 years ago. The interaction of fs-laser radiation with material is characterized by the fact that the pulse duration is shorter than most interaction times between atoms or atoms and electrons. Thus, when material is processed, heat conduction, melting, evaporation and plasma formation only take place after the impact of the laser radiation. In contrast to longer nanosecond pulses or continuous wave lasers, no direct interaction of light and diffusing material takes place, depending on the repetition rate. Moreover in ultrafast laser processing, due to the very high intensities, the ablation is dominated by evaporation with negligible melt formation. High lateral resolution due to precise focusability down to a few micrometers, low heat input and high flexibility enable ultrafast lasers to achieve processing results which cannot be matched by any other method, especially in high precision structuring and surface functionalization.

The Fraunhofer Institute for Laser Technology ILT is developing laser based micro and nano manufacturing technologies and production systems, which are selectively adapted to the customer specific applications:

Laser Ablation

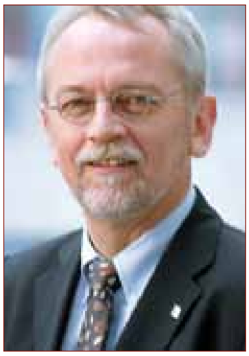
The ongoing miniaturization of products in fine mechanics, electronics, medical technology and sensor devices requires components with structure sizes in the micrometer range and accuracies with less than one micrometer. Laser ablation processes provide appropriate manufacturing processes for micro machining of metals, ceramics and polymers. Using ultrashort pulse lasers allow the exact machining of all types of materials with sub micron accuracies. For mass manufacturing of precise parts by hot embossing, injection molding and stamping, tools with structure sizes in the range of 5 - 10 µm with surface qualities < 200 nm can be produced. Since focused laser beams provide ultra high intensities, laser ablation of hard materials like tungsten carbide and diamond is possible with high accuracies.



Cutting of thin glass with an ultrafast laser.
Source: Fraunhofer ILT, Aachen.

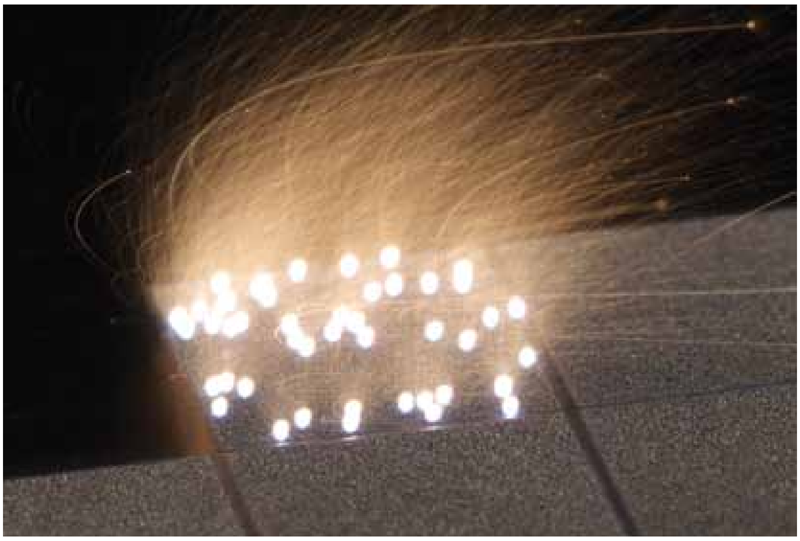
Nano Structuring

Functional surfaces are often based on micro and nano scaled structures, which amplify the intrinsic properties of selected materials or which cause a specific effect only by their structure size. For optical functions, for example for surface or volume holographic gratings, for biological functions like cell guiding



Dr. Arnold Gillner
Competence Area Manager
of Laser Material Processing

structures and analytical functions with specific molecule coupling areas, nano structures are necessary, which provide a reproducible functionality at low manufacturing costs. For these applications, a new laser interference technology has been developed to allow the production of periodic surface structures from 100 nm to 500 nm with high processing speeds.



Ultrafast Laser drilling with drill holes of less than one micro-meter.
Source: Fraunhofer ILT, Aachen.

Laser Drilling

Drilling with laser radiation is used as a manufacturing technology at very small hole geometries, high aspect ratios and ultra hard materials, where conventional processes cannot be applied for. With new drilling technologies like helical drilling, related high speed optics and ultrafast lasers hole geometries in the range of a few 10 micrometers can be processed with drilling depths of up to 2 mm. For applications in filter technology and photovoltaics new laser drilling technologies are available with drilling rates of up to 3,000 holes/s. Using multi beam approaches the productivity of laser ablation with ultrafast lasers can be increased significantly. With new ultrafast lasers and innovative multi photon absorption processes even hole geometries < 1 µm can be achieved. For structuring of dielectrical materials like glass and semiconductors hybrid processes can be applied, in which laser modification and subsequent etching are combined to produce structures with nanometer accuracy.

Microchannels inside Glass and Sapphire

Microfluidic systems can be produced with ultrafast lasers using the Selective Laser Etching (SLE) technique in thermally and chemically resistant materials such as fused silica, borosilicate glass and sapphire for applications such as those found in medical diagnosis. In fused silica the volume modified by the laser radiation is etched 1000 times faster than the unmodified glass. The edge angles of the channels reflect this selectivity. Minimal channel diameters of 10 µm with a length of a few mm are feasible. In-volume scanning produces channels, branches and hollow structures of almost any complexity.

„The future is ultrafast“ – The new possibilities arising out of the industrial availability of ultrafast lasers and their applications are becoming more and more important in the manufacturing industries worldwide. It is to expect that the market for such applications and lasers will increase significantly in the next years.

Dr. Arnold Gillner
Competence Area Manager of Laser Material Processing
Fraunhofer Institute for Laser Technology ILT
Steinbachstraße 15
D – 52074 Aachen
Phone +49 (0)241-8906-148
Mail arnold.gillner@ilt.fraunhofer.de
Mail www.ilt.fraunhofer.de

New Dimensions in Microprocessing

"With the ultrafast laser, we've opened a door into a new realm – and we won't know the full extent of its vast potentials for a long time," said Dr. Peter Leibinger, Head of the TRUMPF Laser Technology/Electronics division, at the award ceremony for the German Future Prize 2013.

'Ultrashort' is the term used for laser pulses with durations in the picosecond and femtosecond range. Pulses as short as these enable new possibilities for micromachining, thereby extending the field of applications in laser technology. Materials processing with longer pulses always is a thermal process: Depending on the beam intensity, the material is heated, melted, vaporized or directly sublimated, and with the correct choice of parameters this can be used for cutting, welding, etc. Here, heat conduction in the material always forms a heat-affected zone, in which structural, mechanical or chemical properties may be altered.

Materials processing with ultrashort laser pulses takes place in a fundamentally different way. In spite of moderate average laser power, the short duration of the pulses results in very high peak powers and, with the right focusing, extreme intensities easily exceeding 100 000 Megawatt per square centimeter at the workpiece. By comparison, deep penetration welding of steel plate requires approximately one Megawatt per square centimeter. As a result of these extreme intensities, the material is instantaneously ionized and converted into plasma. This plasma is under very high pressure and therefore expands from the surface, whereby material ablation is achieved. For ultrashort pulses, whose duration is shorter than the electron-phonon interaction time, the excess energy is transported inside the plasma and material vapor, and cannot spread as heat via diffusion within the surrounding material. This means that the formation of a heat-affected zone can be prevented or at least severely limited – and in connection with ultrashort laser pulses, one also speaks of "cold processing". As a result, picosecond and femtosecond lasers enable an even greater precision during cutting, drilling or ablation.

First steps inside the "new realm" honored by Germany's President

In search of future killer applications into the field of ultrafast micro-processing, TRUMPF took the first step into this new realm together with Bosch and the Friedrich Schiller University in Jena, as well as further partners within federally funded research projects at the beginning of the millennium. In the meantime, many of Trumpf's TruMicro Series 5000 lasers are being used at Bosch to drill holes into injection nozzles. The size and shape of the holes can be controlled so precisely by the ultrashort laser pulses that the fuel is optimally distributed inside the combustion chamber and burned far more efficiently – saving on fuel and reducing emissions. Bosch also has numerous other exciting applications: the sensor element in its lambda sensor, for instance, or the new injection valve for Bosch Buderus oil-fired boilers. The long-term partnership of the University, TRUMPF and Bosch culminated in innovations that were recognized by the German Future Prize 2013 awarded by President Gauck.

Further applications of the TruMicro Series 5000 include the cutting of shatterproof touchscreens for modern smartphones and tablets. Medical implants such as stents can sometimes only be cut with the ultrashort pulse laser – so in certain applications there is actually no alternative to the new technology.

Fig 1: Engraved safety match demonstrating cold ablation by ultrashort laser pulses. Source: TRUMPF.

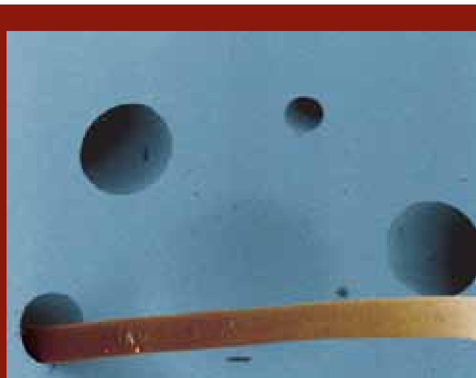


Fig 2: Inside of a gasoline direct injection valve drilled with an ultrafast TruMicro Series 5000 laser, with a human hair for size comparison. Source: Robert Bosch GmbH.

Dr. Dirk Sutter
Head of Ultrafast Laser
Research & Development
TRUMPF Laser GmbH

Another important application: the PCB. The printed circuit board of tomorrow will be very thin but will still comprise several layers, each of them bearing tightly spaced conductor tracks so that extremely complex circuits can be set up in this close space. The PCB will be flexible enough to follow movements or even to be mounted in curved and flexible devices – and will thus present new challenges to the tools in use today. Almost nowhere is this more clearly evident than in the microvias. These holes, lined with copper, make the connections between the conductive layers in modern, multi-layer PCBs.

Currently there are two ways to create these microvias: conventional mechanical drilling and a laser-based process. Mechanical bits cannot achieve diameters less than one-tenth of a millimeter, they can drill only about 20 vias per second, and they wear out within minutes.

Ultrashort pulse lasers do away with these limitations: With their extreme photon flux, they force the molecules or atoms in the material to absorb more than one photon at a time. This makes it possible to machine practically all the plastics which might be used for printed circuit boards – with just a single type of beam source and in a single processing step. At the same time, the ultrashort pulse lasers cover all the laser-based shaping techniques like percussion drilling and trepanning.

The latest TRUMPF ultrashort pulse laser in this regard is the TruMicro 5070 Femto Edition. With mean power of 80 watts and short pulses at 800 femtoseconds, it is the most productive industrial femtosecond laser on the market. It offers high throughput rates when machining components, and it is fully based on technology proven in many years of continuous 24/7 operation in harsh environments.

The interplay of pulse energy, pulse shape and mean power makes it possible for the TruMicro 5070 Femto Edition to achieve significantly higher ablation rates for many materials. The short pulses bring about advantages when working temperature-sensitive materials such as composites and polymers, and even for some metals. Thus the TruMicro 5070 Femto Edition promises to further broaden the applications which are suitable for cold processing.

About TRUMPF

TRUMPF is a leading global high-technology company and produces machine tools, lasers and electronics for industrial applications. Products manufactured with the company's technology can be found in almost every sector of industry. TRUMPF is the world technological and market leader for machine tools used in flexible sheet metal processing, and also for industrial lasers.

In 2013/14 the company – which has approximately 11,000 employees – achieved sales of 2.59 billion euros. With more than 60 subsidiaries, the TRUMPF Group is represented in almost all the countries of Europe, North and South America, and Asia. It has production facilities in Austria, China, the Czech Republic, France, Germany, Great Britain, Italy, Japan, Mexico, Poland, Switzerland, and the USA.

For more information about TRUMPF: www.trumpf.com.

TRUMPF GmbH + Co. KG
Johann-Maus-Straße 2
D – 71254 Ditzingen
Phone +49 (0)7156-303-0
Mail info@trumpf.com
Web www.trumpf.com

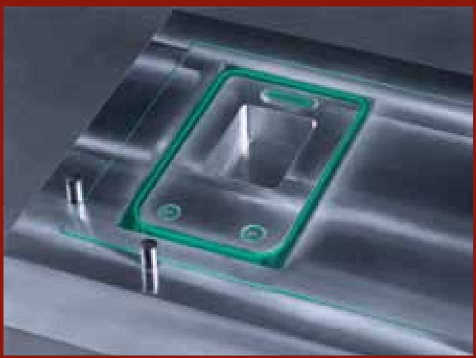


Fig 3: Laser-cutting glass with an ultrafast TruMicro laser minimizes the thermo-mechanical stress, yielding highest bending strength. Source: TRUMPF.

Fig 4: Laser drilling a printed circuit board with a picosecond laser from the TruMicro Series 5000. Source: TRUMPF.

Lithography Optics for EUV – New Technologies for Chip Manufacturing

Martin Lowisch
System Engineer
ZEISS
Oberkochen
Germany

The rapid development of computer chips is the pulse of the digital age. They must perform a constantly rising number of functions and process more and more data in an increasingly short time – any time, any place and all with less and less electrical energy. According to Moore's Law [1] the most efficient way to achieve this and simultaneously reduce cost per function is the continued increase of the transistor density in chips. Optical Lithography is realizing this in mass production of semiconductor elements. In this process, the chip structure layout on a mask is multiplied by optical projection on a silicon wafer. Accordingly, the optical resolution of the projection system determines the maximum achievable transistor density on the chip, and is given by

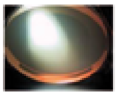
$$\textit{resolution} = k_1 \frac{\lambda}{NA}$$

where λ is the operating wavelength, NA the numerical aperture, and k_1 is a process factor.

Today, chip volume manufacturing is based on immersion systems operating at 193 nm with NA's up to 1.35. Since the resolution is limited further structure shrink can only be achieved by increasing process complexity. Therefore, the ZEISS Semiconductor Manufacturing Technology business group is manufacturing optics for a new lithography technology using so-called Extreme Ultra-Violet (EUV) light with a wavelength of 13.5 nm. ASML, the market leader for lithography machines is integrating this optics in his new EUV scanner generation. Obviously, the 15x reduction in operating wavelength opens up enormous potential for future shrink of chip structures, but is technologically very challenging. In particular, the manufacturing of the completely new optical system required fundamental innovations in optics manufacturing, coating, mechatronics, measurement and vacuum technology. Figure 1 shows that the optics entirely consists of mirrors and also the mask must be reflective. Refractive elements as lenses cannot be used for beam shaping as almost all materials absorb strongly at 13.5 nm. Secondly, the complete light path must be kept under vacuum. Absorption due to air or other gases would result in too high light losses. Furthermore, light reflection at 13.5 nm requires multilayer coatings on the mirrors to achieve reflection of nearly 70 %. The individual coating layers have a thickness around $\lambda/4$ and the thickness of the entire stack with more than 100 layers

Fig. 1: The EUV light path starts at the plasma source, where the emitted light is collected by a normal incidence mirror and imaged into the intermediate focus. Here the illumination system starts which provides a homogeneous light intensity in the reticle plane and a dedicated angular distribution of the light. The structure information of the reticle is imaged with a six mirror projection optic onto the wafer. This projection is done with a demagnification of four at the resolution limit of the optics.

Fig.2: Mirror performance is driving the resolution capabilities of the optics - significant improvements of figure and roughness have been implemented for different tools. For comparison: if a 3300 mirror would be magnified to the size of Germany the highest mountains would be less than 0.2 mm high

	Micro Exposure Tool	Alpha Demo Tool	Starlith® 3100	Starlith® 3300
Photos show relative mirror size				
Figure [pm rms]	350	250	140	75 → aberrations
Roughness [pm rms]	250	200	130	100 → flare

has to be controlled in the 0.1 % range. Nevertheless, as each reflection is accompanied by a light loss, the design is forced to limit the number of mirrors to the absolute minimum. Highest optical performance of each mirror is therefore essential for a perfect image and hence a stable lithographic process. Figure 2 shows that the specification levels for surface figure and roughness are close to atomic dimensions. The 26 mm wide image of the lithographic mask is densely packed with sub 20 nm structures and each of them needs to be well resolved and nearly distortion-free imaged. The small operating wavelength results in a high sensitivity to straylight and thus surface roughness has to be suppressed to a maximum extend. Not only the surface itself requires atomic accuracies, but also positioning and position stability of the mirrors inside the optical system has to be very accurate. Each tilt causes the light to deviate from the intended path. Tilt control in EUV systems is so accurate that the pointing deviation over the distance earth to moon would be less than 10 cm. All these innovations are integrated in the ZEISS Starlith® 3300 systems which offer a numerical aperture of 0.33. Resulting from the extremely small aberration level of individual mirrors, the wavefront performance of the system is around 0.3 nm rms. With that the optics supports lithographic high volume manufacturing down to 16 nm feature size. First imaging tests of the system confirmed the excellent single exposure resolution. Stable imaging of 16 nm dense lines and resolution down to 13 nm structures was demonstrated (figure 3).

Today, several 3300 systems are operational at leading chip manufacturers and further systems are in the installation phase. Also for the future, EUV has the potential for a continuation of Moore's Law. EUV optical systems with significantly increased NA will push the resolution below 10 nm enabling the reduction of chip feature sizes and performance throughout the next decade.

Acknowledgement

This work was partly funded by the German Ministry of Education and Research (BMBF projects 13N10567 and 13N12256) and supported within the frame of the Eureka CATRENE Program (project CT301). Many thanks to the EUV teams of ZEISS and ASML for the continued fruitful collaboration.

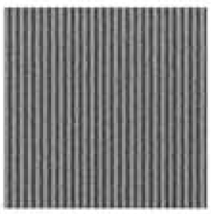


Fig.3: Illumination optic of the ZEISS Starlith® 3300 and 16 nm dense lines printed with ASML's NXE:3300 machine. For comparison, the current immersion optic for 193nm lithography can resolve 38 nm in a single exposure.

Literature:

[1] G.E. Moore, Cramming more components on electronic circuits, Electronics Volume 38, No 8, 1965

Carl Zeiss SMT GmbH
Semiconductor Manufacturing Technology
Ilka Hauswald
D – 73446 Oberkochen
Phone +49 (0)7364-20-9231
Mail ilka.hauswald@zeiss.com
Web www.zeiss.com/press

Digital Photonic Production Research Campus

In Aachen, work is underway on establishing a new Digital Photonic Production research campus where scientists, including researchers from Fraunhofer ILT, will be investigating how light can be made into a production tool of the future.

If Germany wants to hold its ground in international competition, it needs to turn research findings and new technologies into innovations even faster and more efficiently than before. The way to do this is by strengthening the links between basic research, applied research and industry – and that includes bringing them together in a single location. The "Research campus – public-private partnership for innovation" currently under development in Aachen is a good example of how this can work in practice. This idea stems from an initiative from the German Federal Ministry of Education and Research (BMBF). The ministry is funding ten such campuses, each looking at different topics and receiving funding of 30 million euros over a 15-year period, with the goal of encouraging more extensive collaboration between research and industry.

Fig. 1: Engine components can be produced and repaired by Laser Additive Manufacturing. Source: Fraunhofer ILT, Aachen / Volker Lannert.

In Aachen, the campus will focus on Digital Photonic Production (DPP). The plan is to use bits (computer data) to control photons (laser radiation) to assemble atoms into workpieces of any complexity and batch size – at the same low unit cost. The initial research campus application was submitted by Fraunhofer ILT and the Chair for Laser Technology LLT at RWTH Aachen University, and they now coordinate 30 partners in seven projects. What sets the research campus apart is that, beyond these research initiatives, companies will now support institutes on site over the long term as they seek answers to vital questions.

3D printing evolves into innovative production tool

There are now some 40 Fraunhofer ILT and Chair for Laser Technology LLT researchers working on additive laser manufacturing techniques, also known as 3D printing. Once a technology restricted to rapid prototyping, it is developing into an innovative tool for the production of complex and customized parts. Lasers can provide workpieces with new properties and form them into almost any shape layer by layer – and not just prototypes or individual pieces, but in quantities relevant to series production. Many tool manufacturing, medical technology, automotive and aerospace companies use the technology to work on new developments.

The Fraunhofer AdaM innovation cluster, for instance, brings together leading companies in the energy sector and the aircraft industry, such as Siemens, MTU and Rolls Royce, to collaborate with Fraunhofer ILT and the Fraunhofer Institute for Production Technology IPT. With a budget of 10 million

Christian Hinke
Managing Director
of the Digital Photonic
Production
Research Campus

euros, research topics include additive manufacturing techniques for the production of aero engine components as well as gas turbines for generating energy.

Getting new technologies ready to go quickly into series production

At the research campus, partners are experimenting with new forms of collaboration, including the spin-in model. This offers companies the chance to set up on campus and conduct research alongside the scientists from Fraunhofer ILT and RWTH Aachen, focusing on topics that go beyond a short-term interest in new products. The companies – which include machine manufacturers such as TRUMPF and SLM Solutions as well as their customers such as BMW – are actively involved in research and training. Both sides benefit: the scientists learn what is of interest to industry, while the companies are involved in the research process at an earlier stage and obtain access to new findings more rapidly. This greatly increases the overlap between basic and applied research and simplifies the transfer of knowledge.

All these collaborations and projects are part of a bigger construction project: the RWTH campus. The plan is to attract private-sector investment of up to two billion euros to get industry and research working together in themed clusters. This “research city” will feature a total of 15 clusters. One of these is Digital Photonic Production, where the focus will be on optical technologies. The first DPP research teams are due to move into a new building on Campus-Boulevard before the end of the year.

An active role in shaping industry

In order to tie all these activities together, the 3D printing experts in Aachen have now set up an open group of interested industrial companies. The Industry Circle Additive Manufacturing (ICAM) offers these companies the opportunity not only to follow the activities going on in Aachen but also to take an active role in shaping the process.

Fig.2: Digital Photonic Production Research Campus - Options for innovative companies to settle in direct proximity to the Fraunhofer ILT and RWTH Aachen University.
Source: KPF Architects.

Fig. 3: Complex micro component, made with Selective Laser Melting. Source: Fraunhofer ILT, Aachen.

Dipl.-Phys. Christian Hinke
Managing Director of the
Digital Photonic Production Research Campus
Steinbachstr. 15
D – 52074 Aachen
Phone +49 (0)241-8906-352
Fax +49 (0)241-8906-121
Mail christian.hinke@ilt.fraunhofer.de
Web www.ilt.fraunhofer.de

Measuring during Production Using Optical Shaft Metrology

Steffen Richter
Jenoptik Industrial Metrology

Metrology works particularly efficiently when it can be used for operator-controlled inspections directly in the production line, or integrated in a fully automatically and cycle-dependent manner. However, this places high demands on precision, robustness, user-friendliness, measuring speed and stability. The Jenoptik Industrial Metrology Division has optimized its optical shaft metrology for these areas of application.

Measuring during production means performing measurement tasks directly on the production line rather than in the measurement lab. This allows quality assurance to be performed between the different production steps for a product, as an SPC measuring station for operator-controlled inspections, or as a fully automatic system that is incorporated directly into production. Due to the short response times on modern production lines, quality controls must be performed increasingly quickly and flexibly, while also achieving maximum precision and stability. This onsite relationship between measuring instruments and production machines also entails further challenges. Besides fluctuating temperature conditions and partially contaminated ambient conditions, these also include the potential for measurement results to be influenced by the operator.

HOMMEL ETAMIC opticline CA618 for operator-controlled inspections; measuring a crankshaft

For these precise reasons, the Jenoptik Industrial Metrology Division has for several years been investing in expanding optical shaft metrology for use in the tough production environment. HOMMEL-ETAMIC opticline instruments are designed precisely for these requirements, and with the C series, they offer measuring instruments for operator-controlled inspections during production, as well as the CA series, which are optical non-contact shaft measurement systems that support full automation and achieve the specified production cycle times.

Efficient Camera System

Non-contact optical metrology is almost universally suitable for all shaft-type parts. Whether these are electric motor shafts, crankshafts, pistons, turbochargers or other rotating parts, the speed and flexibility of an opticline represents an excellent alternative to conventional measuring systems. Dimensional parameters such as lengths and distances can be measured, as well as form elements, angles, radii, roundness, radial run-outs and much more.

The HOMMEL-ETAMIC opticline system is based on a cascaded camera system using the shadow image principle. Its unique diametric probing, i.e. from both sides simultaneously, enables measured values to be recorded quickly with fewer errors on the part. All measurements are taken fully automatically according to the set measuring program, and the optical principle provides measurements in rotation to a level of precision unrivaled by any other technology.

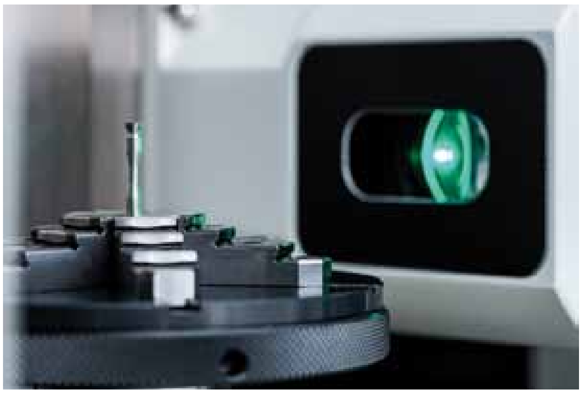
Robust with Long-Term Stability

The measuring machines must provide a high level of insensitivity in order to guarantee reliable results in the tough production environment. Jenoptik has therefore integrated

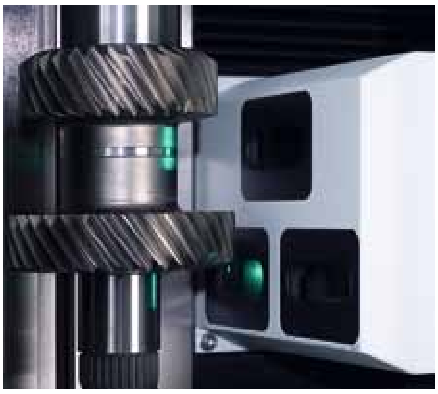
various monitoring functions into the machines, which can respond quickly to changing ambient conditions and eliminate unintended operator errors. This includes automatic calibration with integrated temperature compensation, and thus eliminating the need for a setting master for daily use in the operator's work process.

In addition, the robust design and precise assembly of the mechanical components ensure the highest level of reliability, guaranteeing consistent long-term stability in terms of quality assurance, specifically for lean production processes. Today, over 80% of Jenoptik's installed optical shaft measuring instruments have already been operating on the production line itself, right alongside machining centers, for many years and with a low level of wear.

For example, complete measurements are already being taken on engine valves with cycle times of under five seconds. The complete part contour is analyzed quickly and with high precision thanks to the high measurement resolution per individual measured value. This allows the system to measure diameters with tolerances of under 10 nm. The HOMMEL-ETAMIC opticline CA series can also be equipped with a tactile measuring system in order to handle special measuring tasks, such as axial run-outs and special length measurements, or even for features such as perpendicularity.



Measuring a valve piston



Measuring a drive shaft

Simple Operation and Fast Measurement Cycles for Operator-Controlled Inspections

The operator is provided with clearly structured software with an intuitive user interface in Windows, so test plans can be created, evaluated and displayed simply. The straightforward mapping of even complex testing tasks significantly reduces the amount of programming training required, and enables the measuring equipment to be used effectively in the process after only a very short period of time.

The simple but highly precise clamping mechanisms support both manual and automatic loading. The operator can then select from a range of viewing and output options for the measurement results. The measurement reports can be adjusted on a customer-specific basis and clearly document the production quality. If required, the measurement results can be analyzed directly on the screen. In automated processes, the results can also be fed directly in the upstream production process, massively reducing rejection rates.

In contrast to remote measuring stations, metrology located close to production, or even integrated into it, can be used to record, analyze and trace comprehensive measured data. This means that responding to errors is considerably faster and more effective. The measuring systems of HOMMEL-ETAMIC opticline products therefore not only ensure the quality of the parts, but also help to shape effective production line process control.

About Jenoptik and the Industrial Metrology Division

An integrated optoelectronics group, Jenoptik operates through five divisions: Lasers & Material Processing, Optical Systems, Industrial Metrology, Traffic Solutions and Defense & Civil Systems. Its customers around the world primarily include companies in the semiconductor and semiconductor equipment industry, automotive and automotive supplier industry, medical technology, security and defense technology and the aviation industry.

Jenoptik is one of the leading manufacturers of high-precision, contact and non-contact production metrology in the industrial metrology sector. Its portfolio includes total solutions for a wide range of measurement tasks, such as inspecting roughness, contours and form, and determining dimensions in every phase of the production process and in the measuring room. The portfolio is rounded off by an extensive range of services such as consulting, training and servicing, including long-term maintenance contracts.

JENOPTIK I Industrial Metrology
Steffen Richter
Produkt Manager Opticline
Prüssingstraße 41
D – 07745 Jena
Phone +49 (0)3641-232 904 51
Mail steffen.richter@jenoptik.com
Web www. jenoptik.com

Airyscanning – A Novel Approach to Confocal Imaging

We make it visible.

Confocal laser scanning microscopy (CLSM) is the recognized standard for 3D fluorescence microscopy. It combines excellent optical sectioning performance with flexible scanning strategies for imaging and photomanipulation, making it the method of choice for a vast range of applications. Airyscanning is a new detection concept that uses an array detector to oversample each Airy disk in order to gain sensitivity, resolution and speed.

Pinhole based laser scanning microscopy

In CLSM the sample is illuminated by a scanned focused laser beam. The emitted fluorescence signal is sent to a detector through a pinhole aperture which efficiently blocks out-of-focus light. Making the pinhole smaller increases resolution, yet at the same time less light reaches the detector, and - as a consequence - the signal-to-noise ratio (SNR) drops. In a typical experiment the pinhole will not be smaller than one Airy Unit (AU), sacrificing resolution for better SNR.

Limitations of classical CLSMs

Phototoxicity

The key challenge when imaging live samples is to maintain physiological conditions – especially for 3D acquisitions or long term time-lapse recordings.

While environmental conditions such as temperature or pH can be controlled by incubation systems, continuous exposure to excitation light induces cell damage (phototoxicity caused by the generation of free oxygen radicals). Therefore, the intensity and dose of excitation light needs to be minimized in order to get unbiased data from live samples. On the other hand, less excitation light means fewer photons will be emitted by the fluorescent label and the detector will struggle with a low SNR.

Expression levels of fluorescent labels

To make things worse, expression levels of exogenous recombinant proteins in cell assays should be kept low to avoid artifacts from overexpression. For example, viral transfection of vectors in effect adds populations of additional molecules to the pool of endogenous molecules of interest, potentially disturbing the "natural" balance and ultimately leading to biased results.

Genome editing technologies (CRISPR / Cas9 system, TALEN, ZFN; Nature Methods' Method of the Year 2011, [1]) have recently been developed to address this issue. They allow the interrogation of virtually any protein or set of proteins at endogenous expression levels. This poses an additional challenge for imaging systems as signal levels

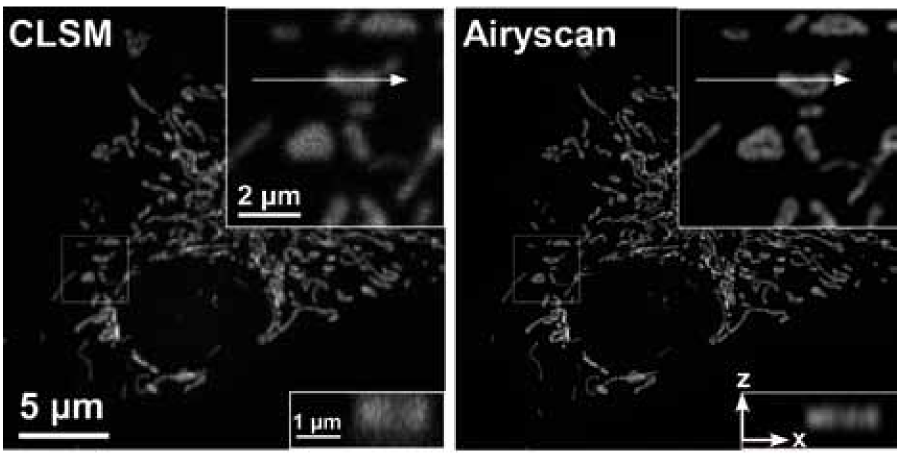


Figure 1: Confocal (CLSM) and Airyscan recording of a FluoCell #1 (InVitroGen) imaged for MitoTracker to visualize mitochondria. Shown in the upper right corner is a magnified view of the area indicated by the smaller squared box. The lower right corner shows an xz section along the indicated arrow in the inset. Image conditions were identical with a pixel size of 58 nm and a sectioning of 125 nm. Scales are indicated.

Dr. Ralf Engelmann
Product Manager
for Confocal Microscopy
Carl Zeiss Microscopy GmbH

Dr. Klaus Weisshart
Product Manager
for Confocal Microscopy
Carl Zeiss Microscopy GmbH

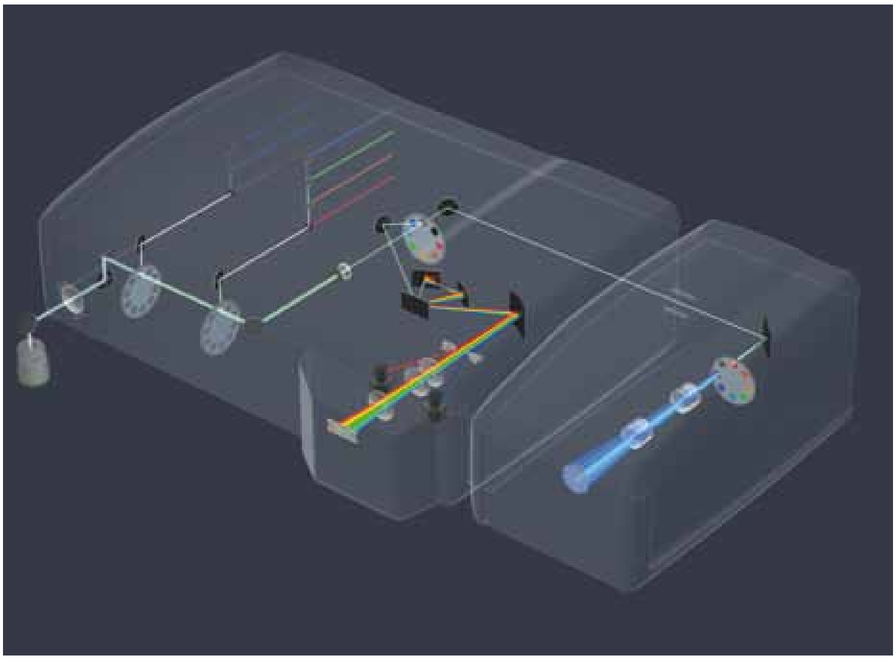


Figure 2: Beampath of ZEISS LSM 880 with Airyscan: Emission light travels through the Twingate main dichroic beam splitter, which has a very efficient laser suppression, delivering supreme contrast. Then all emission light travels either via the recycling loop to the internal spectral detection unit (Quasar) with up to 34 channels. Or, light is sent to the Airyscan detector with GaAsP technology.

can be very low. A quick calculation shows that, at 10 nM protein concentration, only 6 fluorescent molecules will be found in the typical confocal detection volume of 1 fL.

Small structures

Cellular machinery is organized in cellular subcompartments with sizes in the sub-micrometer to nanometer range. Decoding this machinery and watching it at work requires an imaging system with sufficient spatial and temporal resolution. For practical reasons the resolution of conventional CLSMs is limited to about 200 nm or more in X and Y, and 700 nm in Z, respectively.

Thus the ideal next generation CLSM would need to provide a balanced and flexible combination of:

- image quality (SNR) to identify and localize biological molecules of interest while minimizing input of light,
- speed to monitor these molecules and their interactions in space and time, and
- high resolution to image intracellular structures with sufficient detail in X-Y-Z.

Image scanning with a segmented detector array

An acentric, shifted pinhole detector produces an image of about the same resolution as a pinhole detector which is aligned to the optical axis, although smaller in amplitude and shifted by half the displacement. This insight has been the motivation for constructing an area detector for a confocal microscope.

Such a detector should cover more than 1 AU and contain multiple sub-Airy detector elements (Figure 2). Detection efficiency will be significantly increased by reassigning the detected photons from the shifted detector elements to the central detection position and summing up the back shifted signal from all detector elements [2]. No light is rejected by a closed pinhole but instead collected by the off-axis detector elements. Therefore an increased signal level arises from the reassignment of photons to a smaller spatial region [3]. At the same time this method delivers a lateral resolution enhancement by a factor of 1.7 [4, 5, 6, 7].

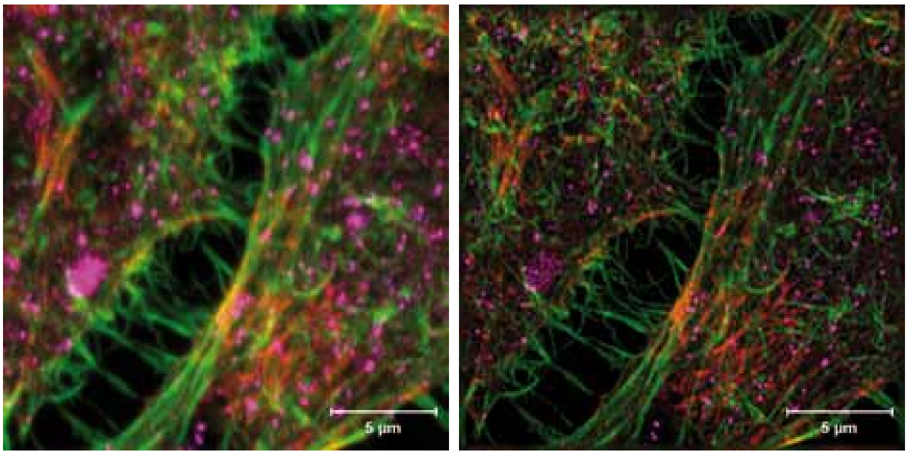


Figure 3:
Confocal (CLSM) and Airyscan imaging of HeLa cells, Actin stained with Phalloidin-Alexa 546, AP3 with Alexa 488, DAPI. Courtesy of S. Traikov, BIOTEC, TU Dresden, Germany

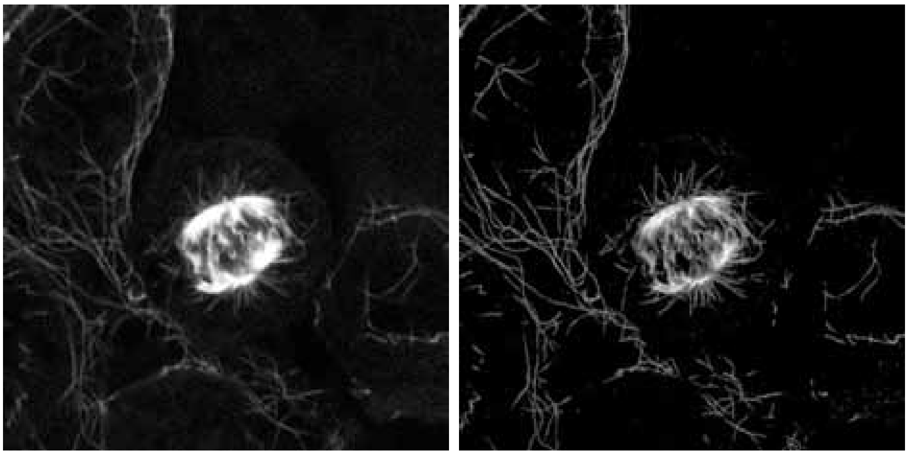


Figure 4:
Confocal (CLSM) and Airyscan imaging of fixed tumor cells, tubulin labelled with Alexa 555.
Sample courtesy of P. O`Toole and P. Pryor, University of York, UK

Airyscanning delivers enhanced resolution in all three spatial directions

Pure reassignment of detection does not improve axial resolution [5]. However, each detector element also acts as an individual pinhole. Each image can be individually deconvolved and weighted, and photons can be precisely reassigned. The additional information can be used for an isotropic, 1.7 fold- increase in resolution in all spatial directions (Figure 1).

Conclusion

Airyscanning allows a confocal microscope to realize its full potential, achieving resolutions comparable to an extremely small pinhole but with a much better signal-to-noise ratio (see Figures 3 and 4). Higher SNRs enable higher acquisition speeds, thus making it possible to image fast processes in 3D. Airyscanning works for any dye and is especially suitable for live cell imaging as the high sensitivity of the detection system allows the application of lower laser powers.

Airyscanning is based on confocal point scanning. Even thick samples can be penetrated easily in a situation where widefield-based superresolution techniques would struggle. Airyscanning lets the user decide whether to gain 1.7x higher resolution in all three dimensions, resulting in a 5x smaller detection volume. Or to push sensitivity beyond the limits of conventional confocals. Or to use the increase in signal-to-noise ratio to speed up image acquisition. It is simply a question of choice.

References:

[1] Nat Methods, 2012. 9 (1)
[2] Sheppard, C.J., Super-resolution in confocal imaging. Optik, 1988. 80(2): p. 53-54.
[3] Sheppard, C.J., S.B. Mehta, and R. Heintzmann, Superresolution by image scanning microscopy using pixel reassignment. Opt Lett, 2013. 38(15): p. 2889-2892.
[4] Muller, C.B. and J. Enderlein, Image scanning microscopy. Phys Rev Lett, 2010. 104(19): p. 198101.
[5] York, A.G., et al., Resolution doubling in live, multicellular organisms via multifocal structured illumination microscopy. Nat Methods, 2012. 9(7): p. 749-754.
[6] Roth, S., et al., Optical photon reassignment microscopy (OPRA). Optical Nanoscopy, 2013. 2(5): p. 1-6.
[7] York, A.G., et al., Instant super-resolution imaging in live cells and embryos via analog image processing. Nat Methods, 2013. 10(11): p. 1122-1126.

Carl Zeiss Microscopy GmbH
Carl-Zeiss-Promenade 10
D – 07745 Jena
Phone +49 (0)1803 33 63 34
Mail microscopy@zeiss.com
Web www.zeiss.com/microscopy

LOCI Technology – The next Step in High Sensitive Detection of Biomolecules

Since decades immunoassays play a pivotal role in clinical diagnostics. During the last years the demands for the detection of clinical relevant biomolecules significantly increased. Automation, lower detection limits, shorter turnaround times and cost effectiveness are the challenges to overcome. One approach to fulfill these expectations is the LOCI technology, a bead based immunoassay combining the advantages of chemiluminescence with a homogenous assay format, allowing the automated measurement of a wide range of biomolecules.

How does LOCI technology work?

The LOCI technology is an established homogeneous assay format that allows for fast, robust, and highly sensitive detection of binding reactions.

The assay is based on the proximity effect of two latex bead reagents (chemibeads and sensibeads) with a diameter of about 250 nm, each containing one half of a signal chain. The chemibeads contain an olefin that can react rapidly with singlet oxygen ($^1O_2$). The reaction yields a dioxetane that spontaneously decomposes emitting light, detected at a wavelength of 612 nm. The sensibeads, in which a photosensitizer such as phthalocyanine is dissolved, generate singlet oxygen when excited by light of 680 nm wavelength.

Because of the extremely short half live (4 µs) of the singlet oxygen, signal generation can only take place when sensibeads are bound to a chemibead. Unbound beads generate no signal.

The chemiluminescent reaction takes place within the interior of these latex beads where it is completely isolated from the sample matrix. This reduces backgroundsignal in the assays to a minimum, allowing to differentiate the specific signals down to extreme low analyte concentrations.

With specific reagents bound to the bead surfaces selected for the desired assay format the analyte-specific signals can be generated. Competitive assays can have a ligand on one bead and an antibody on the other. Sandwich assays can have different antibodies on each bead. During the immunoreaction the bead pair immunocomplexes are formed and the singlet oxygen source (sensibeads) is in close proximity of the singlet oxygen receptor (chemibeads).

Because the ligands coated to the bead reagents are arbitrary, using different crosslinking methods, a variety of biological reactions and interactions between biomolecules can be assayed, e.g. between proteins, peptides, haptens,

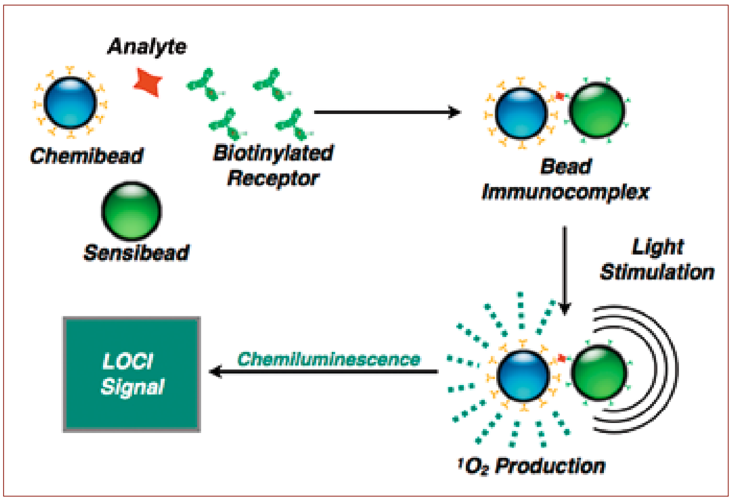


Figure 1:
Example for a LOCI sandwich assay using analyte-specific antibodies for detection with the streptavidin/biotin system as signal enhancer.

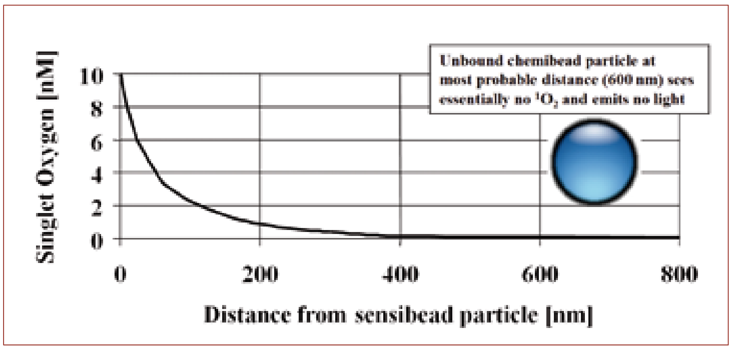


Figure 2:
Dependency of singlet oxygen concentration from distance between chemibeads and sensibeads

Dipl.-Ing. Matthias Ehm
Head of Development 4
Siemens Healthcare
Diagnostics Products GmbH

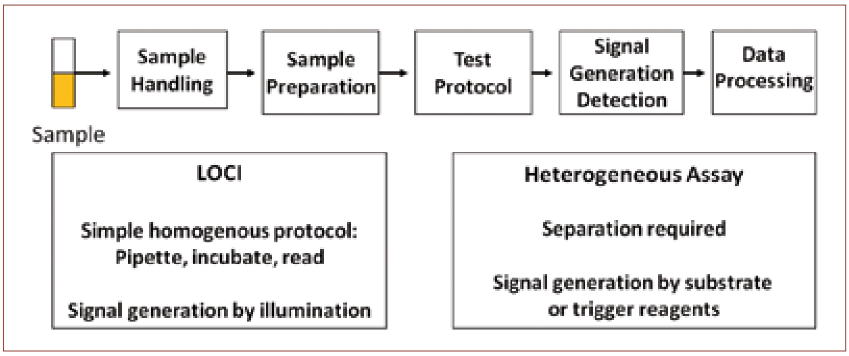


Figure 3:
Comparison of LOCI as homogenous assay format vs. heterogenous assays.

DNA, RNA, mRNA, enzymes or receptor-ligand interactions.

Advantages of LOCI technology in comparison to other immunoassay technologies

One benefit of the LOCI technology is its high sensitivity. The reason for this are the low background signals generated in the assays. Due to the long excitation wavelength of 680 nm and the shorter emission wavelength of 612 nm, interferences such as fluorescence, chemiluminescence, or stray light from the assay components are minimized. The accumulation of signal resulting from the singlet oxygen molecules generated by the sensibeads allows detection limits down to the attomole level.

Using small sample volumes down to 1 µl helps to prevent matrix effects and minimizes interferences caused by nonspecific binding. A blocking layer surrounds the beads to minimize potential nonspecific binding as well. Thus, the measurement of different sample materials like plasma, serum, urine, cerebrospinal fluid or whole blood samples and even of pediatric samples is possible without pretreatment or dilution of the sample material.

In comparison to other homogenous technologies, such as latex agglutination assays, interferences caused by light scattering are avoided by the LOCI technology.

Nonspecific binding to the beads increases linearly with time and can be minimized by measuring the signal during the initial rapid stage of the specific binding reaction, which results in fast turnaround times of the immunoassays.The average turnaround time for a single tube LOCI assay on a fully automated analyzer system is <10 minutes, making the technology highly attractive for measurement of acute care parameters in the clinical laboratory.

An ancillary effect is a wide assay range allowing the measurement over 4-5 decimal powers of analyte concentrations without predilution of the sample.

With 250 nm diameter of 250 nm, the beads do not settle out of water suspension allowing automated liquid handling. Because no washing or separation steps are needed the processing of the assay protocols is easy. The possibility to minimize the reaction volumes without changing reagent concentrations and without compromising sensitivity even allows the adaption to 96-, 384- and even 1536-well microtiter plate formats.

Conclusions

With the wide range of possible applications and significant advantages in comparison to other immunoassay technologies, LOCI technology has the potential to overcome so far established assay formats, such as latex enhanced immunoassays or heterogeneous immunoassays. The ease of automation makes it highly attractive for applications on diagnostic analyzers for detection of clinical relevant parameters in even lowest concentrations. Key features of the technology are high precision, great sensitivity, rapid assay processing times, wide assay ranges, ease of automation and increased accuracy by using low sample volumes.

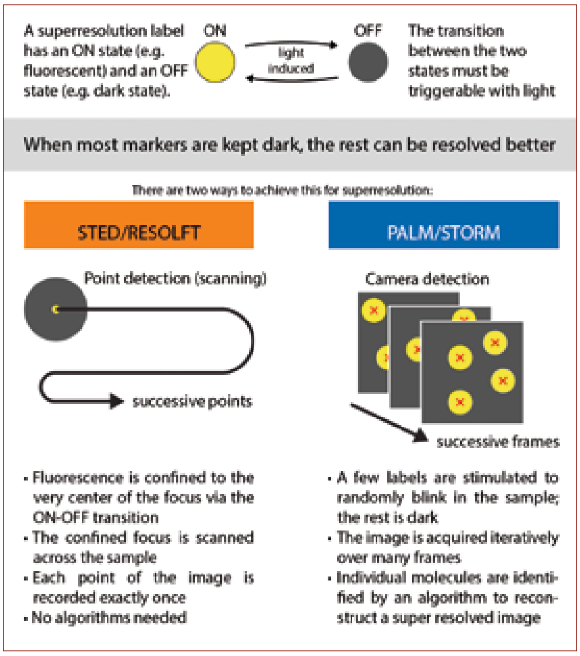
Dipl.-Ing. Matthias Ehm
Pre-Development
Head of Development 4
Siemens Healthcare Diagnostics Products GmbH
Emil-von-Behring-Str. 76
D–35041 Marburg
Phone +49 (0)6421-396020
Fax +49 (0)6421-394688
Mail matthias.me.ehm@siemens.com
Web www.healthcare.siemens.de

Breaking the Diffraction Barrier – Today's Rapid Transition from Microscopes to Nanoscopes

Light microscopy has revolutionized our understanding of matter and living matter in particular. Light can penetrate whole and even living cells, and is exceptionally suitable for observing the structure and live workings of cellular machinery. The importance of this can hardly be underestimated and is further underlined by the fact that light microscopy has been successful for centuries despite its relatively poor resolution. Even after better-resolving electron and X-ray microscopes had become available, light microscopy continued to play a key role in biology due to its versatility, ease of operation and overall usefulness.

Yet, a major drawback was the resolution limit, i.e. the effect that any two points in the sample that are closer than ~200 nm undiscernibly mingle into a single spot. The fundamental breakthrough in this direction came in the early 90s when Stefan W. Hell invented STED (Stimulated Emission Depletion), the first type of light microscopy that was able to truly overcome the resolution barrier in the far field. Already a few years after the publication of the theoretical concept, cells and even living cells were super resolved with the new STED nanoscopes and in the late 2000s more technologies followed in the wake, such as PALM/STORM and RESOLFT. As of today, the current superresolution performance leaves no doubt that the new technologies will sweep aside the microscopes of the 'old world' (Fig1) and this irresistible displacement is further fueled by the 2014 Nobel Prize in Chemistry awarded to Stefan Hell and two U.S. colleagues.

Top: Confocal and STED image of two nuclear pore complex proteins: gp210 (red) and pan-FG(green) Bottom: Widefield and RESOLFT image of living HeLa cells expressing keratin (red) and Vimentin (green)



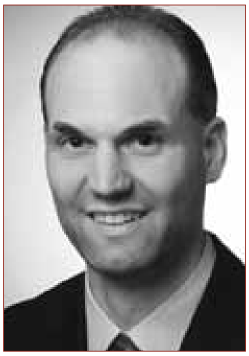
Chemistry and Nanoscopy?

The common denominator in all optical superresolution technologies is that marker molecules are repeatedly transferred between two distinct states, namely a bright one and a dark one.

It is easily realized that when most markers are dark at a particular instant of time, the few remaining bright ones can more easily be told apart, instead of mingling together.

The only difference between all methods is merely how the markers are transferred between the states: with STED and RESOLFT this is achieved in a deliberate manner through a light field shaped such that it suppresses all markers except a few in the very center of the targeted readout focus, while in the PALM/STORM world, the mark-

Dr. Gerald Donnert
Managing Director
Abberior Instruments GmbH



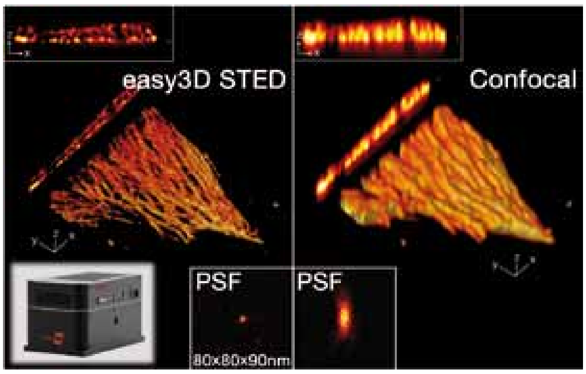
Dr. Matthias Reuss
Manager R&D
Abberior Instruments GmbH

ers are made to blink randomly such that only a few are emitting at each moment in time, but at random positions in the sample (Fig2). The latter methods create super resolution images only with the help of reconstruction algorithms.

Superresolution microscope products and vendors

Rapid market transformation

These new technologies have already conquered the portfolio of existing microscope vendors. On top of that, new companies such as Abberior Instruments have successfully entered the scene with new, innovative products and fast time-to-market capabilities (Fig3) – as is often observed when disruptive technologies stir up settled markets.



easy3D STED module and resolution performance demonstrated by imaging a volume sample of tubulin labeled with Abberior STAR635P. Top inset: x-z section of the same stack. Bottom inset: PSF (point-spread-function) of easy3D STED compared to confocal imaging

The ongoing development in superresolution is rapid; new innovations are published on a half-year basis by the scientific community. The most recent wave of innovation has pushed nanoscopy from two to three dimensions, a transition that virtually all superresolution techniques have followed. With resolutions below 80x80x90 nm, easy3D STED microscopes now routinely surpass the diffraction barrier by far (Fig4) and many more major improvements are on their way. Users can expect the methods to advance further in all aspects, e.g. resolution, speed and contrast. Interestingly, the biggest single lever here is the improvement of the superresolution labels themselves. Already as of today, nanoscopes could immediately deliver a much better performance and even sharper images, if only the markers supported it.

Optical imaging is and has been a vital tool in biological and medical sciences. We can only imagine how its importance will increase in the next years, now that the one major drawback of limited resolution has been put out of the way. Undoubtedly, the new methods will play a major role in understanding the mechanisms of life on the nanoscale, all with the joint perspective to fight diseases in a more sophisticated way and more sucessfully than today.

About Abberior Instruments:

Abberior Instruments is a spin-off from the department of Stefan Hell commercializing the latest innovations of STED and RESOLFT nanoscopy in an open platform. This approach supports innovations cycles of 6 to 9 months to develop new innovations into commercial offerings. Its sister company Abberior develops fluorescent markers dedicated to superresolution imaging. The combination of superior STED dyes and nanoscopes adopted to these markers leads to the best resolution performance technically possible.

Abberior Instruments GmbH
Hans-Adolf-Krebs-Weg 1
D – 37077 Göttingen
Phone +49 (0)551-30724-170
Fax +49 (0)551-30724-171
Mail info@abberior-instruments.com
Web www.abberior-instruments.com

3D Technology – Improving the OR Situation in Laparoscopy

Fig. 1
Einstein Vision 2.0 - 3D camera technology from Aesculap

Laparoscopic techniques in surgery are nothing new. This minimally invasive - or “keyhole” surgery - has been used for more than 20 years in general surgery, gynecology and urology. Although these procedures were initially used as a diagnostic tool, they have evolved into therapeutic and surgical procedures. Laparoscopic surgical techniques are continuing to gain acceptance worldwide. On the one hand new surgical procedures are being developed, on the other hand laparoscopic techniques are increasingly replacing the classic open surgical procedures. Smaller incisions, less pain, faster healing, better cosmetic outcomes, less medication, shorter hospital stays: These are the advantages patients reap from undergoing laparoscopic surgery.

The Standard Today

The prerequisite for operating laparoscopically is the ability to transfer images from the closed abdominal cavity to a visualization medium. Various components are required for this, e.g. lenses, a camera, light source and a monitor. The current standard is a two-dimensional representation of the operating image on the monitor. Consequently, the surgeon must train himself to imagine the third dimension, i.e. the image depth. With proper training and experience, it can be done, and can result in excellent surgical outcomes. It is an undisputed fact that excellent image contrast, realistic colors and superior image resolution is critical to a surgeon. This is the only way to clearly distinguish fine tissue structures and vessels. In recent years, all of these factors have been technologically optimized step by step. For example, the trend has been moving away from analog technology and toward developing full HD technology.

The Third Dimension Returns

The surgeon of today is closer than ever to incorporating this missing third dimension into surgical procedures. In the consumer sector, 3D is almost part of everyday life, such as 3D TV or 3D movies at the cinema. The idea of using 3D in laparoscopy is not new. Surgical laparoscopy first made inroads into medicine back in the 90s. However, the then technical solutions could not be implemented, due either to technology that was still insufficiently developed, or the fact that some surgeons have worn glasses - and all of them have worn medical garb - both of which severely restricted the surgeon; or due to the fact that prohibitive acquisition costs prevented hospitals from purchasing this technology. Moreover, criticism is constantly levied that, to date, no randomized studies have been carried out that demonstrate that 3D technology achieves significantly better surgical outcomes than other technologies. These conditions have, however, been changing. Investment costs are now economically feasible. Even experienced surgeons report that 3D imaging makes their work much easier, and that using it, they are less fatigued after performing several operations in one day. By now, it is an undisputed fact that younger, inexperienced surgeons are becoming proficient in laparoscopic surgical techniques more quickly, and can perform more complex operations more competently. Therefore, it is not surprising that in a few years, it is expected that more than half of all cameras in operating theaters will be 3D cameras.

Fig. 2
3D camera head and control unit

Klaus Hebestreit
Director Group
Product Management
Endoscopic Technologies
Aesculap AG

Three-Dimensional Technology

The 3D concept Einstein Vision 2.0 from Aesculap is based on delivering extremely high-resolution image quality in full HD. Without any compromises. Current technology uses two cameras that record the image from two different angles and then superimposes the images. The image is rendered on a medically approved 3D monitor. Lightweight 3D polarized glasses allow the surgeon and the entire surgical team to see the image in 3D. 3D medical imaging is used in laparoscopy, minimally invasive procedures in cardiothoracic surgery and in pediatric surgery.

Fig.3: Single-use camera cover for sterile product handling

Fig. 4: Einstein Vision 2.0 - a solution for daily clinical use

Challenges of the Future

Without a doubt, one challenge is to offer an entire range of different lens diameters. Whereas 2D technology comprises rigid lenses ranging from 10mm to 2.7mm, 3D technology primarily offers 10 mm solutions. Smaller diameters are available but require significant compromises in the usual picture clarity.

Another challenge is of course cost. Cost here includes not only the purchase price but the cost of maintaining this technology as well. In particular, these costs are determined by the number of daily operations, the number of endoscopes/camera heads required, and the reprocessing procedure. By default, endoscopes today are autoclaved. This has a demonstrably negative effect on lens service life. Einstein Vision 2.0's concept is different and more cost-effective. Sterility is provided using a sterile cover. This results in a significantly reduced number of endoscopes/camera heads that need to be held available. The life of these products is extended considerably, and Einstein Vision 2.0 are available at any time and do not require much preparation.

No doubt, vision without glasses (autostereoscopy) will be possible in the foreseeable future. In this respect, however, the medical industry is extremely dependent on monitors being advanced in the consumer sector. It is expected that in the coming years a number of new developments will further influence 3D camera technology. 3D visualization is now an integral part of the modern operating room and is sure to establish itself worldwide.

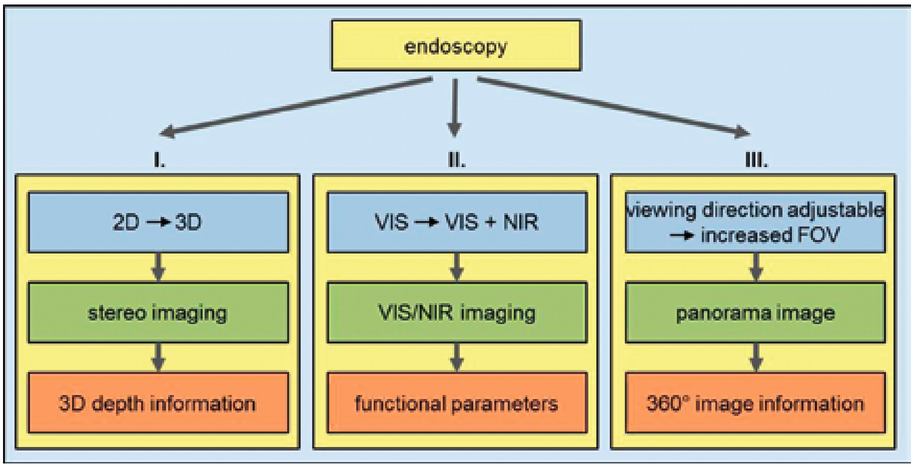
Klaus Hebestreit
Director Group Product Management
Endoscopic Technologies
Aesculap AG
Am Aesculap-Platz
D – 78532 Tuttlingen
Phone +49 (0)7461-95-2645
Mail klaus.hebestreit@aesculap.de
Web www.aesculap.com

Current Innovations in Endoscopy

**Dr. Klaus-Martin Irion, Global Vice President
Research & Technology, KARL STORZ GmbH & Co. KG**

Today, endoscopy and minimally invasive surgery are used in a significant percentage of surgical treatments. Although current endoscopic systems have reached high quality standards in terms of imaging and illumination, efforts are underway to further advance endoscopes in various ways.

Fig. 1: Trends in endoscopy



In addition to endeavors to further improve image quality, specific areas of development (Fig. 1) include:

I. Expanding image acquisition from 2D to 3D,
II. Expanding the spectral range beyond the visible range, and
III. Designing a variable direction of view and increasing the field of view (FOV).

I. 3D endoscopy

As was the case for microscopes, calls for binocular endoscopes were voiced very early. Not surprisingly, the first patents for stereoscopic endoscopy date back to over 100 years ago. With the beginnings of video-assisted endoscopy, the first stereoscopic video endoscopes were developed and launched in the mid 1990s. These first generation systems were not competitive due to their low image quality. The newest generation stereoscopic video endoscopes from KARL STORZ (Fig. 2) successfully integrate two high-resolution optoelectronic imaging systems at the distal end ("twin chips on the tip").

When compared to the previous approach with two optical transmission systems and proximal cameras, distal integration offers the following advantages:

- Easy and ergonomic support and handling
- High system stability
- No relative misalignment of the two optical transmission systems
- Autoclavability
- Full HD resolution and full frame 16:9 display

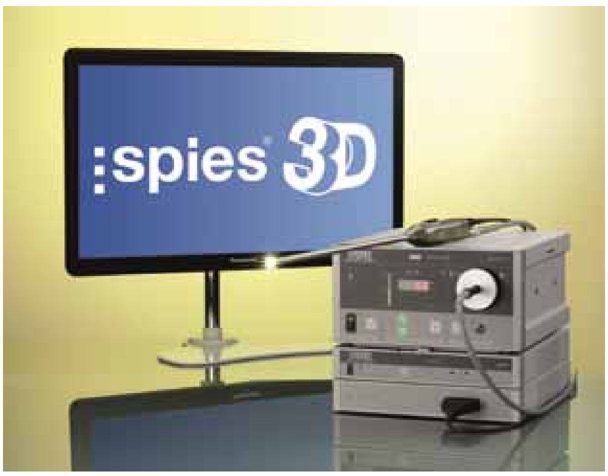


Fig. 2:
Stereoscopic video endoscope:
KARL STORZ TIPCAM® 1 3D

Pre-clinical testing has demonstrated that this newest generation system enables beginners as well as highly experienced surgeons to work faster and more safely. The high-resolution 3D view makes distances between various instruments and between instruments and the surgical site much more visible. Accurate depth perception is a great advantage, particularly in difficult maneuvers such as endoscopic suturing. In addition to supplying a stereoscopic view of the surgical site, this system permits 3D surface reconstruction of intracorporeal structures. This 3D reconstruction from the optical image data permits advanced correlation with tomographic image data /1/.

II. Near infrared endoscopy

Standard white light endoscopy is conducted in the visible spectrum (VIS) at 400 to about 700 nm. The employed Xenon and LED light sources guarantee sufficient luminance for endoscopic procedures. Spectral expansion into the near infrared range (NIR) generates additional tissue information. Near infrared endoscopy is supported by optical contrast agents, such as indocyanine green (ICG), which allow fluorescence imaging of vascular structures (Fig. 3) or quantitative perfusion assessment. By overlaying the NIR fluorescence image and the white light image, the anatomy and tissue perfusion information can be optimally combined. If tumor-specific NIR markers are available, tissue can be endoscopically differentiated or characterized as well /2/.

III. "Flexibility" in rigid endoscopy

A great advantage of flexible endoscopes is the fact that their direction of view can be adjusted, allowing the user to look straight ahead as well as "around the corner". Thanks to a novel optical design and microintegration, rigid endoscopes can now be designed with a variable direction of view (Fig. 4). Currently, rigid endoscopes are available with 0° to 120° variable direction of view and diameters of 10 mm to 4 mm. In procedures requiring different directions of view, surgeons can now use a single telescope, thereby eliminating endoscope switches. Applications include laparoscopic intestinal surgery, arthroscopy, and sinus surgery. With controlled changes in the direction of view and endoscope rotation, users can even record panoramic images /3/.

Fig.3 Imaging of a lymph node using ICG fluorescence

These innovations improve endoscopic procedures and expand endoscopic applications to new fields and treatments. Technology transfer from medicine to non-destructive optical materials testing is an obvious next step.

In the past, endoscopy has supplied purely qualitative image information – but it is increasingly also becoming a quantitative imaging method that allows acquisition and display of depth information, functional information, and information about a wider field of view.

Literature

/1/ Peter Mountney et al.: An Augmented Reality Framework for Soft Tissue Surgery; MICCAI 2014

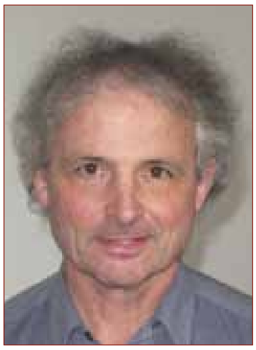
/2/ Zhenyue Chen et al.: Single camera imaging system for color and near-infrared fluorescence image guided surgery; Biomedical Optics Express, 2014

/3/ BMBF-Verbundprojekt Endoguide, 2012

Dr. Klaus M. Irion
KARL STORZ GmbH & Co. KG
Mittelstraße 8
D – 78532 Tuttlingen
Phone +49 (0)7461-708-275
Mail Klaus.Irion@karlstorz.com
Web www.karlstorz.com

Fig. 4:
Endoscope with variable direction of view: KARL STORZ ENDOCAMELEON®

New Network (Node) Concepts in Optical Networks



Dr. Eugen Lach
Alcatel-Lucent
Bell Labs Germany

Currently optical networks are evolving away from a static network architecture which was optimized before the deployment towards a flexible and reliable optical infrastructure. This is considered as a basic prerequisite for future elastic communication networks which are able to supply the steadily growing demand for transport capacity, exhibit flexibility to adapt to permanently changing traffic, enabling reliable transport and supporting the setup of new services. Elasticity enables flexible adjustment of network resources to the network load.

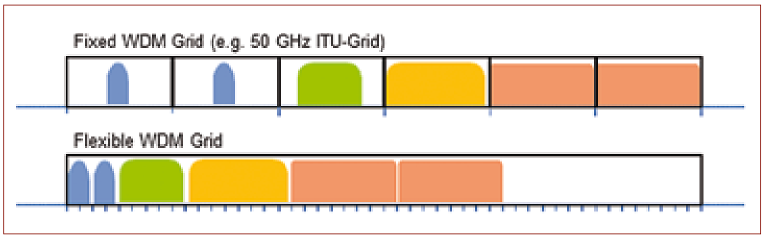


Fig. 1: Optical channel allocation on a fixed WDM Grid and on a flexible WDM Grid.

Flexibility of optical networks covers both, the flexibility of the optical network nodes concerning switching and routing of optical lightpaths as well as a variable utilization of the optical spectrum of wavelength division multiplexed (WDM) channels.

In the upper part of figure 1 spectra of several WDM channels on a periodic standardized fixed wavelength grid are depicted schematically. The figure displays a mixture of WDM-channels with different data rates e.g. 10 Gbit/s, 40 Gbit/s, 100 Gbit/s as well as 400Gbit/s formed by two 200 Gbit/s channels.

Depending on the data rate of WDM-channels which are collocated on a fixed periodic wavelength grid the utilization of the optical spectrum is different leading to inefficient use of the optical bandwidth. By re-arrangement of the WDM channels on a flexible quasi continuous wavelength grid at lower granularity, as shown in the lower part of figure 1, unused spectral gaps between the optical channels can be avoided and continuous spectral regions are cleared which can be populated with further optical channels in order to increase the transport capacity of a WDM link. On the other hand a re-arrangement of WDM channels is required to realize new optical light paths over concatenated fiber spans.

Logical optical channels carrying even higher data rates, e.g. 400 Gbit/s or 1 Tbit/s can be realized by a combination of multiple neighboring WDM channels form-

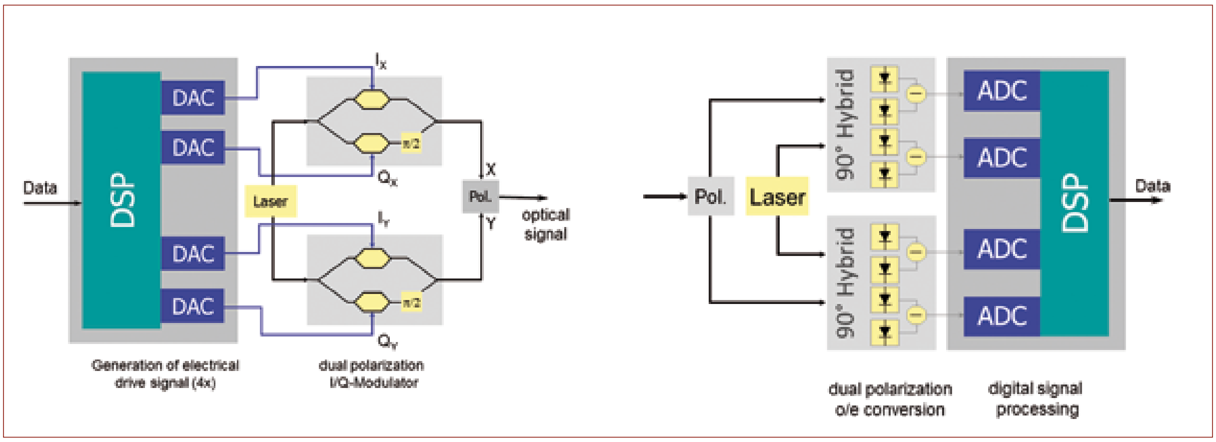


Fig. 2: Schematic setup of an optical software-defined multi-format transponder (left: Tx part, right Rx part).

ing a super channel which is transmitted as one conjunct channel in a flexible WDM-grid.

Flexible optical networks are based on programmable flexible network nodes as well as on software controlled terminal equipment like multi-format transponders.

Flexible optical transponders consist of adaptive multi-format transmitters and coherent receivers with software controlled wavelength and data rate. The data rate is defined by the symbol rate, by the selected modulation format

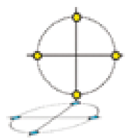
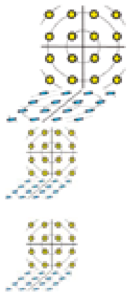
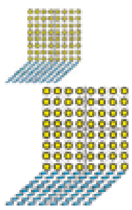
Modulation format	DP-QPSK	DP-16QAM	DP-64QAM
Spectral efficiency [Bit/s/Hz]	2	4	6
Constellation			
Reduction of sensitivity [dB]	0	7.0	13.3

Fig. 3: Comparison of constellations of dual-polarisation signals with various modulation formats.

and by the polarization multiplex which is usually applied in coherent systems.

The setup of multi-format transponders is depicted in figure 2 schematically. Digital signal processing (DSP) in combination with high speed electronic digital-to-analog-converters (DAC) which drive a dual polarization I/O-modulator are the main building blocks of multi-format optical transmitters. In the receiver coherent detection together with analog-to-digital converters (ADC) and digital signal processing enable polarization demultiplexing, chromatic dispersion compensation and data recovery. Coherent system utilize combined modulation of the optical amplitude and optical phase of the carrier to achieve very high channel capacity enabling very high spectral efficiency (up to 10 Bit/s/Hz or even more) in contrast to classical optical systems applying sole amplitude or sole phase modulation reaching only low spectral efficiency of typically 0.2-0.4 Bit/s/Hz.

Figure 3 depicts constellations of a selection of dual-polarization signals with various modulation formats and summarizes their main characteristics.

Programmable transponders enable the adaptation of an optical channel to different optical characteristics in WDM links for optimum utilization of available network resources. The symbol rate which determines the optical signal bandwidth can be adjusted to cope with the available optical channel bandwidth. The modulation format can be adapted to enable reliable optical transmission for a given noise level of a link. The selection of an adequate signal format under varying conditions and boundaries is key for reliable transmission and optimum usage of resources and to reach the maximum capacity of a network.

Future agile optical WDM networks which will be operated on a flexible wavelength grid require reconfigurable optical add-and-drop multiplexer (ROADM) which increased flexibility in the optical part. Fixed optical multiplexer and demultiplexer of current ROADMs are replaced by novel wavelength selective switches (WSS) which provide multiplexing and demultiplexing functionality with adjustable filter curves compatible with flexible WDM-grid.

A schematic setup of a flexible node with WSS based ROADM architecture is depicted in figure 4.

In summary, flexible optical networks comprising programmable flexible nodes as well as software controlled multi-format transponders are the basis for future agile communication networks. WDM transmission on a flexible

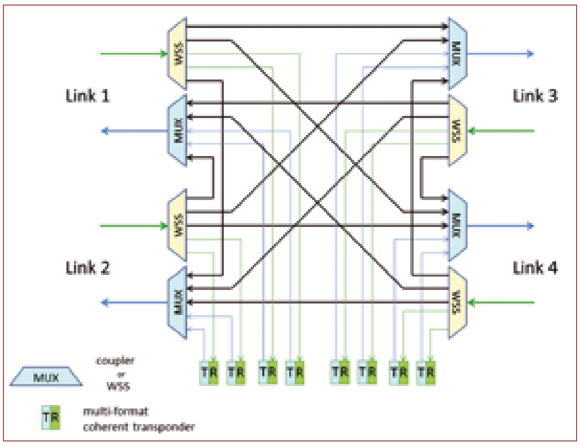


Fig. 4: Scheme of a flexible optical network node with WSS-based ROADM architecture.

WDM grid together with adaptive multi-format transponders enable realization of software controlled elastic optical networks, which are characterized by reliable high capacity transport and efficient utilization of network resources.

Alcatel-Lucent Deutschland AG
Dr. Eugen Lach
Bell Labs Germany
Lorenzstraße 10
D – 70435 Stuttgart
Phone +49 (0)711-821-34168
Fax +49 (0)711-821-32436
Mail eugen.lach@alcatel-lucent.com
Web www.alcatel-lucent.com

Wavelength-Division Multiplexing for Next-Generation Broadband Networks

Dr. J.-P. Elbers
ADVA Optical
Networking SE

Dr. K. Grobe
ADVA Optical
Networking SE

Over the last 20 years, communications have drastically changed: What once provided means for voice calls between persons now delivers media streams and files between machines and users. Consequently, bandwidth demands have dramatically increased. Broadband connectivity is becoming a critical resource for the modern society and a prerequisite for industrial competitiveness.

Fostering the broadband build-out is on the strategic agenda of governments worldwide. In the Digital Agenda 2014-2017, the German Government declared a broadband infrastructure delivering download speeds of at least 50 Mb/s as national target for 2018 [1]. The Network Alliance Digital Germany, a high-level group of network operators and telecommunication providers under leadership of the Federal Ministry of Transport and Digital Infrastructure (BMVI), defines measures to achieve this goal in a fast, modern and sustainable way while preparing the ground for future Gigabit connectivity [2]. The broadband coverage is continuously monitored and reported in the Breitbandatlas [3]. Fig. 1 shows some key figures for broadband in Germany, derived from publicly available data (rounded numbers). While a mix of technologies will be used to provide ubiquitous end-user access in the first mile, there is broad consensus that optical fiber networks need to be brought closer to the user. Fiber to the distribution point, building, home and antenna (FTTdp/B/H/A) technologies will become mandatory for Gb/s and beyond per-user speeds, as the serving areas for copper and wireless technologies rapidly decrease with increasing data rates. As the average revenue per user and capital cost reductions are limited, service providers are seeking ways to better exploit their network infrastructure and to significantly reduce the operational costs of their next-generation networks. Specifically, two concepts are currently being debated: active site consolidation and fixed-mobile convergence.

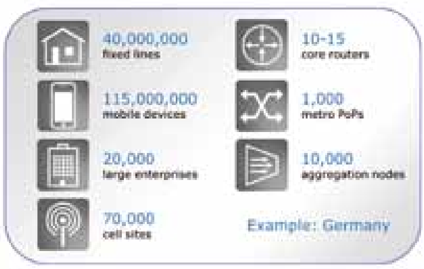


Fig. 1: Broadband in Germany – Key Figures

Active site consolidation describes the concept of shutting down a significant part of the active sites (local exchanges, cabinets, distribution points) in a network. This step is complemented by a concentration of the necessary network functions in fewer but bigger remaining sites. This approach reduces real-estate related expenses, energy consumption, and maintenance costs.

Fixed mobile convergence describes the concept of merging fixed and mobile networks to achieving resource pooling gains and operational simplifications. Convergence can be realized on a structural level by leveraging a common network infrastructure and employing a unified access and/or backhauling technology. Convergence on a functional level means sharing of common network functions such as firewalling, authentication, load balancing.

Active site consolidation and fixed mobile convergence leave few choices for an efficient and scalable network infrastructure. Site consolidation leads to an increase of access link lengths. Fixed mobile convergence causes an increase in fiber bandwidth. With fiber becoming a scarce resource at the network edge, transmission of a single channel per fiber is increasingly uneconomic.

Introducing wavelength division multiplexing as convergence technology allows the transport of high-bitrate business, backhauling and mobile front- hauling services over the same passive infrastructure and paves the way to high-capacity residential fiber access. The wavelength domain provides a clear separation between different services and serves as passive "underlay". While CWDM (coarse wavelength division multiplexing) technology has historically been used in this context, the capacity and reach of such technology are limited. A DWDM (dense wavelength division multiplexing) passive optical network (DWDM-PON) is desirable allowing transport of 40 and more channels over distances in excess of 40 km at comparable cost (Fig. 2).

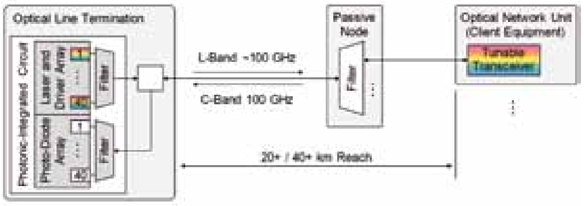


Fig. 2: Base configuration of a tunable DWDM-PON system

Automatic wavelength tuning and integrated monitoring functions can facilitate an auto-configuration of the optical layer and reduce sparing and maintenance efforts. Different optical filter configurations allow tree-type, drop-line and ring architectures and avoid the loss problems inherent in competing approaches employing optical power splitters.

The potential of tunable DWDM-PON technology has long been recognized, but maturity and availability of cost-effective optical technology as well as the lack of standards were impediments preventing a commercial introduction so far. With financial support by the BMBF and in collaboration with partners from industry and academia, substantial progress was made in overcoming these obstacles. In the projects ADVAntage-PON [4] as well as PIANO+ IMPACT and TUCAN [5], system concepts for a tunable DWDM-PON as well as missing optical and RF components along with related assembly technologies were developed.

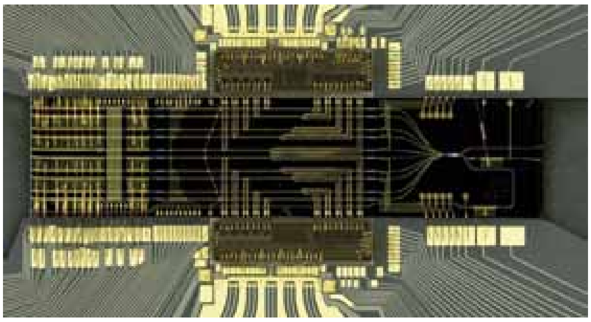


Fig. 3: 10 x 10 Gb/s tunable DWDM PIC, integrated with high-speed drivers (courtesy of Fraunhofer IZM Institute)

Fig. 4: Tunable 1-2.5 Gb/s bidirectional transceiver on Polymer motherboard (courtesy of Fraunhofer Heinrich-Hertz-Institute).

[1] http://www.bmwi.de/English/Redaktion/Pdf/digital-agenda-2014-2017
[2] http://www.bmvi.de/SharedDocs/DE/Publikationen/Digitales/kursbuch-netzausbau.pdf
[3] www.breitbandatlas.de
[4] http://www.photonikforschung.de/fileadmin/Verbundsteckbriefe/2._Kommunikation/ADVAntage-PON_Projektsteckbrief-korr02.2013.pdf
[5] http://www.pianoplus.eu/

As an example, Fig. 3 shows a 10 x 10 Gb/s tunable DWDM photonic integrated circuit (PIC) from the PIANO+ IMPACT project. The PIC is developed by Oclaro Inc. integrated with drivers co-developed by Saarland University and Micram GmbH, fabricated by Infineon AG, and assembled by the Fraunhofer IZM institute. The PIC includes 10 full-band tunable lasers along with Mach-Zehnder modulators to allow low-chirp modulation up to 10 Gb/s speeds for reaches up to 80km.

Another example is a tunable bidirectional optical transceiver chip for the ONU, which was realized by the

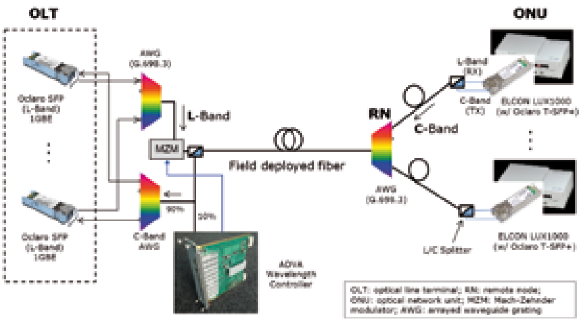


Fig. 5: Experimental set-up of tunable DWDM-PON system with central wavelength control.

Fraunhofer Heinrich-Hertz-Institute in the ADVAntage-PON project using their Polymer motherboard technology. The transceiver incorporates a full C-band tunable laser and an L-band receiver along with a diplexer facilitating operation over a single input/output fiber.

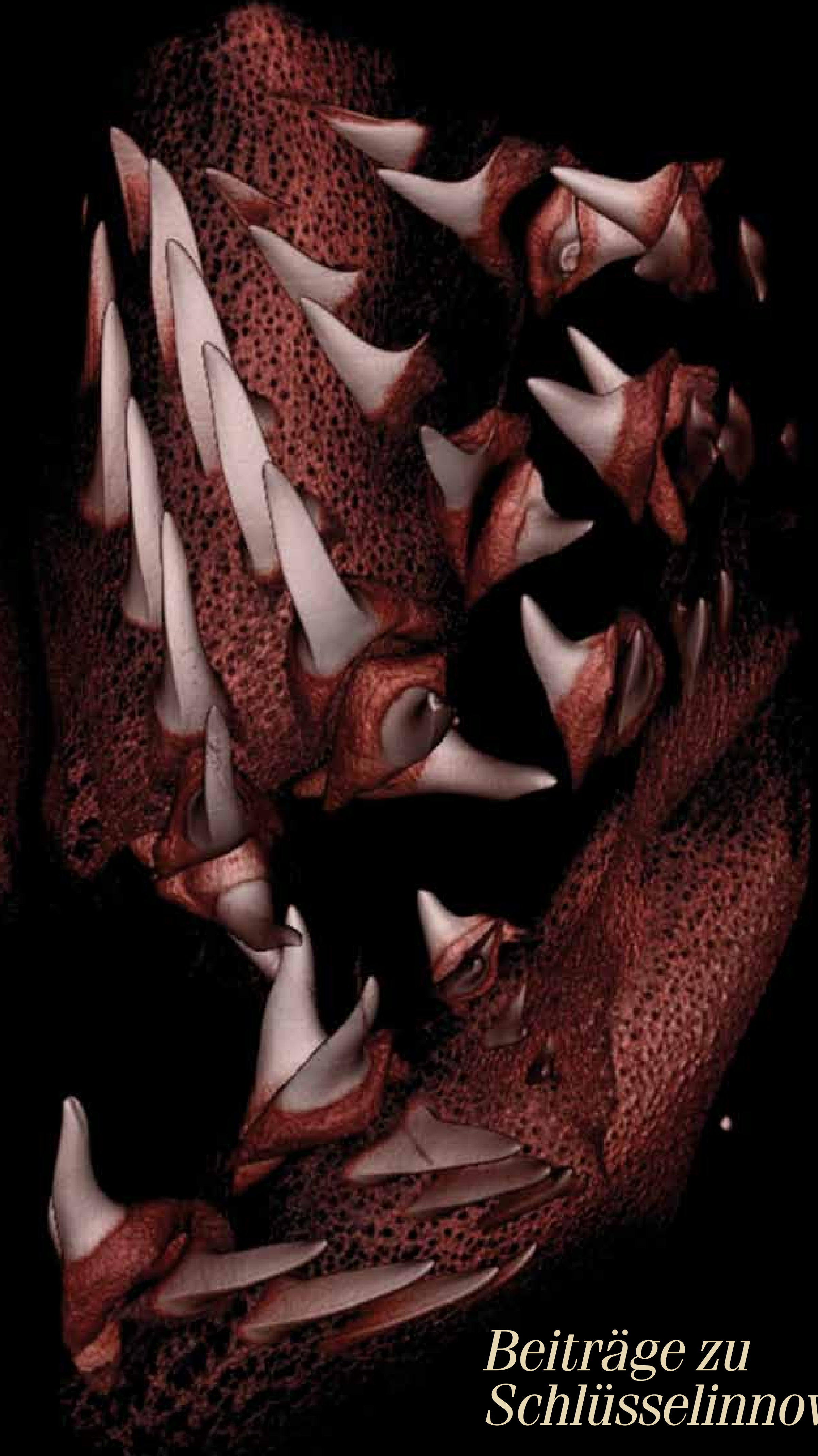
A further example of project results is a joint field demonstration of the PIANO+ IMPACT and TUCAN projects, performed together with ELCON Systemtechnik, Energie AG Oberösterreich, Oclaro, and University Cambridge in Austria. Automatic remote wavelength tuning of the ONUs was demonstrated using a centralized wavelength controller from ADVA Optical Networking.

Technical outcomes of the projects formed also the basis for contributions to international standardization for next-generation PON and next-generation passive metro WDM systems, primarily in ITU-T Study Group 15, Questions Q2 (Access) and Q6 (Metro). Part of this work can now be found in upcoming ITU-T recommendations G.989 and G.metro.

Looking back to early WDM-PON concepts, significant progress has been made in recent research projects, paving the way to a commercial introduction of DWDM-PON technology in next-generation access and backhaul networks.

ADVA Optical Networking SE
Dr. Jörg Peter Elbers
Vice President Advanced Technology
Fraunhoferstrasse 9 A
D – 82152 Martinsried
Phone +49 (0)89-890665-617
Mail JElbers@advaoptical.com
Web www.advaoptical.com

Contributions to Key Innovations



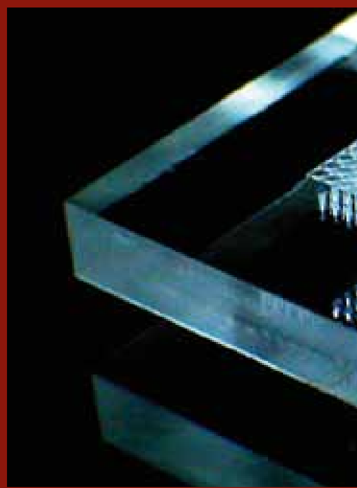
Beiträge zu Schlüsselinnovationen

Fiber-based Femtosecond Lasers – a Reliable Tool for Innovative Processes

Dr. Klaus Hartinger, Dr. Matthäus Halder, Dr. Ronald Holzwarth, Dr. Michael Mei

Femtosecond (fs) laser systems with high pulse energies on the micro-Joule (µJ) level are moving into medical and industrial applications and are becoming ever more widespread in life science. The key advantage lies in the fact that with fs lasers almost any material can be machined with equal precision and quality. There are numerous examples where the particular advantages of fs µJ laser pulses as a precise and versatile tool become significant. For many years now, ophthalmologists have been using fs lasers as indispensable tool in refractive surgery. In particular, in the Laser-ASsisted In situ Keratomileusis, in short LASIK, fs lasers are being used to cut the cornea flap with highest precision and reliability in a contact free manner. Besides the use in the operating room fs lasers are very often the best choice when it comes to machining medical devices like stents or intra-ocular lenses. Femtosecond lasers make the process more reliable and cost effective compared to the traditional ways of machining. More recently, ultrafast lasers have increasingly found their way into industrial processes. One of the most prominent applications is drilling the holes of fuel injection nozzles. For their outstanding results, the team of scientists that has professionalized this application has been awarded with the 'Deutsche Zukunftspreis' in 2013. A second high-profile example where fs lasers are used innovatively is cutting Sapphire glass, which is used for displays in the cell phone industry.

Figure 1: Shown is a picture the BlueCut laser head. Dimensions of the laser head are 325 x 445 x 110 mm³.



All of these applications have in common that reproducibility and productivity of the production process crucially depends on the level of stability and reliability provided by the laser source. With the BlueCut fs lasers (shown in figure 1) Menlo Systems has introduced a new family of lasers that meet these requirements. The lasers have been designed from the ground up with quality in mind and are based on an integrated all-fiber platform. Due to the inherent robustness and insensitivity of fiber technology to vibrations and shock, the lasers are predestined for harsh environments. As important, the lasers are cost-efficient and compact due to the all-fiber platform, allowing for cost-efficient throughputs in manufacturing. The design is based on our proprietary figure 9® technology, which we have developed to satisfy the high level of reliability and stability industrial and scientific applications demand from fs lasers. The inherent stability of the modelocking mechanism is the corner stone on which the quality of the system is built. Long-term stable and maintenance-free operation is guaranteed by exclusively integrating parts with a very long lifetime. Saturable absorbers, which can be susceptible to degradation throughout their lifetime, are not required. With pulse durations of 300 fs and pulse energies of 10 uJ the BlueCut family of lasers is ready for a wide range of new processes.

In the following, we now want to highlight two innovative manufacturing processes that were enabled by the BlueCut: First, laser-assisted etching of photonic structures in transparent material, and second, manufacturing of volume phase gratings.

In direct laser writing one makes use of 2-photon absorption within the material. The nature of this non-linear effect enables the precise and fast writing of 3D photonic devices. If combined with other processes like etching, this leads to fabrication capabilities not possible previously. Figure 2 shows an example of such a device. It was fabricated utilizing laser-assisted etching. Using the focus spot from the BlueCut as an essentially unrestricted "tool-path", it is possible to directly write the surface of numerous lenslets in three dimensions within the volume of the transparent material, followed by the etching process to remove the unwanted material. In the shown application the shape and position of each lenslet was tailored to match the spatial position of a two-dimensional array of multimode fibers. The devices are engineered to serve as efficient and compact solutions to deliver and guide light within telescopes.

In figure 3, an image of several volume phase gratings is shown. The gratings are used in infrared astronomical spectroscopy. They were inscribed directly into Gallium Lanthanum Sulphide glass (GLS) by using the BlueCut. GLS is a widely transparent material, from 500 nm all the way to 10 um. Using ultrafast laser inscription, the gratings work efficiently from the near- to the mid-infrared. Using 2-photon absorption, it is possible to machine a wide range of dielectric, transparent materials with equal precision and quality using one and the same tool.

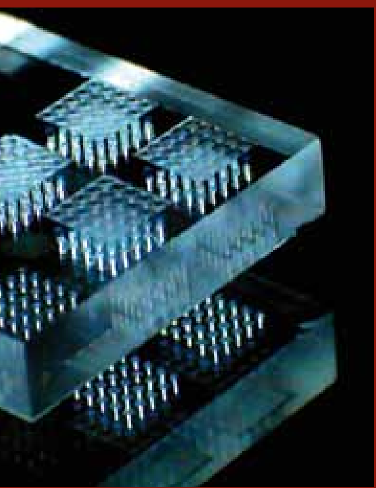


Figure 2:
A 2D-array of microlenses fabricated by using laser-assisted etching.
Each lenslet can be shaped individually. This allows for coupling light into a fiber array very efficiently.

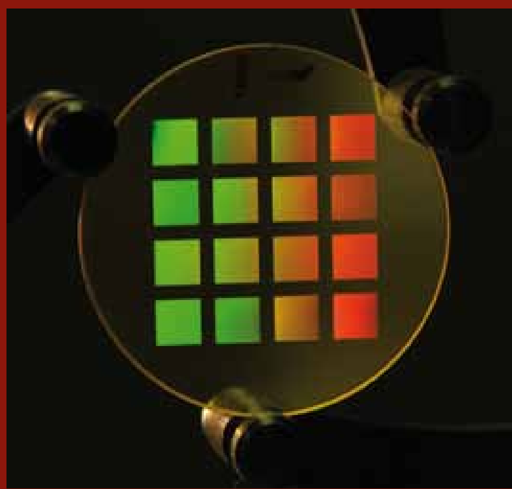


Figure 3:
Shown are several volume phase gratings for use in astronomy. They were manufactured by making use of ultrafast laser inscription. The material is gallium lanthanum sulphide glass which is transparent from 500 nm to 10 um.
Source Fig. 2/3: Prof. Robert R. Thomson, Heriot-Watt University

In conclusion, various applications for fs lasers both in industry and science already exist. Economic lasers with pulse energies in the µJ level support the need for cost efficiency and quality that is indispensable for volume applications. With the BlueCut family of lasers, we have introduced a tool that allows for new, economical processes and in turn for innovative products with previously unattainable functionality and quality.

About Menlo Systems:

Menlo Systems is a leading developer and global supplier of femtosecond fiber lasers. Based in Martinsried Germany, with an office in Newton, NJ, USA, it has been founded in 2001 around a revolutionary application of these lasers known as Optical Frequency Comb technology. Since then, Menlo Systems has been supplying instrumentation for high-precision metrology as well as for applications of femtosecond lasers in industry and life science. The strong bond to co-founder and Nobel laureate Theodor W. Hänsch resulted in various new products around ultrafast fiber lasers, Optical Frequency Combs, and Terahertz systems over the last 10 years.

Menlo Systems GmbH
Am Klopferspitz 19a
D – 82152 Martinsried
Phone +49 (0)89-189 166-0
Mail m.mei@menlosystems.com
Web www.menlosystems.com

Unimoph Deformable Mirrors for Applications in High Power Lasers and Laser Communication

Claudia Reinlein, Matthias Goy, Michael Appelfelder, Ramona Eberhardt
Fraunhofer Institut für Angewandte Optik und Feinmechanik (IOF), Jena

Deformable mirrors (DM) are used in laser systems to compensate for wavefront aberrations induced by thermal lensing in high power applications or atmospheric turbulence in free space propagation. Wavefront aberrations are deviations from ideal reference wavefronts that downgrade the beam quality and decrease the focusability.

Aberrations in high power laser systems are caused by the absorption of a fraction of laser light in the beam transfer optics (BTO) of the beam path and converted into heat. The heat absorption results in a temperature increase in the optics that leads to unwanted aberrations.

Another typical source of aberration is atmospheric turbulence in free space propagation. Here, the fluctuations of air pressure and temperature lead to temporal and spatial variation of the refractive index. Deformable mirrors may be used for compensation for both types of aberrations.

Fraunhofer IOF develops unimorph deformable mirror that are based on a substrate with high quality optical surface and a piezoelectric layer with patterned electrodes. The application of an electric field results in a contraction of the intermediate piezoelectric element. This active piezoelectric element is firmly fixed to the mirror substrate in order to multiply the piezoelectric elongation. Two different setups of such deformable mirrors may be selected; (i) the standard setup based on optical glass with adhesively bonded piezoelectric disc, and (ii) the thermally-piezoelectric deformable mirror (TPDM). The TPDM is a high power setup based on sinter-fused piezoceramic layer, and additional thermal actuators to compensate for large thermal lensing. It has been developed in close cooperation with TU-Ilmenau and Fraunhofer IKTS. Depending on the application and the requirements one of these mirror types is chosen, based on the following mirror characteristics.

The substrate of the standard setup is optical glass that is bonded with a low outgassing adhesive to a commercially available piezoelectric disk. The thickness of this assembly is ground to specified thickness (typically to thicknesses between 0.8 and 2 mm); subsequently it can be polished by Magnetoreological Finishing (MRF) that is a classical sub-aperture polishing technique. Therewith, we achieve deviations from spherical surfaces below 50 nm rms and better. The next step is the application of a coating that can be applied in-house in case of special requirements or with a job coater. For the completion of the deformable mirror, the electrical and the mechanical contacting have to be achieved. For ease of implementation of the DM into customer setups are standard kinematc mounts used (Figure 1). This standard setup has a specified aperture of 22 mm, but this technology can be adaped to develop mirrors up to 210 x 210 mm that are designed for applications in Peta-Watt Systems. Another application is focus-only mirrors that are applied in laser machining due to their low

Figure 1: Standard Deformable mirror setup ready for integration.

Dr. Claudia Reinlein
Fraunhofer Institut für
Angewandte Optik und
Feinmechanik (IOF),
Jena

mass and fast response times in exchange for moveable lenses.

The TPDM features the advantage of applicability in laser setups with high power continuous wave setups. The piezoelectric layer is screen printed on the rear surface of a ceramic (multilayer) substrate. Not only the piezoelectric layer but also the electrodes and electrical wiring are screen printed, and sinter-fused with the substrate. Moreover, the (multilayer) substrate features buried heaters and temperature sensors that are used to measure the incoming laser power and control the laser-induced mirror deformation. The front surface is electro-plated with copper and machined by an ultra-precision turning process before it is dielectrically coated. This setup has been successfully applied up to 6.2 kW (2 kW/cm²) at a laser wavelength λ=1 µm (Figure 2).

Figure 2: Thermal-piezoelectric deformable mirror (TPDM) for high power applications.

The standard actuator layout for both deformable mirror setups offers 40 pie-slice actuators each with a stroke of several micrometres on an aperture of 22 mm. Therewith, numerous aberrations with several with micrometres peak-to-valley may be compensated for. Moreover, the piezoelectric actuator layouts can be adapted to customer request as we have laser structuring techniques and lift-off processing in-house.

The applications of the deformable mirrors are in the field of (high power) laser machining, laser experiments in research, and free-space propagation. Together with TU Ilmenau, we have developed a FPGA-based controller for real-time processing of Shack-Hartmann wavefront sensor data to enable the wavefront control in free-space propagation. Therewith, we can achieve processing/sampling frequencies of 850 Hz.

The future challenges are the setup of a laser communication breadboard based on our standard deformable mirror, Shack-Hartmann wavefront sensor and FPGA-based control.

Dr. Claudia Reinlein
Fraunhofer Institut für
Angewandte Optik und Feinmechanik (IOF)
Albert Einstein Strasse 7
D – 07745 Jena
Phone +49 (0)3641-807-343
Mail claudia.reinlein@iof.fraunhofer.de
Web www. iof.fraunhofer.de

New Interconnection Technologies for Silicon-CMOS-Technologies

Matthias Hutter, Fraunhofer IZM

Nowadays the demands on lighting and optoelectronic packages are to enable a high level on system integration, and therefore providing interconnects, which are optimized regarding their thermal and electrical conductivity and exhibiting reliable thermo mechanical properties even beyond 150 °C. In this article an insight into new, innovative and highly reliable bonding technologies for the die attach is given.

Introduction

The main driving force for new developments in the field of interconnection technologies within the ambit of micro- and optoelectronics is the need to withstand higher operating temperatures. Due to the ban of SnPb37, new Sn-based solder alloys like SnAg3Cu0.5 (so called SAC-solder) have become the most common alternative. Since, research activities have been focused on improving the reliability of SAC-solders in terms of resistance to fatigue during thermal cycling, it could be found that by adding certain elements like Bi and Sb to the solder the maximum allowable operating temperature of 150 °C can be increased slightly. However, beyond 160 °C Sn-based solders are not suited regardless of the alloying elements added. In order to reach even higher temperature resistance the usage of Au-rich solders like AuSn20, AuGe12 or AuSi3 is one possibility. For the first level interconnects of optoelectronic components the eutectic AuSn20 solder, which has a melting point of only 280 °C is often used already. For Si-based components this solder is not so common, because it is extremely hard compared to other soft solders. Therefore, in order to have a choice, there are research activities ongoing regarding new materials and interconnection technologies to be able to operate not only the optoelectronic components but also the surrounding components at conditions which are harsher than today.

Au joints made by thermal compression bonding of nanoporous gold

Metallic interconnects, which are made of Au only, have advantages over solders especially due to their distinctively higher electrical and thermal conductivity. Furthermore, Au has a very high melting point of 1064 °C compared to the lead-free solders whose melting points are lying in the range of 217 to 232 °C. Accordingly, an Au interconnect should be applicable at very high temperatures. However, monometallic Au joints can be manufactured by using electroplated Au structures or Au stud bumps, which are joined to an Au metallized substrate using thermo-compression bonding (TC bonding) at temperatures of about 150 °C and by applying a rather high force. These high bonding forces are a limiting factor in terms of generating die attaches. This was the impulse to develop a new interconnection technology, which is based on nanoporous and therefore compressible Au structures. Using a co-electro-deposition process of Au and Ag and applying a subsequent etching process step in which the Ag is selectively removed this kind of nanoporous Au structure (npg), shown in figure 1 can be manufactured. In addition, figure 1 shows an almost completely densified Au joint, which can be accomplished by TC bonding using pressures of less than

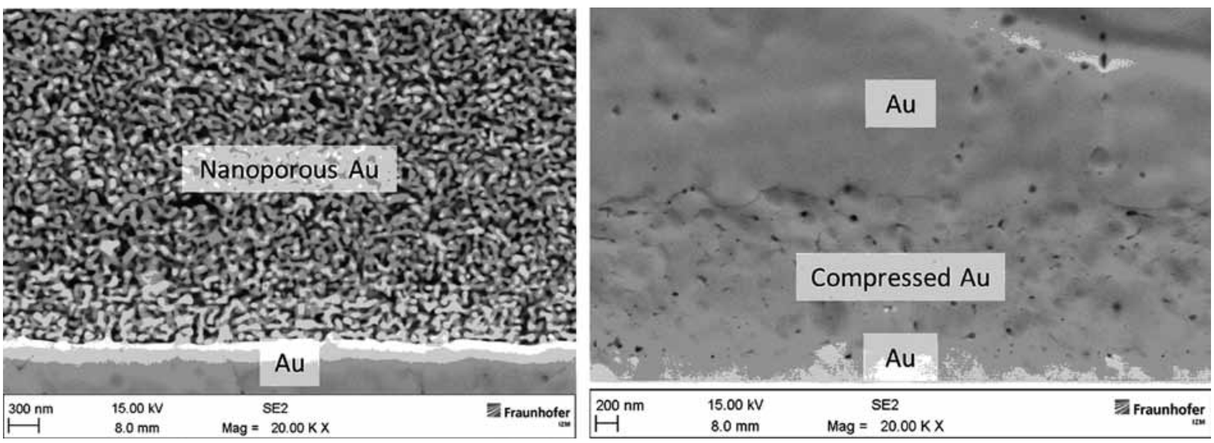


Fig. 1: Cross sections showing a nanoporous Au structure after etching selectively the Ag (left) and after TC bonding onto a substrate with Au metallization by applying a pressure of 50MPa at 250 °C (right).

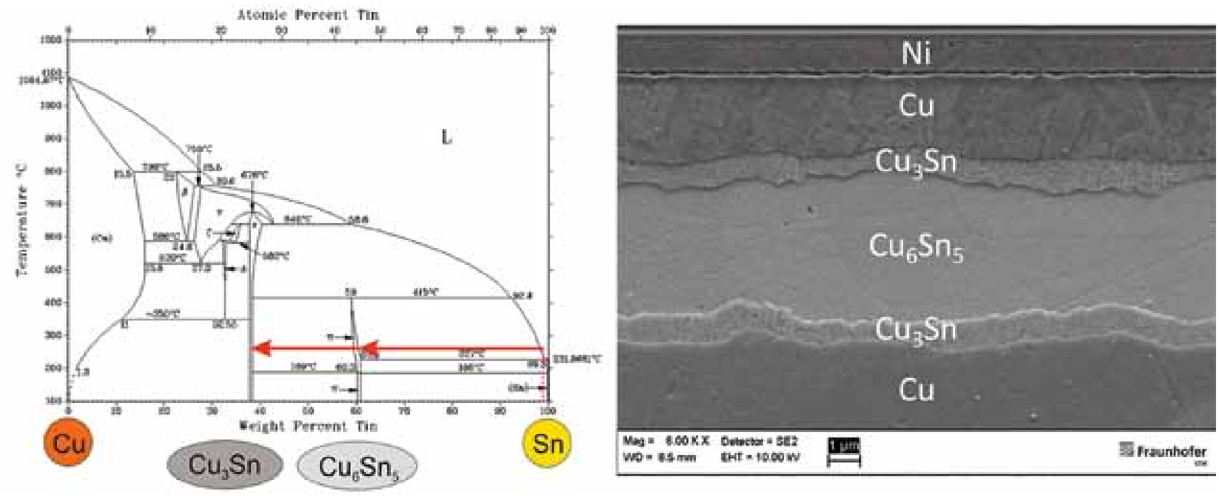


Fig.2: Schematic drawing showing the principal of TLPB (left) and cross section of Cu-Sn-TLPB interconnection with marking of the intermetallic phases (right).

50 MPa. Surface roughness, unevenness of joining components or even a warpage can be compensated using this technology. Npg structures are usable for die attaches or flip-chip applications.

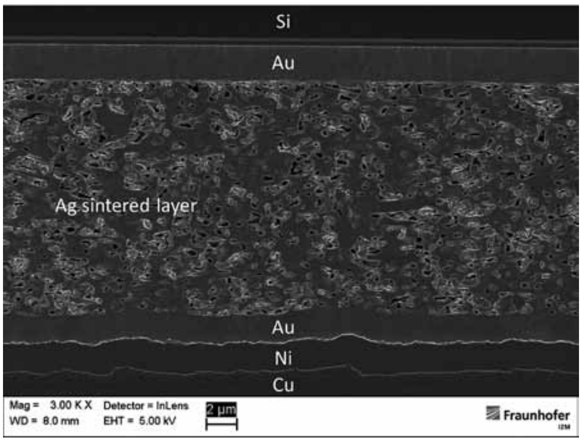


Fig.3: Cross sections showing a Si die Ag sintered on a Cu substrate (with a noble metallization each) by applying pressure of 10 MPa pressure at 230 °C.

Transient liquid phase bonding - TLPB

The TLPB, an alternative interconnection technology for higher operating temperatures, is based on the transformation of solder into intermetallic phases due to a diffusive reaction. According to the selected alloying elements (i.e. Cu-Sn or Au-Sn) the melting point of the joint is shifted to a higher temperature. Depending on the geometries of the materials used, the transformation can generally be accomplished during the soldering process but also during solidification or by phase growth at elevated temperatures after the soldering process has been finished. For instance, TLPB can be done by using dies, which have just a few microns thick layers of Cu and Sn electroplated selectively and which are soldered to a substrate with a Cu surface. However, the solder material can either be deposited on the back side on a full area or as single bumps at a pitch down to 50 µm or under special boundary conditions even to 30 µm. During soldering, as explained in figure 2, the Sn can be transformed totally into the intermetallic phases Cu_6Sn_5 and Cu_3Sn. For Au-Sn-TLPB it is possible in a similar way. The intermetallics have melting points of more than 400 °C and even 600 °C. Hence, TLPB interconnects exhibit a very high creep resistance. TLPB is usable for die attach and for flip-chip applications.

Ag sintering

Pure Ag has an even higher thermal conductivity than Cu or Au and a melting point of 962 °C. Therefore, the Ag sintering, which facilitates monometallic Ag die attach interconnects, again had been advanced especially due to its potential for high temperature applications. Compared to the classic soldering Ag sintering offers a totally new way for first-level die attach interconnects, in which a die and a substrate are joined i.e. by printing Ag sinter-paste, which is composed of Ag particles and organic additives, onto a substrate and placing the die onto the dried paste layer. Afterwards a certain force and temperature is applied in order to achieve a joint, which is made of pure Ag (figure 3). Using pressure of more than 20 MPa an almost dense Ag layer can be manufactured. The joint between the Ag particles is generated using solid state diffusion since the process temperature is always significantly lower than the melting point of pure silver (ca. 250 °C). First reliability tests showed already that with Ag sintered die attach interconnects have more than 10 times better life times than certain solder joints. Silver sintering is usable for die attach.

Dr. Matthias Hutter
Fraunhofer Institut für Zuverlässigkeit und Mikrointegration
Gustav-Meyer-Allee 25
D – 13355 Berlin
Phone +49 (0)30-464 03 167
Mail matthias.hutter@izm.fraunhofer.de
Web www. izm.fraunhofer.de

Overcome Write Time Problems in the Nanolithography using Character Projection e-Beam Lithography

Uwe Hübner, IPHT Jena

Uwe D. Zeitner, IOF Jena

Metamaterials, artificial nanomaterials constructed of millions of very small metallic pattern and layered dielectric thin films, are a today's hot topic for basic research. Optical metamaterials in the VIS and IR wavelength range consist of metallic "meta-atoms" or submicron- and nanogratings with typical feature sizes from $\lambda/2$ down to $\lambda/10$. There are a large number of different concepts (2D and 3D) and different layouts to realize principally new optical devices with such unusual properties like negative refractive index, super lenses, impedance matched optical devices and effective refractive index structures. Plasmonic substrates for surface enhanced vibrational spectroscopy, which use effects of strong local electric field enhancement, are currently being developed in chemical or bio-sensing application fields.

For first experiments and later on for the reproducible preparation of such nanomaterials with sub-100 nm pattern and pitches down to 100 nm electron beam lithography is used in most cases. In the research labs the basic experiments are mostly made by using SEM based Gaussian e-beam writers which provide highest structure resolution, high pattern flexibility, and easy operability. The serial write mode allowed write times for a typically write field of 100 x 100 µm² in the range of minutes to hours (depending on the pattern type, pattern density, resist sensitivity, beam current, write-tool specific features etc.). In principle the exposure of larger areas is possible by making field stitching, but then the write times may rise dramatically. Especially for larger device areas the write time for serial processing electron beam lithography may be in the order of days, weeks or more and therewith impractically long. Hence, for applied research and for future applications, e.g. in the field of chemical or bio-sensing, the fabrication of such nanomaterials over large areas, with frequently changing layouts and with a few million nanostructures per mm² presents a major challenge for lithography in this research field.

While in Gaussian beam writing for the exposure of a rectangular area a large number of single shots are necessary, a Variable Shaped e-Beam writer (VSB) can expose such an area in only a single shot. Since the write time is roughly proportional to the number of shots, the total exposure time is reduced strongly. This advantage is lost if not axis-parallel structures shall be written. In this case, all sloping structure edges must be approximated by rectangles and the shot number can considerably increase with the fineness of the decomposition. The problem can be overcome using the Character Projection e-beam lithography which allows the transition from a time-consuming serial to a fast quasi-parallel writing method. This technique uses hard coded stencil masks to exposure patterns, but only the presence of a large number of different stencil masks allows a high flexibility for use in research and for various applications (Figure 2).

Such high flexibility in terms of pattern diversity was achieved by the implementation of a computer controlled aperture stage with a multi-stencil diaphragm array in our SB350 OS Variable Shaped E-beam system (from Vistec Electron Beam GmbH Jena) which we use in collaboration with our scientific partners Fraunhofer Institute for Applied Op-

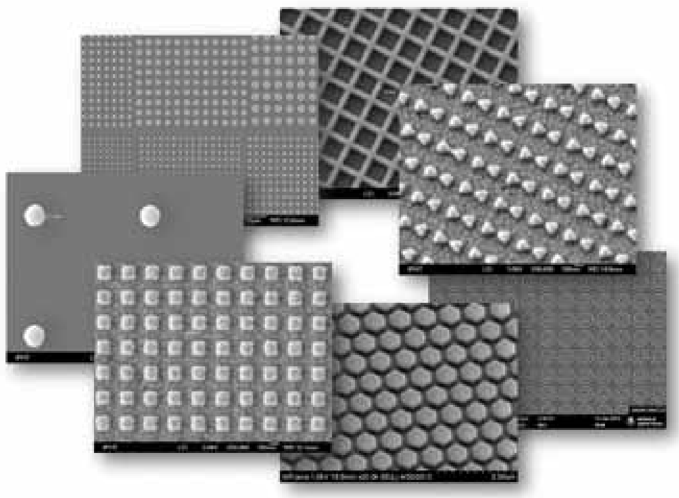


Figure 1:
Examples for different nanogratings and metamaterials, fabricated by means of the Character Projection mode.

Uwe D. Zeitner
IOF Jena

Uwe Hübner
IPHT Jena

tics and Precision Engineering IOF and Institute of Applied Physics IAP of the Friedrich Schiller University Jena. More than 2000 different aperture geometries can be addressed and also combined with the Shaped Beam pattern by the e-beam within one exposure job. Especially for metamaterials with complex pattern geometries and with millions or billions nanostructures per mm² the Character Projection offers a significant advantage in writing speed by factors >100 compared to the relative fast Variable Shaped Beam technique and opens the way for the fabrication of device areas which are impossible to realize with SEM based Gaussian electron beam-writers often used in R&D. For example, the exposure times for a metamaterial which spend nearly 1 year for the Gaussian-mode were 2.4 h for the VSB-mode and only 1.4 min for the CP-mode! Due to the strong write time reduction also the pattern quality and the pattern homogeneity on large areas are significantly improved. Statistical fluctuations in the deflection system, in the electron optics, and effects of electric charges especially for dielectric substrates are minimized.

Summarized, Character Projection e-beam lithography is a promising technique for the fabrication of complex nano-optical structures for plasmonics, photonic-crystals, or meta-materials on application relevant areas.

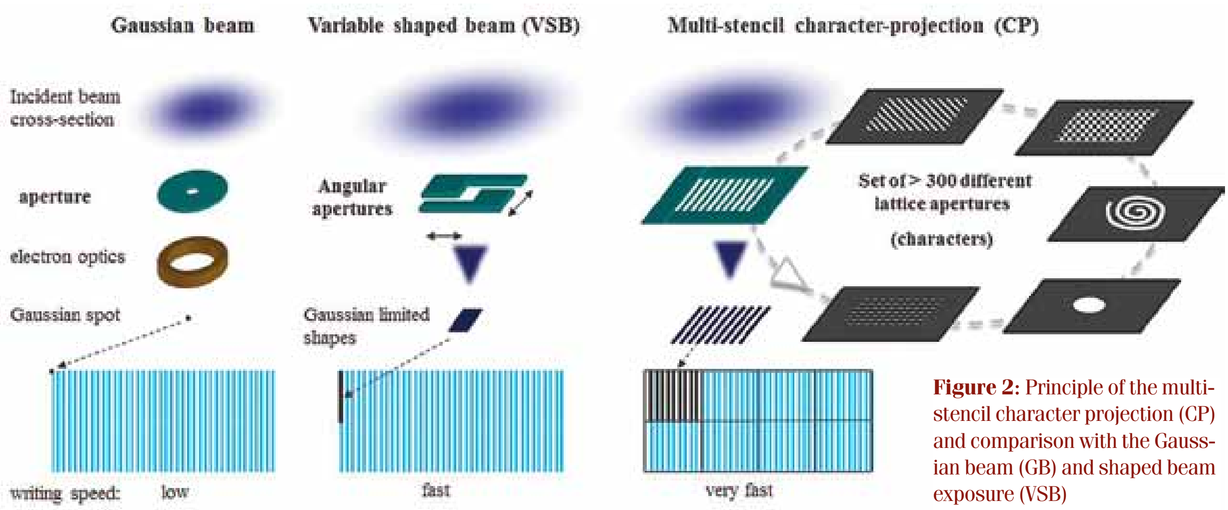


Figure 2: Principle of the multi-stencil character projection (CP) and comparison with the Gaussian beam (GB) and shaped beam exposure (VSB)

Ref:
Uwe Hübner; Matthias Falkner; Uwe D. Zeitner; Michael Banasch; Kay Dietrich; Ernst-Bernhard Kley „Multi-stencil character projection e-beam lithography – a fast and flexible way for high quality optical metamaterials";
SPIE Proceedings Vol. 9231, 30th European Mask and Lithography Conference 2014
Uwe D. Zeitner; Torsten Harzendorf; Frank Fuchs; Michael Banasch; Holger Schmidt and Ernst-Bernhard Kley "Efficient fabrication of complex nano-optical structures by E-beam lithography based on character projection", Proc. SPIE 8974, Advanced Fabrication Technologies for Micro/Nano Optics and Photonics VII, 89740G (March 7, 2014)

Dr. Uwe Huebner
Leibniz-Institut für Photonische Technologien e.V.
A. Einstein Str. 9
D – 07745 Jena
Phone +49 (0)3641-206 126
Fax +49 (0)3641-206 199
Mail uwe.huebner@ipht-jena.de
Web www.ipht-jena.de

Dr. U.D. Zeitner
Institute of Applied Physics
Friedrich-Schiller-University Jena
Albert-Einstein-Str. 15
D – 07745 Jena, Germany
Phone +49 (0)3641-807 403

Ultraviolet LEDs – from Research to Real-World Applications

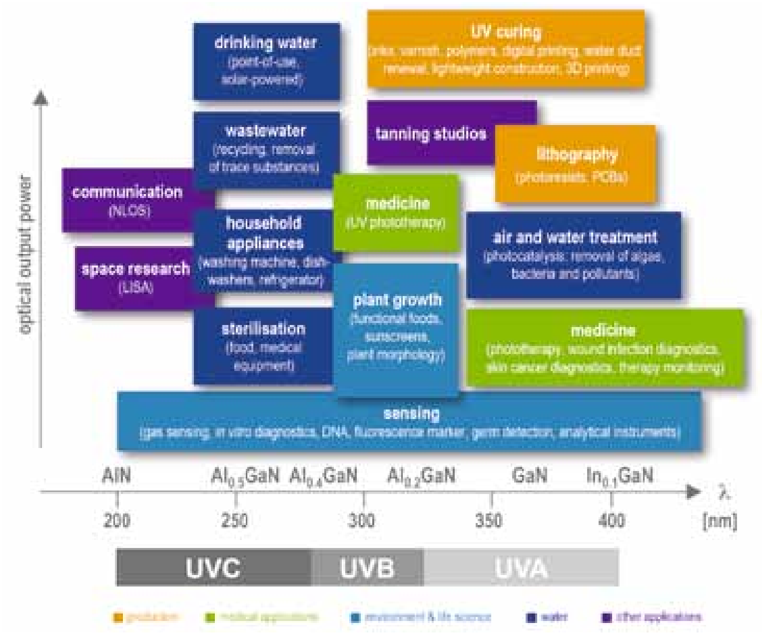


Fig. 1: Applications of AlGaN-based LEDs emitting in the UV-A (400nm-320nm), UV-B (320nm-280nm), and UV-C (280nm-200nm) spectral range. Source: FBH

UV-LEDs: An emerging technology

It took less than five years from the fundamental breakthroughs in gallium-nitride (GaN) materials technologies to the first demonstration of candela-class blue light emitting diodes (LEDs). Just a few years later, GaN-based white LEDs entered the markets, and today high-efficiency white LEDs are about to completely transform the lighting market. A similar transformation can be expected from UV optical sources in the near future. Up to now, we have only accessed a very narrow sliver of the emission spectrum that is reachable through semiconductor LEDs. By alloying aluminium-nitride (AlN) and gallium-nitride (GaN) materials in AlGaN-based LEDs the emission can be tuned to cover any wavelength in the UV-A (400nm-320nm), UV-B (320nm-280nm), and UV-C (280nm-200nm) spectral range. Compared to conventional sources UV-LEDs are compact, robust, and environmentally friendly; they can be rapidly switched on and off, are operated at moderate voltages, and exhibit very long lifetimes. Although the technological development of UV-LEDs is still at the very beginning, there is no doubt that this new technology offers immense economic potential. And UV-LED devices are the key enablers for a wide range of new applications including water purification, UV curing, environmental sensing and life sciences, medical diagnostics, and therapy. All in all, the development of UV-LED technologies provides significant leverage for a wide range of applications. Its economic potential is therefore by far greater than the mere commercialization of semiconductor UV components.

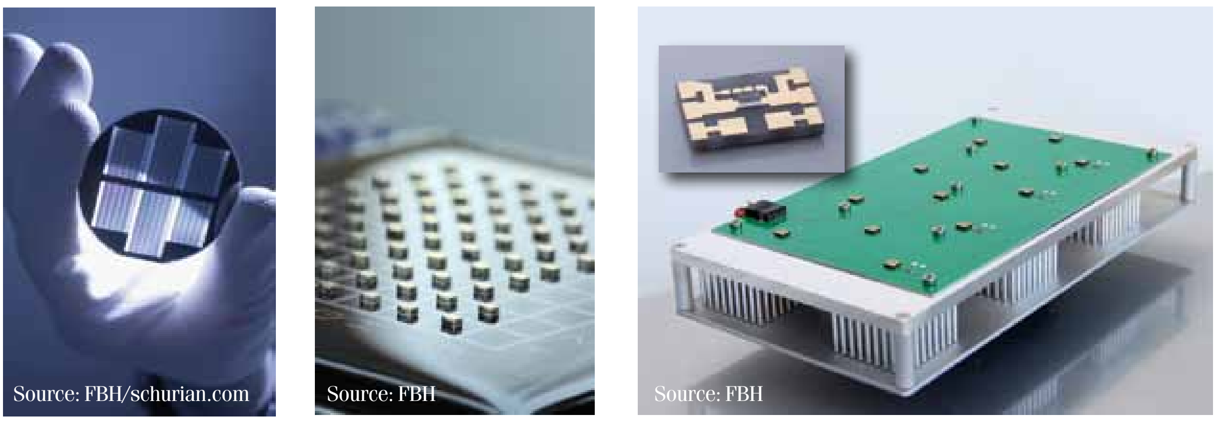


Fig. 2: Covering the entire value chain from materials growth to device fabrication and systems integration.

Prof. Dr. Michael Kneissl
Ferdinand-Braun-Institut,
Leibniz-Institut
für Höchstfrequenztechnik
Source: FBH/M. Schönenberger

UV-LEDs: The challenges ahead

Despite the great progress in the development of UV-LEDs over the past few years their performance levels still lag behind their blue wavelength counterparts. Although there seem to be no fundamental limitations that would prohibit the development of high-efficiency, high-power UV-LEDs, there are a number of challenges ahead. One is the relatively high defect density in AlGaN materials limiting the internal quantum efficiencies of UV emitters. Hence, low defect density AlN substrates and advanced deposition methods, like lateral epitaxial overgrowth are being developed. Current UV emitters also suffer from low light extraction efficiency. Therefore, new approaches such as nanopixel contact designs and laser-induced substrate lift-off technologies are being explored. For high-power LEDs advanced thermal management techniques like flip-chip mounting on AlN ceramics and wafer-level packing are being investigated. Pushing the wavelength limits towards the lower end of the UV-C spectral range and developing custom solutions for UV-LEDs, e.g. UV-LED point sources for sensing applications, are additional challenges.

Advanced UV for Life: Linking up devices and applications

In order to accelerate the development of UV-LED technologies and their applications, research institutions, universities, and industrial partners joined forces within "Advanced UV for Life". The network is funded by the German Federal Ministry of Education and Research within the "Zwanzig20 – Partnerschaft für Innovation" initiative. The consortium, headed by the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, brings together more than 30 interdisciplinary partners from research and industry to develop high-efficiency UV-LEDs, UV modules, and systems. The "Advanced UV for Life" consortium cross-links partners along the entire value chain, starting with materials research and UV-LED fabrication through to system integration and the respective application. The wide range of applications involves medicine, like phototherapy, blood analysis, and detection of multi-resistant germs, as well as the purification of drinking water in point-of-use systems and water treatment in home appliances like washing machines. UV-LEDs can also be used in UV-curing equipment for 3D-printing, water duct renewal, gas detection systems, for environmental monitoring, and in life science applications like plant growth lighting.

Fig. 3: UVB-LED module for plant growth lighting. The exposure to UV-B light significantly increases the secondary plant metabolites in broccoli, which reduce the risk of cancer and cardiovascular diseases. Source: Leibniz Institute of Vegetable and Ornamental Crops Großbeeren/Erfurt e.V.

Thus, the economic and societal benefits resulting from the development for a wide application range that require UV-LED technologies are perfectly obvious. Latest market studies predict rapid technological advances in the development of semiconductor-based UV-LED sources. For the world market of UV-LED components alone an annual growth rate of 43% is being forecasted, reaching a total volume of US$ 270 million by 2017.

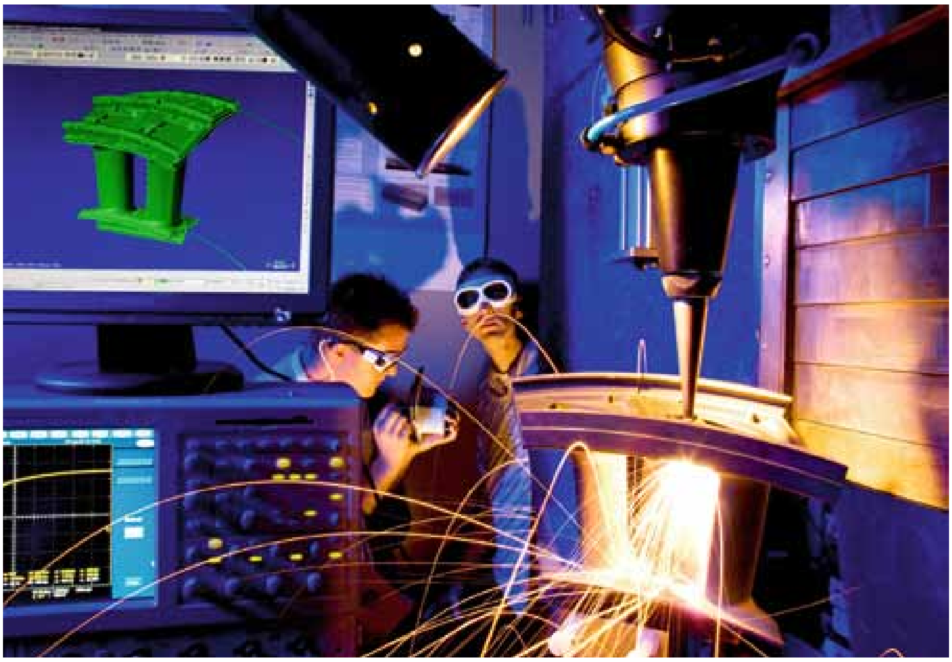
Prof. Dr. Michael Kneissl
Ferdinand-Braun-Institut
Leibniz-Institut für Höchstfrequenztechnik
Gustav-Kirchhoff-Str. 4
D – 12489 Berlin
Phone +49 (0)30-6392-2812
Mail michael.kneissl@fbh-berlin.de
Web www.fbh-berlin.de

Institute of Solid State Physics
Technische Universität Berlin
Hardenbergstr. 36, EW 6-1
D – 10623 Berlin
Phone +49 (0)30-314-22563
Mail kneissl@physik.tu-berlin.de
Web www.ifkp.tu-berlin.de/?id=agkneissl

Results and Services from Research Institutions

Ergebnisse und Dienste von Einrichtungen der Forschung

Fraunhofer Institute for Laser Technology ILT – Partner of Innovators



Source: Thomas Ernsting

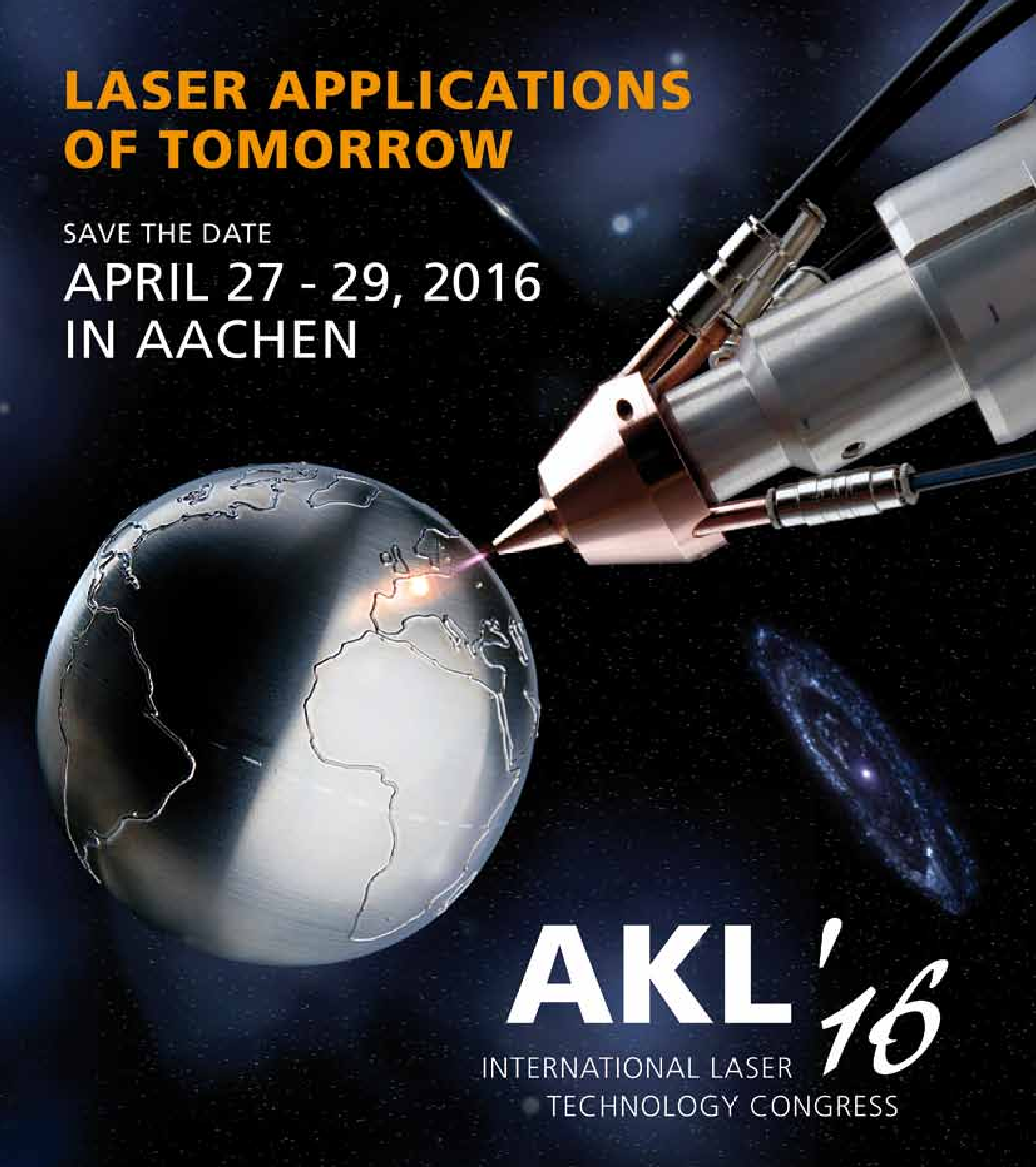
ILT – this abbreviation has stood for focused know-how in the sector of laser technology since 1985. Innovative solutions for manufacturing and production, development of new technical components, competent consultation and education, highly specialized personnel, state-of-the-art technology as well as international references: these are guarantees for long term partnerships. The numerous customers of the Fraunhofer Institute for Laser Technology ILT come from branches such as automobile and machine construction, the chemical industry and electrical engineering, the aircraft industry, precision engineering, medical technology and optics. With around 420 employees, over 400 patents, 11,000 m^2 of usable space and over 30 spin-offs the Fraunhofer ILT is among the most significant contracting research and development institutes in its sector worldwide. In the technology area »Lasers and Optics« the Fraunhofer ILT develops tailor-made beam sources as well as optical components and systems. The spectrum reaches from freeform optics over diode and solid state lasers all the way to fiber and ultrashort pulse lasers. In the technology area »Laser Material Processing« the Fraunhofer ILT solves tasks involving cutting, ablating, drilling, cleaning, welding, soldering, marking as well as surface treatment and micro manufacturing. Process development and systems engineering stand in the foreground. Along with partners from life sciences, ILT's experts in the technology field »Medical Technology and Biophotonics« open up new laser applications in bioanalytics, laser microscopy, clinical diagnostics, laser therapy, biofunctionalization and biofabrication. The development and manufacture of implants, microsurgical and microfluidics systems and components also count among the core activities here. In the technology area »Laser Measurement Technology and EUV Technology« the Fraunhofer ILT develops processes and systems for customers which conduct inline measurement of physical and chemical parameters in a process line. In addition to production measurement technology and material analysis, environment and safety as well as recycling and raw materials lie in the focus of the contract research. With EUV, Fraunhofer ILT is entering the submicron world of semiconductors and biology.

Recent awards

Stifterverband's Science Award 2012
Joseph-von-Fraunhofer Prize 2012
Berthold Leibinger Innovation Prize 2012
Innovation Challenge Award 2012 Aviation Week
Innovation Prize 2011 of North Rhine-Westphalia
Ferchau-Innovation Prize 2011

Fraunhofer ILT

Fraunhofer-Institut für Lasertechnik ILT
Steinbachstr. 15
D – 52074 Aachen
Phone +49 (0)241-8906-0
Mail info@ilt.fraunhofer.de
Web www.ilt.fraunhofer.de



Fraunhofer Institute for Laser Technology ILT

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Supporting Organizations of the AKL'14

SPECTARIS German Hightech Industry Association

VDI Technologiezentrum

VDA Verband der Automobilindustrie

VDMA

AKL Arbeitskreis Lasertechnik e.V.

ELI European Laser Institute

EPIC European Photonics Industry Consortium

European Commission

Fraunhofer ILT

Enabling Photonic Solutions – Leading Replication Technologies for Optics at the Fraunhofer IPT

Within the Business Unit Optics, the Fraunhofer Institute for Production Technology IPT focuses all of its expertise on the production and evaluation of complex optical components and systems. Our engineering know-how enables us to produce highly efficient glass or polymer components for a variety of applications, such as automotive and lighting as well as the fields of laser systems and life science. We have each stage of the production process covered throughout the entire supply chain – starting with the design of optical systems and culminating in their final qualification.

Our goal is to achieve continuous improvement of complex manufacturing processes or in some cases, to enable them to be implemented on an industrial scale for the first time. By striking a balance between the demands of innovation, quality and cost, we make a long-term and effective contribution to the success of our clients.

Our activity areas cover the following:

- Tools and mold inserts alongside coating systems for replicating optics,
- Process and material development for direct optics manufacture,
- Software for ultra-precision manufacture of complex geometries,
- Automated assembly of optical systems,
- Metrological characterization of the components produced using customized sensor and measuring technologies.

Precision molding of optical glass components

Modern measurement or entertainment devices have a strong demand for high quality glass lenses with increasing requirements regarding their optical functionalities. These optics have aspheric or even free-formed surfaces with complex structures on micro-scale. Conventional manufacturing methods as grinding and polishing reach their limit in terms of efficiency and feasibility. A manufacturing method that is growing in importance is the replicative production of ultra-precise glass optics, the so-called Precision Glass Molding (PGM).

The process of PGM starts with a polished glass preform that is inserted into the molding machine. The molding tools have the inverted surface of the desired glass shape. Molding tools and glass preform are heated up to the molding temperature together. After a homogenization time, the glass is shaped into the ready-to-assemble glass lens. Finally, the lens can be removed from the machine as soon as the cooling is finished.

Fig. 1: Double sided condensor lens for homogenization of coherent (excimer lasers) or incoherent light sources

The Fraunhofer IPT has carried out research in the field of PGM for more than 15 years. It is possible to recreate the complete process chain at the institute. The manufacturing of the molding tools can be done by ultra-precision machining and the lifetime of the molding tools can be increased by applying protective coatings specially developed by the IPT. The field of moldable glass types includes glasses for visible light and UV such as common low-Tg-glasses or even fused silica, but also new glass types for NIR and MIR, the so called chalcogenide glasses.

Mold making and automated assembly of polymer micro-optics

The continuing trend of using ever smaller and more complex optical components covers also the polymer world. Free-form surfaces with superposed microstructures, allow the realization of miniaturized optical systems and their integration into higher-level assemblies. Typical product examples include adaptive endoscope cameras in the field of medical technology but also more powerful camera object lenses for consumer electronics.

The challenges in the manufacturing of these polymer components include the optimization of the injection molding process, in order to produce highly-precise optics. For this purpose the Fraunhofer IPT provides an adapted tool- and mold making process cycle. Next to the adjustment of a very precise shaft guiding and centering of the optical mold inserts, the demolding process of the polymer optics from the mold requires exceeding attention. This includes especially the sprue system, which has to be designed as large as possible to obtain a homogenous filling quality of the mold cavity, but as small as necessary to ensure a precise and simple sprue separation from the actual polymer optic.

The following measurement, preferable contactless, acquires the geometric shape accuracy and other component features and feeds back possible corrections in the tool design. Once the final single optic is obtained, the automated assembly of several components into a well working system-structure needs to be conducted. The Fraunhofer IPT has the capability to manufacture all necessary structural components like lens tubes, apertures etc. with the techniques of micro milling and diamond turning. Furthermore the IPT realizes completely automated assembly stations using proprietary high precision handling tools. The actual assembly process can be controlled via geometric features of the optical components or by evaluating the optical function of the system.

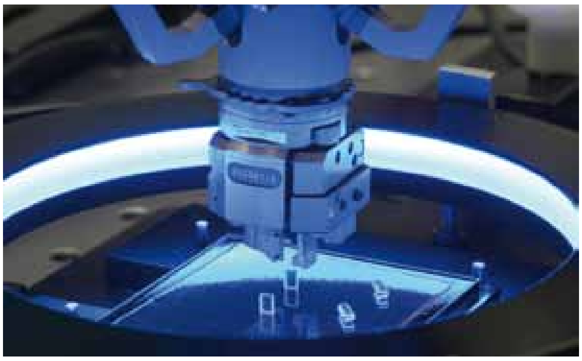

Fig. 2: Ultra precision multi-axis handling of micro-optical components

Two-Photon-Lithography for future optics

Functional integration is a decisive element in meeting the growing requirements of light shaping components. In many cases, the goal is to maximize efficiency and to allow defined intensity distributions or diffraction patterns. Typical applications include the areas of metrology, displays, solar cells or illumination purposes in general. This framework demands sophisticated geometry features and surface structures of the optical elements, providing a maximum in individuality and yet a high resolution and capacious efficiency rates – these dichotomic specifications have to be addressed by adequate high performance manufacturing technologies.

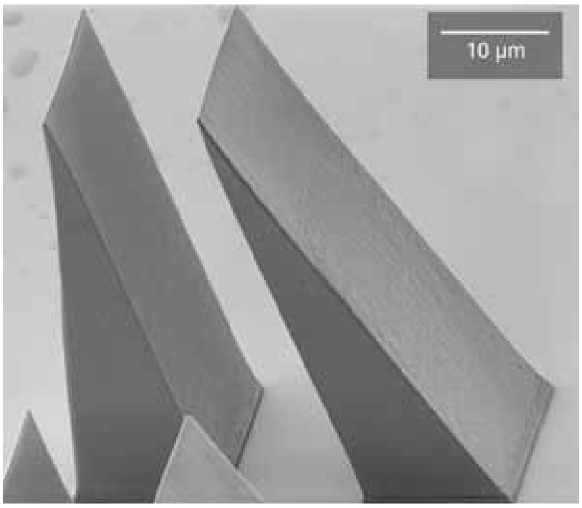

Fig.3: Photonic structures with a large aspect ratio and extraordinary steep flanks

Such an approach is represented with the two-photon-lithography, a technology that is characterized by its extraordinary degree of freedom as a structuring method for the production of individual optical microstructures. The unique features of this technology include the high resolution of down to 150 nm, the structuring on curved surfaces and virtually no limitations to the surface angles and aspect ratios.

Since this technology is not fast enough to allow an efficient mass production, the Fraunhofer IPT embeds it into a process chain containing appropriate molding steps such as injection molding, galvanic molding or UV-replication. In combination with suitable resist features like heat resistance, mechanical durability and contour accuracy the written structures can be scaled in a recombined tool, ready for high capacity molding.

Fraunhofer IPT

Fraunhofer Institute
for Production Technology IPT
Reik Krappig
Steinbachstraße 17
D – 52074 Aachen
Phone +49 (0)241-8904-327
Mail optik@ipt.fraunhofer.de
Web www.ipt.fraunhofer.de/optik

Solutions with Light – Expertise in Optical System Technology

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF develops innovative optical systems to control light from the generation to the application.

Our claim is to cover the entire photonic process chain from optical, optomechanical and optoelectrical system design to the manufacturing of customized solutions and prototypes.

The close cooperation with the Institute of Applied Physics (IAP) at the Friedrich Schiller University is of particular importance to both, covering the scientific lead work and training young scientists.

Thin compound eye cameras with refractive freeform arrays

Artificial compound eye cameras enable the realization of ultra-flat imaging systems on wafer scale. Based on their imaging principle, they permit a reduction in thickness by a factor of two in comparison to single aperture objectives with comparable optical performance.

Low cost fabrication technologies are needed in order to use these systems in high volume markets such as consumer electronics. Fabrication is therefore based on an UV-replication process. First, the reflow of photoresist is applied to generate master wafers that can be used subsequently to replicate optics wafers. Due to physical limitations, only spherical and ellipsoidal lens shapes are achievable. Consequently, the potential for correcting optical aberrations is restricted, leading to limited image quality and resolution. In order to further enhance the imaging performance, the use of refractive freeform arrays instead of conventional micro lens arrays is inevitable. Due to the non-symmetrical and aspherical surface shape of the single lens segments, fabrication by the reflow of photoresist is no longer possible.

Fig. 1: Master of a single refractive freeform array fabricated by an ultra-precise machining process.

A new fabrication approach based on a step and repeat process was therefore developed. This technology enables the replication of a single refractive freeform array fabricated by an ultra-precision machining process several hundred times on an 8 inch glass wafer. Inevitable surface deviations are minimized by a carefully adopted exposure strategy in combination with an active movement of the stamp. Current 8“-masters permit the replication of 253 single freeform arrays in parallel. The arrays themselves consist of 135 single lenslets with a pitch of 500 µm and sag heights up to 160 µm.

Metal mirrors with metal-dielectric HR-coating for ultrashort lasers pulses applied in scanner applications

Ultraprecise metal mirrors are an attractive solution for optomechanical high-performance components for scanners working with ultrashortpuls lasers. Each ultrashort laserpuls has to be matched very precisely to the correct spot. In order to achieve very fast and precise positioning, small mechanical inertia and a small mirror mass are required. The mirrors have to be stiff and a high quality optical surface has to be provided. This can be achieved with ultraprecise machined lightweight AlSi-based mirrors with diamond-turned NiP polishable plating. The amorphous NiP is thermal matched with the AlSi alloy better than 0.5 ppm. The polishing results regarding the surface roughness are lower than 1 nm rms.

Different coating options are available in order to provide the necessary high reflectivity and a satisfactory laser damage threshold for ultrashort laser pulses in the few ps to fs regime at $\lambda = 1030$ nm. It was found that metal-dielectric coatings exhibit similar or even higher laser damage thresholds than pure dielectric coatings and offer at the same time the advantage to be thinner than pure dielectric coatings. They are therefore suitable for the deposition onto lightweight mirrors for scanner applications. The coatings are deposited by magnetron sputtering. High-reflective metal layers enhanced by dielectric HfO_2/SiO_2-stacks were found to be the most advantageous coating option. For these coatings laser damage thresholds above 1 J/cm^2 have been determined both for 8 ps and for 600 fs pulses.

Fig.2:
Ultraprecise lightweight AlSi-mirrors with diamond-turned NiP plating and polished surface for scanner applications

Curved artificial compound eyes for autonomous navigation

Insect compound eyes consist of a mosaic of optical units whose composition matches specific ecological demands. Compared to vertebrate camera eyes, they offer a panoramic field of view with low aberrations and negligible distortion, and show superior temporal resolution while trading adequate spatial resolution for diminutive size.

Compound eyes possess local sensory adaptation mechanisms capable of compensating for large changes in light intensity at the photoreceptor level. This is likely an adaptation to visually controlled navigation including tasks such as collision avoidance, take-off, landing, and other optomotor responses which do not require a high density of photoreceptors.

Fig.3: Cylindrical curved multi-aperture navigation sensor (radius of curvature 6.35 mm).

Inspired by its natural antetype, diverse morphologies of curved artificial compound eyes (CURVACE) have been realized in collaboration with EPF Lausanne, Université de la Mediterranée Marseille, and Universität Tübingen and were tested on robotic stages. The optical design, the cost-effective wafer-level fabrication of the multi-aperture imaging system, and the assembly were carried out at Fraunhofer IOF.

The optical navigation sensor is characterized by a gapless registration of a field of view of 180°×60° with low distortion and uses neuromorphic auto-adaptive photodetectors which enables the detection of the optical flow in a wide illuminance range of $10^{-7} – 10^{-3}$ W/cm². The high temporal resolution of 300 Hz allows for a precise determination of the device's ego motion against its environment. Such curved visual sensors may be useful for autarkic terrestrial and aerial vehicles, prosthetic devices, surveillance, motion capture systems, and intelligent garments. Artificial compound eyes may also foster the development of visual algorithms for novel human-machine interfaces.

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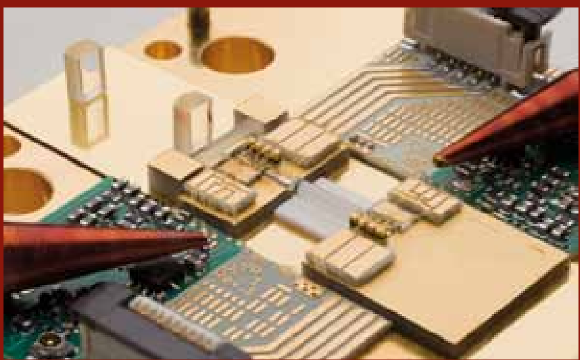
Fraunhofer Institute for Applied Optics and Precision Engineering IOF
Dr. Kevin Füchsel
Albert-Einstein-Str. 7
D – 07745 Jena
Phone +49 (0)3641-807273
Mail kevin.fuechsel@iof.fraunhofer.de
Web www.iof.fraunhofer.de

Ferdinand-Braun-Institut:

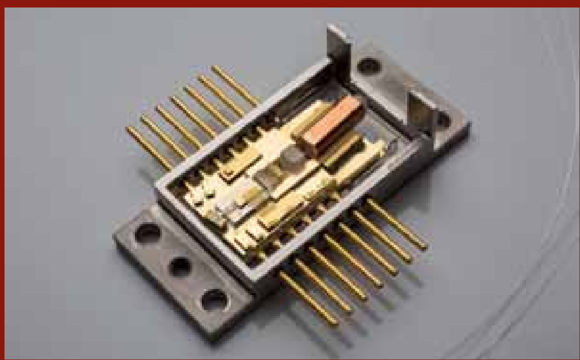
Excellence in optoelectronics – a highly capable partner for research and industry

The Berlin-based Ferdinand-Braun-Institut (FBH) is one of the world-wide leading institutes in optoelectronics. From materials processing to applications in medicine, sensors, and space – diode lasers and UV LEDs based on research results from the FBH are key components in a wide range of applications. As a matter of fact, many systems would not work or would have to be constructed considerably larger without the compact all-rounders from the institute. FBH's focus of optoelectronic research is to push the limits of NIR lasers regarding power, brilliance, and efficiency as well as of LED chips reaching deep into the UV-C spectral region. The institute not only develops such cutting edge chips, but also very compact laser modules that are tailored precisely to fit individual needs. The FBH offers its international customer base complete solutions and covers the full range of capabilities, from design to fabrication to device characterization.

One main focus of research is to further improve diode lasers, thus enabling direct utilization for cutting and welding in materials processing. Accordingly, special emphasis is given to the development of spectrally stabilized high-power, high-efficiency diode lasers. Moreover, the FBH develops high-power diode laser modules for pumping sophisticated short-pulse solid-state laser systems in high energy class applications including X-ray generation, laser peening, and laser-induced fusion systems for future energy production. For example, in a joint project with the Max Born Institute, the FBH supplies the necessary pump modules delivering an overall pump energy of 36 J at 200 Hz repetition rate for their high-power short-pulse laser system. The single laser beams of the module are geometrically coupled into a glass fiber, offering power conversion efficiency at the working point of over 60 % and a coupling efficiency of more than 90 %.



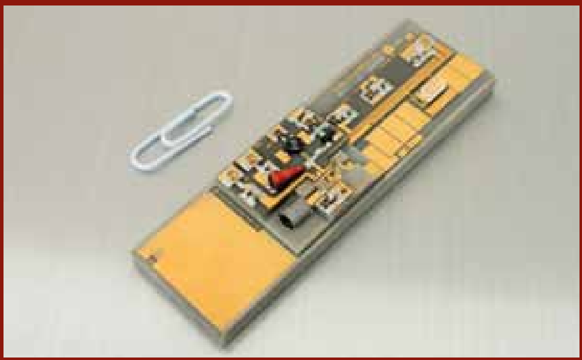
ps light source with DBR laser und GaN amplifier, suited as seed laser for materials processing. Source: ©FBH/schurian.com



Miniaturized laser module for efficient fiber coupling of high-power diode lasers. Source: ©FBH/schurian.com

The FBH has comprehensive experience in the development of customized hybrid diode laser modules which are mounted onto micro-optical benches. Depending on the respective application, they contain beam shaping optics, external cavities for optical gain chips, oscillator-amplifier combinations, crystals for second harmonic generation, and last but not least specific electronics circuits for short-pulse generation in the ps and ns range. Coupling to fibers whilst maintaining the brilliance of the diode laser sources is one big issue for such modules. In a common project with regional SMEs, for example, more than 3.5 W ex single-mode fiber and a coupling efficiency in excess of 60 % from a highly brilliant single laser chip have already been reached.

These hybrid modules serve as a very flexible technology platform for further applications including laser sensors. Developments in this field comprise dual-wavelength diode lasers enabling miniaturized Raman sensor systems for real-world applications, especially for in-situ measurements in security, food control, and point-of-care diagnostic areas. Another application area is high-precision measurements using optical clocks and matter-wave interferometers for research on fundamental rules of physics. These experiments will be carried out in space and therefore require not only ultra-stable, but also extremely robust laser systems. For this purpose, FBH develops space-qualified modules featuring narrow linewidth ≤ 10 kHz and output powers > 1 W using semiconductor optical amplifiers.



Hybrid-integrated MOPA module for atomic spectroscopy in space. Source: ©FBH/P. Immerz

High-power diode laser stack delivering 3 kW output power, suitable for pumping of solid-state lasers. Source: ©FBH/P. Immerz

Developments in the field of GaN-based optoelectronic devices focus on LEDs from the UV-B to the deep UV-C spectral region. These include 310 nm UV-B LEDs with long lifetimes exceeding 1,000 hours with output powers in the milliwatt range. Such sources are ideally suited for surface treatment of polymers, resist curing, sensors, and phototherapy.

These are only a few examples for customized solutions developed by FBH. The institute continuously cooperates with around 60 companies in the framework of R&D projects and offers related services. These collaborations comprise not only various international business relations and industrial contracts, but also long-term strategic partnerships which have been established with global players as well as with regional enterprises. In addition, FBH plays a vital role in networks like ‘Advanced UV for Life’, coordinating 23 partners from research and industry. Aim of the interdisciplinary consortium is to develop novel components, systems, and treatments based on UV LEDs and make them accessible for a variety of applications.

As cross-sectional technology, the excellent developments and long-term know-how from the FBH substantially contribute to the technological provisions for the future. They are of vital importance improving the capability of existing applications and opening up entirely new ones, hence addressing today’s society’s needs in vital fields like communications, health, energy, and security.

Ferdinand-Braun-Institut
Leibniz-Institut für Höchstfrequenztechnik
Gustav-Kirchhoff-Straße 4
D – 12489 Berlin
Phone +49 (0)30-6392-2600
Fax +49 (0)30-6392-2602
Mail fbh@fbh-berlin.de
Web www.fbh-berlin.de

Electrically Switchable Diffractive Optical Elements Based on Polymer Liquid Crystal Composites

Liquid crystal (LC)-based switchable or tuneable diffractive optical elements (DOE) are key components in electro-optical thin film devices used in spectroscopy, light-management and optical communication networks. Recently developed H-PDLCs (holographic polymer dispersed liquid crystals) are low cost devices with good diffraction efficiency and effective switchability. However, their application is limited by light-scattering due to µm sized LC-droplets inside the polymer matrix. In order to overcome this drawback, a new type of low-cost switchable DOE has been developed at Fraunhofer IAP. They are characterized by a LC droplet-free morphology and excellent optical and electrical performance. New developed photo-curable composites consist of monomers, nematic LCs and photo-initiators. Optimized material formulation and pattern-wise one-step holographic exposure result in photopolymerization-induced phase separation that forms a stripe-like periodic structure of polymer walls alternating with channels of neat LCs at room temperature. The exposure intensity determines the balance between photopolymerization and diffusion rates so that the crosslinking of the monomers in the bright regions does not prevent LC molecules from diffusing into the dark regions. Furthermore their planar alignment forms continuous anisotropic LC planes without the formation of LC droplets. The uniform droplet-free morphology provides a diffraction efficiency (DE) of about 99 % in the spectral range from UV up to NIR combined with excellent optical transparency in both electrical OFF and ON field states. Due to the fact that the LCs molecules are well aligned in uniform stripes rather than in small droplets, the application of an electric field of only a few V/µm is enough to reorient the LC director. This completely switches the grating (or tunes DE) to a µs timescale.

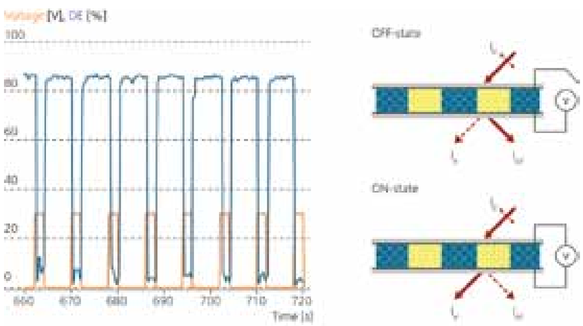


Fig. 1: ON/OFF electrical switching upon application of an electrical field and dependence of diffraction efficiency on applied electric pulses.

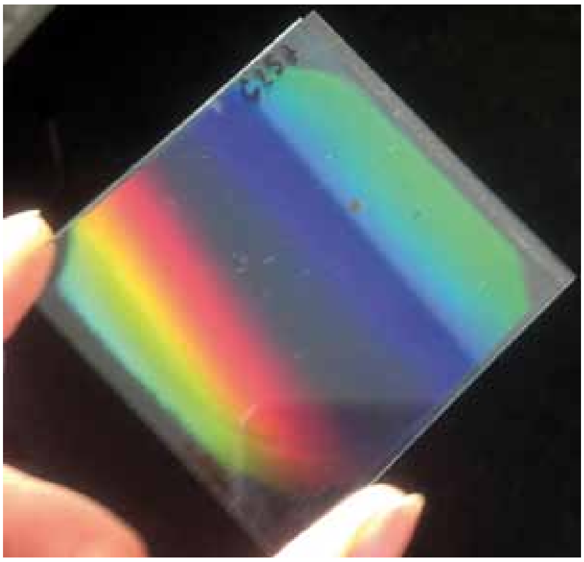


Fig. 2: High efficiency of new polymer-LC transmission gratings

Key features of the switchable diffractive optical elements are as follows:

- volume Bragg gratings with DE up to 99 % at a proper wavelength in the range of 400 – 900 nm,
- all-optical structuring in one step at room temperature using UV or vis light,
- excellent optical quality, high polarization dependence (DE^s < 1% and $DE^p \approx$ 99%),
- periodicity of the gratings: 350 nm – 10 µm,
- non-slanted and slanted gratings,
- high switching On/Off - contrast,
- ON/OFF switching times: tens of µs – 1 ms at driving voltages of approx. 3 V/µm.

This new type of switchable DOE has great potential for miniaturization and system integration in different optical technology fields. This includes applications such as beam switchers, splitters and steering elements, light in/out couplers, polarization valves for spectroscopy, and elements for display and laser technologies.

Dr. Oksana Sakhno
Fraunhofer-Institut für Angewandte Polymerforschung
Bereich Funktionale Polymersysteme
Abteilung Sensoren und Aktoren
Geiselbergstraße 69
D – 14476 Potsdam-Golm
Phone +49 (0)331-568-1247
Mail oksana.sakhno@iap.fraunhofer.de
Web www.iap.fraunhofer.de

Innovations and Competencies in Industry

Innovationen und Kompetenzen aus Unternehmen

Surface Functionalization by Thin Film Technology

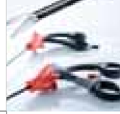
COTEC®

COTEC® GmbH is specialized in functional and ennobling coatings. Refinements to realize functional or protective coatings as final layer are custom in praxis in the field of optics and precision optics. The line of materials called DURALON is COTEC® 's super hydrophobic coating material to generate an excellent water repellent and easy-to-clean performance on several types of glass. This material forms a thin layer of less than 10 nm, does not affect the optical properties and ensures a long-lasting protection again watermarks, dust and grease. By default, it is coated using the physical vapor technique.

Due to the fact that adherent and abrasion-resistant functional layers become more and more attractive in the field of automotive, décor, plastics and medical application COTEC® is continually developing its line of materials. This includes both the functionality and the adhesive strength on various surface types. Functionalities as anti-fog, anti-static or anti-icing in combination with excellent transparency are of just as much interest as oleophobic or hydrophilic properties, always provided that an abrasion-resistant film is formed. To optimize the adhesive strength the structure of the coating material has to be adapted to the nature of surface material.

By the variety of technologies and the in-house research COTEC® has the capability to develop customized solutions. Our long-term experience in Government and European-funded projects as well as project cooperation with industry partners reflects our conviction that ongoing development is essential to meet the increasing demands of the industry.

COTEC GmbH
Frankenstraße 19
D – 63791 Karlstein
Phone +49 (0)6188-99462-0
Fax +49 (0)6188-99462-62
Mail cotec@cotec-gmbh.com
Web www.cotec-gmbh.com



WWW.FIBERWARE.DE

fiberware

the fiber specialist

1. MANUFACTURER OF SPECIALTY OPTICAL FIBERS

The company manufactures specialty optical fibers with synthetic fused silica in Germany. Production includes the modeling of optical waveguides and the drawing of fibers with core diameters from 3 µm to 2000 µm. Single-mode microstructured fibers can cover a spectral range with a wavelength of up to 3 µm. Passive as well as optically active structures are produced according to customer specifications. The fibers are also available made with biocompatible materials.

2. SPECIALTY CABLES MANUFACTURER

The fibers are used for various applications. Cables with a variety of core and sheath materials are therefore used. The cables are suitable for extended temperature ranges, for instance. Lengths of less than one kilometer are produced for special applications to meet customer requirements. The core and cables can be filled with jelly to allow use in humid environments.

3. PASSIVE AND ACTIVE FIBER OPTIC COMPONENTS

The company fiberware develops and assembles ready-made specialty products using fiber-optic components. Fused couplers are manufactured using fibers with large core diameters, for instance. For spectroscopy, capillary are fused with optic fibers in order to avoid interfaces. A number of sensors were developed for the optical monitoring of gas turbines. With our vast number of technologies and components, we provide universities and research laboratories with professional experimental systems sets for student training (e.g. supercontinuum generation, fiber-optic amplifier, and optical autocorrelators).

fiberware GmbH
Georg Kuka
Bornheimer Straße 4
D – 09648 Mittweida
Phone +49(0)30-567007-30
Fax +49(0)30-567007-32
Mail fiberware@t-online.de
Web www.fiberware.de

fiberware
HARNESSING LIGHT

PASSIVE AND ACTIVE FIBER OPTIC COMPONENTS ASSEMBLING
- fused couplers
- sensors
- fiber laser
- student experimental sets

SPECIALTY CABLE MANUFACTURER
- different sheeting materials
- short lenght manufacturing
- duplex
- jelly filled

SPECIALTY FIBER DRAWING
- single mode
- multimode
- active
- capillaries
- multicore
- microstructured

SCHOTT AG, Advanced Optics
Your Partner for Excellence in Optics

SCHOTT is a multinational, technology based group developing and manufacturing special glass, specialty materials, components and systems for more than 125 years to improve how people live and work.

SCHOTT Advanced Optics, as part of the SCHOTT group, with its deep technological expertise, is a valuable partner for its customers in developing products and customized solutions for applications in optics, lithography, astronomy, opto-electronics, architecture, life sciences, and research.

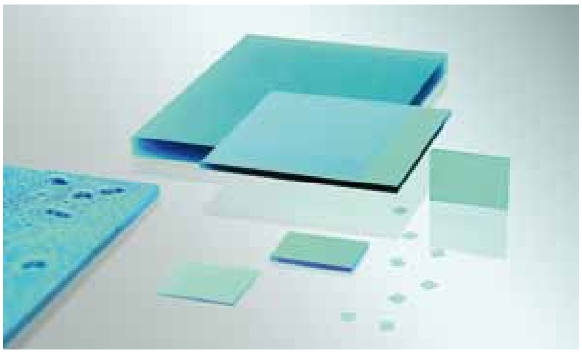
With a product portfolio of more than 120 optical glasses, special materials and components, we master the value chain: from customized glass development to high-precision optical product finishing and metrology.

SCHOTT provides optical glasses with the tightest tolerances for refractive index and Abbe number

SCHOTT is now the first manufacturer to offer special optical glasses in the new tolerance step 0.5. For step 0.5 the maximum deviation from the nominal values listed in the datasheet is only ± 0.0001 for the refractive index n_d and ± 0.1 % for the Abbe number v_d with this new quality grade. This means SCHOTT has the narrowest optical tolerances available in the market.

Glasses of the tolerance step 0.5 are particularly well-suited for the use in high precision applications. To achieve the best possible resolution, several lenses must be precisely in tune with each other. The narrow optical position of the glasses helps to improve the quality of lenses and prisms in industrial applications like inspection systems or microscopy.

SCHOTT now offers step 0.5 in over 15 glass types including: SCHOTT N-BK7® and N-BK7HT, N-KZFS2, N-KZFS4 and N-KZFS4HT, N-KZFS5, N-KZFS8, N-KZFS 11, N-PK51 and N-FK51A and more. Other glasses are available upon request.



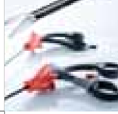
Successful introduction of BG6x HT filters: leading international smartphone manufacturers rely on SCHOTT quality

The new filter variants offer an excellent transmission profile for high quality digital camera applications: significantly higher transmission in the visible spectrum by up to 2 percentage points at 0.21 mm material thickness while still providing high blocking in the IR range. At a material thickness of 1.0 mm, the improvement of the transmittance is as high as 7 to 8 percentage points.

SCHOTT's standard BG6x family as well as the new BG6x HT series also offer excellent climatic resistance for challenging environments. The Blue Glass filters are of a high internal quality, resulting from an extremely low-volume striae level and an extremely low bubble and inclusion level.

Furthermore, the BG6x filters are environmentally friendly and free of hazardous substances antimony, cadmium, lead and chrome. Test reports by the internationally renowned company SGS substantiate this and are available upon request for all BG filters.

Advanced Optics
SCHOTT AG
Hattenbergstrasse 10
D – 55122 Mainz
Phone +49 (0)6131-66-1812
Fax +49 (0)3641-2888-9047
Mail info.optics@schott.com
Web www.schott.com/advanced_optics



BERLINER GLAS GROUP – OEM optical solutions from concept to series production

The Berliner Glas Group is one of the world's leading providers of optical key components, assemblies and systems as well as high-quality refined technical glass.
With our understanding of optical systems and optical production technology we develop, produce and integrate optics, mechanics and electronics into innovative system solutions for our customers and thus provide a significant contribution to their value chain.
Our solutions are used throughout the world in selected market segments of the light-using industries – the semiconductor industry, medical technology, metrology, laser and space technology, analytics, defense and the display industry.

From concept to series production

For our customers we are a reliable, competent long-term partner along the entire process chain – from concept to series production.
With more than 1,100 qualified and experienced employees the Berliner Glas Group develops and produces optical system solutions at five locations in Germany, Switzerland and China.

The complete spectrum encompasses:

Engineering

- System engineering
- Optical design
- Mechanical design
- Coating design
- Customer-specific metrology

Key components

- Spherical/aspherical lenses
- Cylindrical lenses
- Plano optics
- Coatings
- Electrostatic and vacuum chucks

Assemblies & Systems

- Optical assemblies and systems
- Opto-mechanical assemblies and systems
- Electro-optical systems
- Lens systems
- Objectives, zoom systems
- Measuring systems
- Cameras

Berliner Glas KGaA
Herbert Kubatz GmbH & Co.
Waldkraiburger Strasse 5
D – 12347 Berlin
Germany
Phone +49 (0)30-60905-0
Fax +49 (0)30-60905-100
Mail photonics@berlinerglas.de
Web www.berlinerglas.com

FISBA OPTIK – Committed Partner and Specialist for Optical Solutions

FISBA OPTIK is a worldwide leading manufacturer of components, systems and Microsystems. Our highly qualified lens designers and engineers are always on the lookout for the perfectly tailored solutions of specific customer needs. Our core competencies are the design, development and manufacturing of:

- Advanced Optical Components (AOC)
  - Precision molded lenses
  - Fast axis collimation lenses (FACs)
  - FISBA Beam Twister™
  - Aspheres
  - Slow axis collimation lenses (SACs)
  - Lens arrays
- Optical Microsystems (OMS)
  - Objectives
  - Pico projectors
  - Micro cameras
- Optical Systems
  - Lens systems
  - Laser modules
  - Collimators

New technologies for advanced glass optics

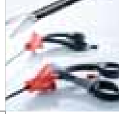
FISBA employs precision glass molding for the production of glass optics with free forms in larger lots, opening up totally new possibilities in the customer's system development and assembly optimization. Geometric forms made of glass, which were considered „impossible" so far, can now be realized.

Tailormade solutions that work

FISBA's optical systems offer extraordinary solutions for standard tasks as well as for completely new challenges. For example system components can be integrated even in the range of a few thousandths of a millimeter – mostly under clean room conditions. Semi-automatic assembly processes guarantee the smallest tolerances of less than 0.001 mm.

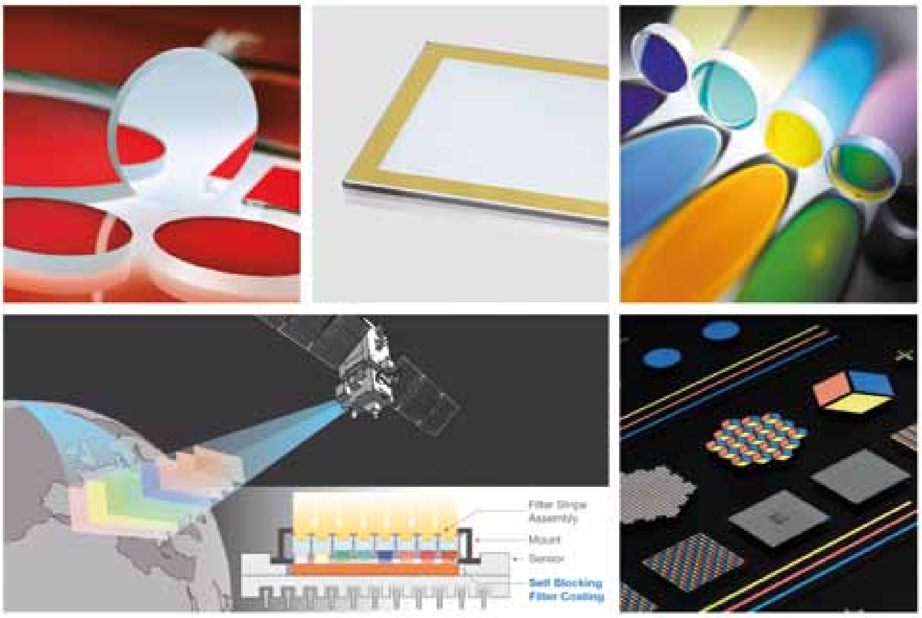
FISBA OPTIK

FISBA OPTIK AG
Birgit Rauch
Marketing Communications
Rorschacher Strasse 268
CH – 9016 St. Gallen
Phone +41 (0)71-282 31 31
Fax +41 (0)71-282 31 30
Mail info@fisba.com
Web www.fisba.com



Solutions from Optics Balzers

Optics Balzers is the innovative and independent industry partner for the development and production of coated optical components and subassemblies. The company possesses a broad and in-depth know-how in optical thin-film coating processes, complemented by sophisticated patterning, glass bonding and sealing, and further processing capabilities necessary for producing optical thin-film coated components up to optical subassemblies.



Highly experienced and skilled development and engineering teams closely collaborate with customers to develop innovative solutions meeting their specific and unique requirements and design robust processes to manufacture customer specific components. The combination of these capabilities and skills places Optics Balzers at the forefront of markets in the photonics industry such as Automotive, Biophotonics, Laser, Space & Defence, Lighting & Projection, Sensors & Imaging, and Industrial Applications.

With more than 65 years of experience in optical coating technology, Optics Balzers possesses profound knowledge in optical component manufacturing. Customers benefit from state-of-the-art vacuum-deposition technologies, various adapted patterning, bonding and glass processing technologies operated in modern facilities with clean room environments.

Optics Balzers' continuous innovation, quality improvements, additions of expertise and production sites in Liechtenstein and Germany, will continue to support customers' novel product development efforts with Optics Balzers as a trusted, reliable, and innovative partner.

Examples of Optical Coatings & Components

- Alflex™/Silflex™ folding mirrors
- Antireflection coatings
- Bandpass filters
- Chrome coatings
- NIR filters
- Notch filters
- Raman & Fluorescence filters
- Polarizing Beamsplitters

Coating Plus

- Patterning (photolithography, laser ablation, masked coatings)
- Bonding & Sealing (Gelot™ solderable coatings, B-stage Epoxy)
- Marking Solutions
- Glass Processing
- Subassembly
- Volume Production
- Packaging & Handling
- Development Partners

Optics Balzers AG
Neugrüt 35
9496 Balzers
Liechtenstein
Phone +423 388 9200
Fax +423 388 9390
Mail info@opticsbalzers.com
Web www.opticsbalzers.com

Optics Balzers Jena GmbH
Otto-Eppenstein-Straße 2
D – 07745 Jena

SCHÖLLY – EXCELLENCE INSIDE

SCHÖLLY is a global engineering and manufacturing company focusing on high-end visualization systems in medical and technical fields. Looking ahead, one of our main objectives will remain to develop sustainable solutions and innovative products using state-of-the-art technology, in order to create real value for our customers and users. A total of around 600 employees ensure that these products come into operation globally and these people aim at taking care of your needs: from the initial consultation, through modern production and global after-sales service.

Our visualization systems are distinguished by high-quality imaging, robustness and adaptability to a wide area of use. Their field of application ranges from use in manual and robot-supported visualization systems in medicine, to manual and automatic applications in industrial quality control, and all the way to complex visualization systems for tasks for example given in a high-temperature environment. Our integrated systems for visualization are created within a network of optical, mechanical and electronic components, light modules, image processing technologies with specific video algorithms. In production, we place the highest value not only on the excellent quality of the individual components, but also on the optimum interaction of the parts working together.

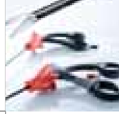
Microlenses and Lens Assemblies

The production of lenses and lens assemblies lies in our hands. Our activities cover all processes from the raw glass to the finished objective lens. We develop, manufacture and coat lenses from 0.25 mm to 19 mm in size and assemble complex objective lenses and assemblies by using high precision mechanics. Complex micro-optic systems are created with manual, mechanized and partially automated adjustment and assembly; for example, objective lenses can be optimally joined together with the integration of inline generated performance data in up to six degrees of freedom. In our manufacturing facility for lens and objective prototyping, we carry out reliable feasibility studies for complex lenses with close-to-production materials.

Electronic Components

The lenses and objective lenses are turned into optoelectronic components and systems by building in electronic parts such as image sensors. Because these sensors are becoming smaller all the time, they make it possible for endoscopes and cameras to increasingly grow together into one unit. Current 2D and 3D chip-in-scope and chip-in-tip systems take advantage of this development. By integrating intelligent and cost-effective cables for light

Microlenses and lens assemblies



and data transmission, we secure the functionality of the system as a whole.

Image processing

The development and production of optoelectronic components can reach its limits through physical and application-specific boundary conditions. In order to widen these boundaries, we are working on various image processing solutions. Not just for manufacturing but also for customer-specific applications. In this way we can produce visualization systems even more reliably and offer these with the latest functions in the form of platform designs. The development and verification of the related video algorithms play a decisive role here.

By means of technologically-specific image processing, we can, for example, correct geometric distortion or compensate a natural boundary light falloff in optical systems (vignetting). By means of application-specific image processing, additional information is generated. For example, colors can be enhanced to illustrate the finest of blood vessels (Selective Color Enhancement) or the view through smoke and/or mist can be enhanced mathematically, in order to make the invisible visible.

Best practice 3D-HD endoscopy

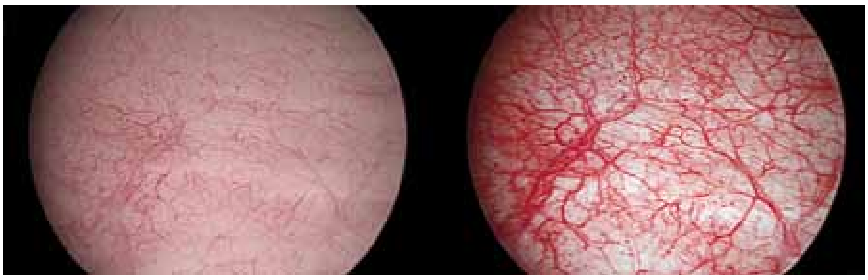
For over 15 years we have been developing and producing 3D systems in series and offer today all necessary video platforms, cameras, endoscopes and lighting modules that match these systems. Devices with a classic rod lens are equally available as modern chip-in-tip and chip-in-scope systems. In order to show correct 3D video sequences in real time, we not only have the competencies to correct spherical and chromatic aberrations, but also 3D specific influences. Only in this way stable video sequences can be created that allow an fatigue free viewing over a long period of time.

In surgical applications, a feeling of “eyes inside the patient” enhances concentration. Complex tasks, especially suturing and knot-tying, can be performed more accurately and in less time. In technical applications the inspection, cleaning and maintenance of in-process-control of complex parts can be performed reliably and efficiently.

Reliable partner and experienced OEM manufacturer

As a specialist for endoscopic visualization solutions, we offer our customers innovations for the future built on validated processes and extensive technological possibilities. Find more information on www.schoelly.de

SCHÖLLY FIBEROPTIC GMBH
Robert-Bosch-Str. 1-3
D – 79211 Denzlingen
Phone +49 (0)7666-908-0
Fax +49 (0)7666-908-380
Mail info@schoelly.de
Web www.schoelly.de



SCE (Selective Color Enhancement)

Smoke reduction

ADVA Optical Networking

The ADVA FSP 3000 scalable optical transport solution

About ADVA Optical Networking

ADVA Optical Networking is a global provider of intelligent telecommunications infrastructure solutions. With software-automated Optical+Ethernet transmission technology, we build the foundation for high-speed, next-generation networks. Our FSP product family adds scalability and intelligence to customers' networks while removing complexity and cost. With a flexible and fast-moving organization, we forge close partnerships with our customers to meet growing demand for data, storage, voice and video services. Thanks to reliable performance for more than 20 years, we have become a trusted partner for more than 250 carriers and 10,000 enterprises across the globe.

It Started with an Idea

Our company began with a single vision: to transport data, storage, voice and video signals at native speeds and lowest latency. A lot's changed since that time, but our vision remains the same. Our products are the building blocks for tomorrow's networks, enabling the transport of increasing amounts of data across the globe. From the access to the metro core to the long haul, we create intelligent, software-automated solutions that will provide future generations with networks that can scale to meet increasing bandwidth demands.

Innovation Is in Everything We Do

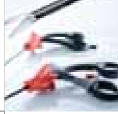
Our team is driven by innovation. It's part of who we are and has enabled our company to become a technology leader. We don't just listen to the industry, we steer it forward. Our team spans the globe and includes some of the industry's leading engineers and developers. Our innovative networking platform is built on a unified foundation of fiber-optic technology combined with Ethernet functionality and intelligent software. This technology enables service providers and enterprises to develop a highly scalable and automated infrastructure that can meet the most rigorous networking requirements.

Building the Future Together

We have become one of the industry's most trusted partners and are responsible for architecting some of the world's most advanced networks. The reason: we listen to our customers. Our technology and innovation is driven by our customers' needs. We develop the right technology at the right time, ensuring our customers have the solutions they need to stay ahead of the competition. Each member of our team is committed to our customers' success. Only by working so closely with our customers can we effectively build the foundation for tomorrow's networks. For more information please visit our website www.advaoptical.com.

ADVA Optical Networking's award-winning R&D and manufacturing site in Meiningen

ADVA Optical Networking SE
Fraunhoferstrasse 9 A
D – 82152 Martinsried
Phone +49 (0)89-89 06 65-0
Web www.advaoptical.com



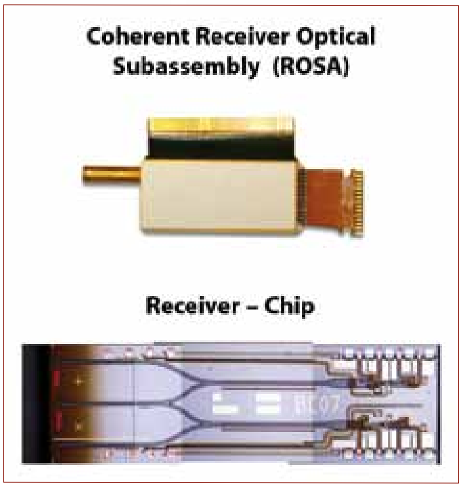
Finisar's Photonic Integrated Components for the Optical Internet

Finisar Corporation is a global technology leader and the world's largest supplier of optical components and subsystems. These products enable high-speed voice, video and data communications for networking, storage, wireless and cable TV applications.

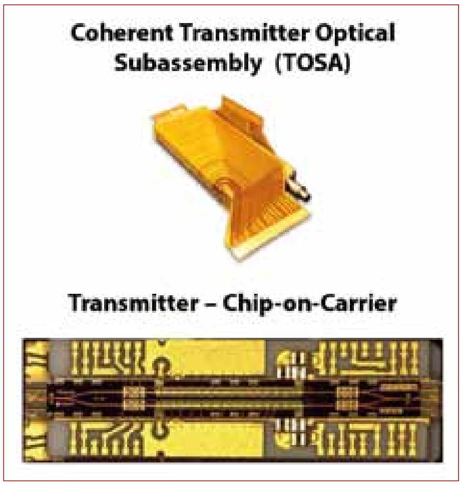
Finisar has provided critical breakthroughs in technology to meet the exploding demand for network bandwidth. With nearly 13,000 employees around the globe and its vertically integrated business model Finisar offers a broad portfolio of transceivers, active optical cables, optical engines, wavelength selective switches, ROADM linecards, optical instruments, RF-over-Fiber, optical amplifiers, high-speed receivers, and optical components.

Coherent CFP2 Transceiver

The 100 and 400 Gb/s long-haul telecommunications market is dominated by coherent systems which enable advanced modulation formats such as dual polarization shift keying (DPQSK) or Dual-Polarization 16 level Quadrature Amplitude Modulation/DP 16-QAM.



In January 2014, Finisar acquired u²t Photonics AG and since then develops new photonic devices for the optical core telecommunications network in Berlin, Germany. In-phase/Quadrature Mach-Zehnder modulators and integrated coherent receivers provide the photonic functionality to encode and transmit, as well as to receive and decode the transmitted signal data, which is required for the complex electrical-optical, optical-electrical transitions of the advanced modulation formats.



In close co-operation with the Fraunhofer-Heinrich-Hertz-Institute, Indium-Phosphide device technology is used which increases the performance of these components while reducing the overall cost. The demand for higher channel densities in the network requires a high level of integration and low power consumption. This can be achieved by the combination of transmitters and receivers as well as by narrow line-width lasers in small form factor CFP2 transceivers. These modules provide an Analog Coherent Optical interface to the electrical signal processing and routing functions in the networking equipment.

With its world-class R&D team Finisar is committed to providing the next-generation of optics with world-class quality and reliability.

Die Finisar Corporation ist weltweiter Technologieführer und der größte Anbieter optischer Komponenten und Teilsysteme. Diese Produkte ermöglichen ultra-schnelle Sprach-, Video- und Datenübertragungen im Glasfasernetz. Mit entscheidenden technologischen Durchbrüchen wird Finisar der stetig wachsenden Nachfrage nach Netzwerk-Bandbreite gerecht. Am Standort Berlin, Deutschland werden vorrangig integrierte photonische Sender- und Empfängerbauelemente für kohärente 100 und 400 Gb/s Übertragungssysteme entwickelt, produziert und vertrieben.

Finisar®

Finisar
Reuchlinstr. 10-11
D – 10553 Berlin
Phone +49 (0)30-726 113-500
Fax +49 (0)30-726 113-800
Mail berlin-contact@finisar.com
Web www.finisar.com

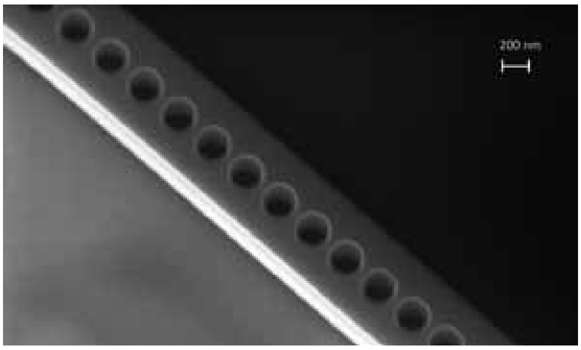
Nanophotonics

AMO GmbH is a German SME specialized on R&D of micro and optoelectronic applications. Our mission is to develop innovative technologies for nanoelectronics and nanophotonics, including their implantation in novel device architectures to a prototype level and small volume fabrication.

Typical applications of the integrated nanophotonic platform are optical communication technologies like high-speed communication. Research highlights have been carried out with partners within projects exceeding data rates of 112 Gbit/s with silicon-organic hybrid modulators[1)]. Moreover, are the areas of medical technology, analytics and biotechnology promising fields of applications for sensors build of nanophotonic devices.

As a research foundry, we provide prototyping and development services to our customers using our CMOS compatible technology. The product portfolio ranges from ultra high accuracy to small volume fabrication of photonic devices and systems. We offer the fabrication of individualized photonic components such as low loss waveguide based on SOI and silicon nitride substrates. Moreover, the functionality of passive photonics components is increased by additional metal layers, enabling heating and electro-optical modulators.

We provide individual service, short turnaround time and guaranteed IP protection to satisfy the customer's needs in the rapid field of photonics.



AMO operates a 350 m² CMOS compatible cleanroom equipped with a broad base of advanced semiconductor process technology for 6" and 8" wafers, including i-line projection lithography, ultra high resolution electron beam lithography (Vistec EBPG5200), several etching and deposition tools for metallic and dielectric materials and an experimental front end SOI CMOS process line. Additionally, AMO offers optical and electrical characterization setups for inline process control and quality management.

[1)] Work has been carried out within the framework of the FP7 European project Photxtrot. More information available on www.phoxtrot.eu

AMO GmbH
Otto-Blumenthal-Str. 25
D – 52074 Aachen
Phone +49 (0)241-8867212
Mail services@amo.de
Web www.amo.de

INNOLITE
TAILORED MOLDS AND OPTICS

Innolite GmbH is your expert partner for the production of plastic and metal optics.

On your products way to market, we help to configure the optic for optimal production and create prototypes to demonstrate the functioning of the final optical system. Our core competence is the ultra-precision mold making for the replication of plastic optics as well as the direct manufacturing of metal optics.

Ultra-precision mold making

With a focus on high precision molds in various geometries, Innolite has collaborated with a diverse range of customers from industries such as automotive, concentrated photovoltaics and street lighting. The geometric complexity of mold inserts increases at a steady pace and demands manufacturing solutions for even larger light guide patterns, more accurate microstructures or better surface figures for high end optics. Innolite is thus actively engaged in the development and integration of measurement devices into machine tools to use data feedback strategies for the continuous improvement of form accuracies.

Fig. 1: Transversal ultrasonic oscillator ILSonic with a depth of penetration up to 70 mm at an operating frequency of 95 kHz

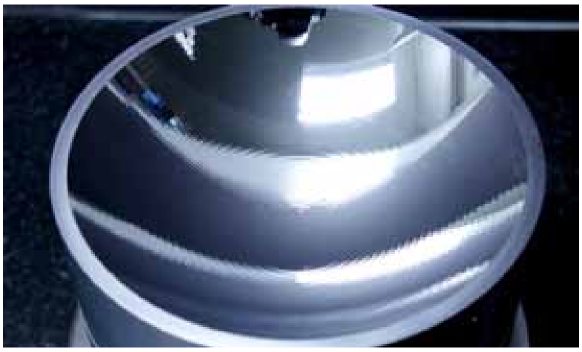


Fig. 2: Ultrasonic assisted diamond turned mold insert with superimposed microstructures for automotive industry

Ultra-precision machines

Based on years of practical experience in the field of diamond machining, Innolite started to develop and distribute ultra-precision machines. Due to consistently implemented automation, modularity and process variety as well as standardized, reliable control technology, the machines are characterized with the highest accuracy in components.

Ultra-precision steel machining

Innolite`s new ILSonic is the leading edge system for ultrasonic assisted diamond turning of steel combining highest frequency for economically efficient cutting, optimized collision geometry for machining strongly concave geometries and full feature integration for ease of use.

Ultra-precision clamping technology

The use of state-of-the-art clamping systems means that ultra-precision and productivity no longer have to be mutually exclusive. The ability to assemble during machine running time, work piece and tool replacement times down to mere seconds, automation using a pneumatic release system and safe mechanical clamping are advantages that are worth money in a state-of-the-art manufacturing environment. These advantages can be yours by retrofitting the NanoGrip clamping series to your ultra-precision machines, regardless of make.

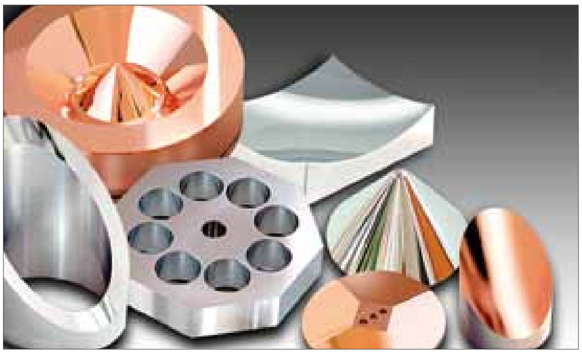
Innolite GmbH
Steinbachstr. 17
D-52074 Aachen
Phone +49 (0)241-8904-220
Fax +49 (0)241-8904-6220
Mail info@innolite.de
Web www.innolite.de

LT Ultra-Precision Technology GmbH

Founded in 1995, LT Ultra-Precision Technology GmbH has become one of the leading manufacturers of high performance metal optics, ultra precision machines and aero-/hydrostatic bearing components as well as beam delivery components. In addition to the serial production of optical surfaces on non ferrous metals, plastics and crystals with shape accuracies in the range of 0.0001 mm, customer specific solutions are elaborated in close co-operation with our customers. Extensive consulting-, support-, training- and after-sales services round out the program.

MMC 1100 Z2, UP-Bearbeitungszentrum

LT Ultra-Precision Technology GmbH has quickly gained reputation among various national and international companies in the field of laser-machining and metrology. It is the same with aero-/hydrostatic stages, spindles and ultra-precision machines. These are often customer specific solutions for the semiconductor- or the optical industry and specifications are derived from the parts to be machined. In this way, know-how in the field of air- and hydrostatic bearings, the machining of metal optics and the manufacture of ultra-precision machines complement each other to the benefit of our customers.



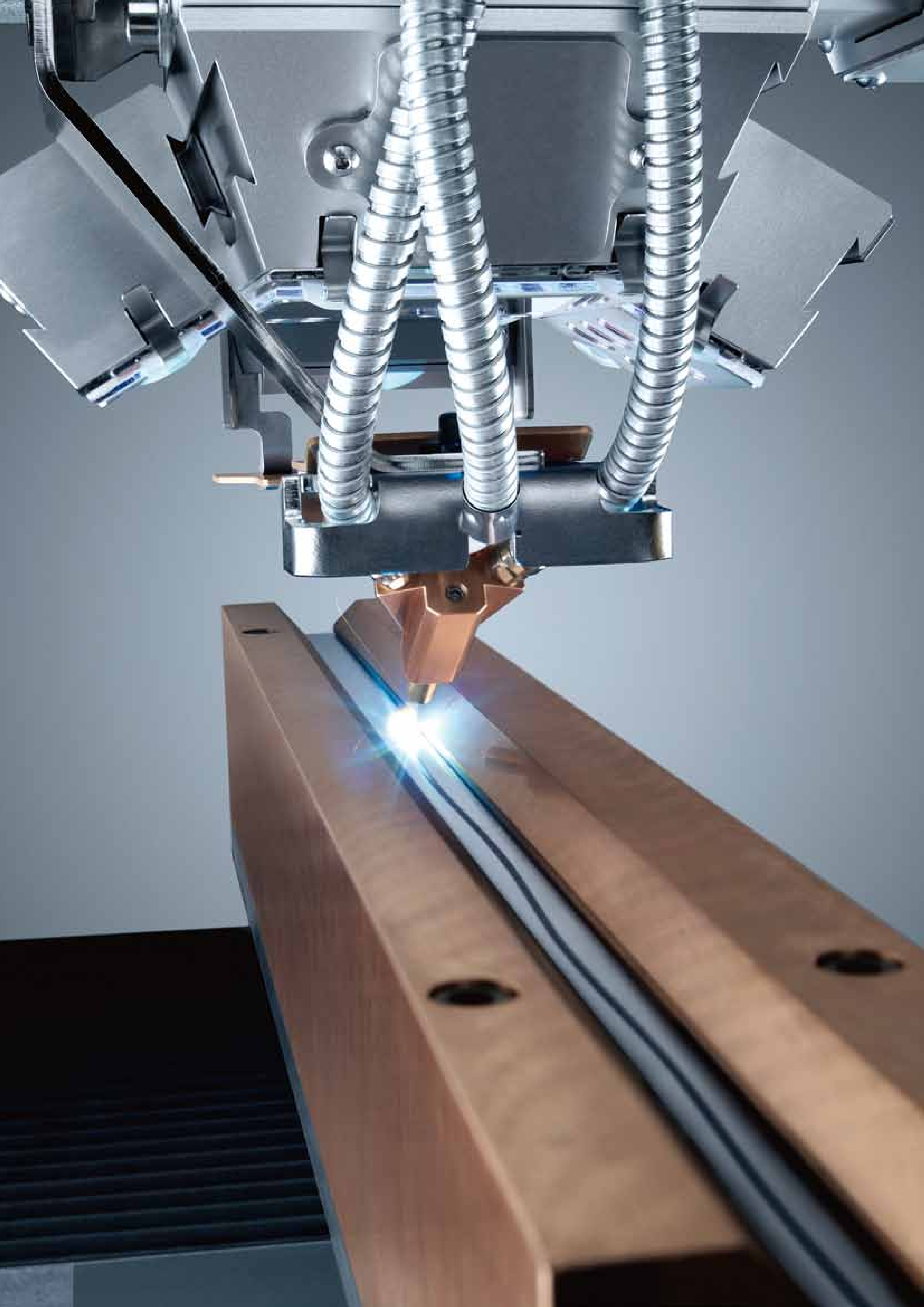
Luftlager und Metall-Optiken

Obwohl erst im Jahre 1995 gegründet, hat sich LT Ultra-Precision Technology GmbH mittlerweile zu einem der führenden Hersteller von Hochleistungs-Metalloptiken, Ultrapräzisionsmaschinen, aero- und hydrostatischen Lagern und Führungen sowie Strahlführungskomponenten entwickelt. Neben der Serienfertigung von optischen Oberflächen auf NE- Metallen, Kunststoffen und Kristallen mit Formgenauigkeiten im Bereich von 0.0001 mm, werden in Zusammenarbeit mit den Kunden auch spezifische Lösungen innovativ erarbeitet und realisiert. Eingehende Beratung, Betreuung, Schulung und ein umfangreicher After-Sales-Service runden das Programm ab.

Die LT Ultra-Precision Technology GmbH hat sich in kürzester Zeit bei vielen nationalen und internationalen Firmen im Bereich der Laser- Materialbearbeitung und der Messtechnik einen Namen als zuverlässiger Lieferant und Partner gemacht. Gleiches gilt für den Bereich der aero- bzw. hydrostatisch gelagerten Rundtische und Linearführungen. Komplexe Ultra-Präzisionsmaschinen sind oft kundenspezifische Sondermaschinen für die Halbleiter- und Optikindustrie, deren Spezifikationen wesentlich von den Bauteilen bestimmt werden, die später mit diesen Maschinen bearbeitet werden sollen. So ergänzen sich Know-How aus Luftlagerfertigung, Optikherstellung und dem Bau von Ultrapräzisionsmaschinen zum Vorteil unserer Kunden.

LT ULTRA
OUR PROFESSION IS PRECISION

LT Ultra-Precision Technology GmbH
Aftholderberg, Wiesenstr. 9
D - 88634 Herdwangen-Schönach
Phone +49 (0)7552-40599-0
Fax +49 (0)7552-40599-50
Web www.lt-ultra.com

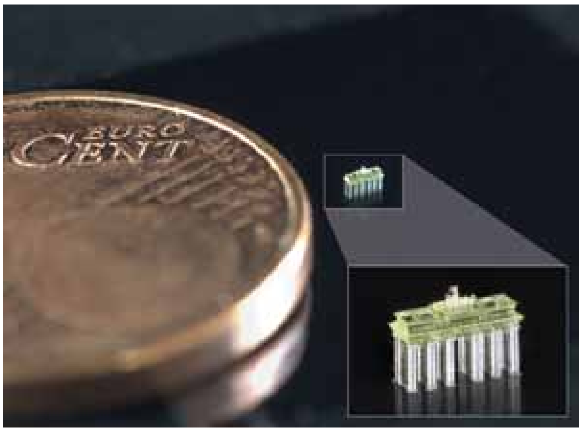


3D Printer for the Nano- and Micrometer Scale

The New Standard in Innovative Labs

Due to its in-depth knowhow in laser lithographic processes, Nanoscribe has established itself as the technological and global market leader of 3D printers for the nano- and micrometer scale. We serve scientific and industrial customers and develop customised solutions and processes for specific applications.

Based on the technique of direct laser writing, the laser lithography system Photonic Professional *GT* allows the fabrication of true three-dimensional structures with sub-micron feature sizes and a previously unavailable freedom of design. When common additive manufacturing technologies like stereolithography reach their limitations in resolution, our 3D laser lithography systems reveal their full potential.



Additive Manufacturing and Maskless Lithography in One Device

In combination with a user-friendly software package, the system is embedded best along the 3D printing workflow and offers a high degree of automation. It allows both additive as well as subtractive manufacturing of polymers on a broad range of substrates. To provide maximum 3D-printer performance with respect to resolution, writing speed, structural accuracy, and ease of use along the process chain, we also develop and sell optimized Nanoscribe photoresists to our customers.

Multitude of Applications

Nanoscribe´s laser lithography systems are being used by academia and industry worldwide to solve tomorrow's challenges. They are the drivers of innovation for numerous key technologies. The multitude of applications ranges from photonics, optical interconnects, micro-optics, micro-fluidics up to biomedical engineering. Driven by the general trend of miniaturization, Nanoscribe´s 3D printers set new standards in 3D microprinting and maskless lithography. The performance of the groundbreaking Photonic Professional *GT* system was emphasized by being awarded the 2014 Prism Award in the category "Advanced Manufacturing".

Nanoscribe was founded in 2007 as a spin-off from the Karlsruhe Institute of Technology (KIT) where since 2001 the technologically applicative basis for the subsequent spin-off was laid.

Nanoscribe GmbH
Hermann-von-Helmholtz-Platz 1
D–76344 Eggenstein-Leopoldshafen
Phone +49 (0)721-60 82 88 40
Fax +49 (0)721-60 82 88 48
Mail info@nanoscribe.de
Web www.nanoscribe.de

Precision in Perfection

The OWIS GmbH is a worldwide leading manufacturer of state-of-the-art precision components for the optical beam handling and of micro and nano-hybrid positioning systems. OWIS® products are applied in fields like information and communication technology, biotechnology and medicine, semiconductor and image processing industry as well as mechanical engineering.

Founded in 1980, OWIS® recognized in time the market demand for special opto-mechanical parts, a segment where only few suppliers were present. In particular, there were almost no enterprises ready to produce customized solutions in very small lots. From the very beginning, OWIS® have concentrated on this market segment and have ever since continued to specialize themselves. Furthermore, OWIS® belonged to the first companies having system components set up on profile rails in their stocks. The fact that this system is still very popular in all laboratories worldwide and that it is still regularly used, confirms its high acceptance.

Today, OWIS® has about 50 employees and is present in many countries worldwide through agencies. In Germany, Austria, Denmark and in the Benelux Countries distribution is made by the own sales force. Individual solutions are also locally worked upon with the customers. Many customers from universities, laboratories and industry enterprises appreciate OWIS® because of their competence and reliability and because of the quality and the compatibility of their products. For OWIS®, quality and precision "Made in Germany" have top priority, not at last ensured by the certification in accordance with DIN EN ISO 9001.

OWIS GmbH
Im Gaisgraben 7
D – 79219 Staufen i. Br.
Phone +49 (0)76 33-95 04-0
Fax +49 (0)76 33-95 04-440
Mail info@owis.eu
Web www.owis.eu / mobile.owis.eu

Dynamic Insitu Monitoring of Atomic Layer Deposition by ALD Real Time Monitor

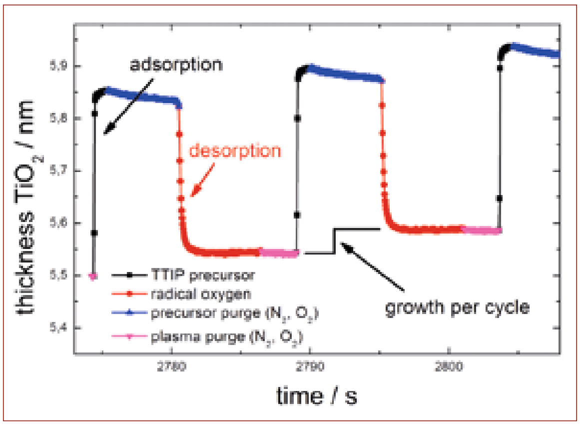
Experts in Thin Film Metrology and Plasma Process Technology

SENTECH Instruments develops, manufactures, and globally sells innovative capital equipment centred on thin films in semiconductor and microsystems technology, photovoltaics, nanotechnology, and materials research. SENTECH is expert in structuring and deposition of thin films by means of plasma process technology. SENTECH offers systems for plasma etching, plasma enhanced chemical vapor deposition, and atomic layer deposition. SENTECH provides innovative solutions for non-contact, non-invasive optical characterization using ellipsometry and reflectometry.

The controlled deposition of ultrathin films is of fundamental importance for further developments of the nanotechnology. 3D conformal deposition and control of film growth and material properties on the atomic level make atomic layer deposition (ALD) the most appropriate thin film technology.

The SENTECH ALD system SI ALD LL including ALD Real Time Monitor is especially suited for nanotechnology and microsystem applications, inorganic and organic semiconductor engineering as well as device passivation.

SENTECH unique ALD Real Time Monitor allows dynamic insitu monitoring of atomic layer deposition during the ALD cycles based on ultra-high sampling rate of up to 40 Hz for the first time. Analyzing of film properties (growth rate, thickness, refractive index) without breaking the vacuum, developing new processes in short time and studying reaction mechanisms during ALD cycles in real time are main applications of SENTECH ALD Real Time Monitor.



ALD process of TiO_2 deposition: Real time monitoring of adsorption, desorption and purging processes during ALD cycles

SENTECH SI ALD LL system with loadlock and ALD Real Time Monitor for process control

Easy Process Development

The real time thickness measurement with ALD cycle resolution confirms processing in ALD regime. The influence of ALD parameters such as temperature, pressure and flow rate as well as plasma parameters on adsorption and desorption processes on the sample surface is revealed.

Process Optimization

To optimize one parameter of the ALD cycle (precursor pulse, purge, co-reactant pulse, purge), this parameter is varied in a recipe-controlled process. The ideal value is used for optimizing the subsequent parameter. Consequently, substrates, precursors, and gasses are saved.

Endpoint detection

The ALD Real Time Monitor enables endpoint detection of the deposition process with sub Angstrom precession.

Integrated software interface for SENTECH ALD systems

Measurements are started and ended via ALD recipe control. Shutters for ALD Real Time Monitor view ports are controlled using ALD software. The ALD Real Time Monitor measurement is linked with the ALD hardware. Each switching of valves is depicted in a different colored plot. Measurement data is included into the system data logging.

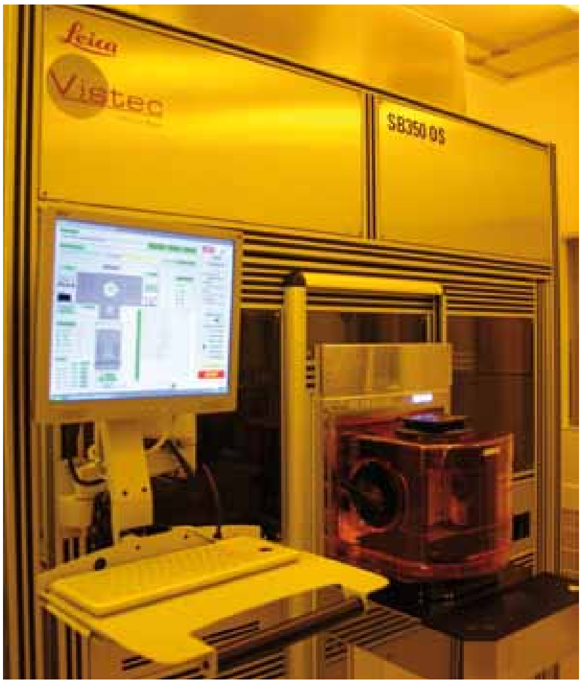
SENTECH Gesellschaft für Sensortechnik mbH
Konrad-Zuse-Bogen 13
D – 82152 Krailing
Phone +49 (0)89-8979 607-0
Fax +49 (0)89-8979 607-22
E-mail sales@sentech.de
Web www.sentech-sales.de

SENTECH Instruments GmbH
Schwarzschildstrasse 2
D – 12489 Berlin
Phone +49 (0)30-6392-5520
Fax +49 (0)30-6392-5522
E-mail info@sentech.de
Web www.sentech.com

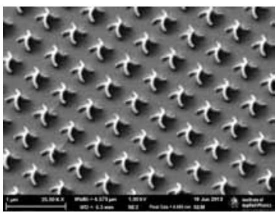
Electron-Beam Lithography for Optical Applications

As a long-standing equipment supplier, Vistec Electron Beam GmbH is providing leading technology solutions for advanced electron-beam lithography. Based on the Variable Shaped Beam (VSB) principle, the electron-beam lithography systems are mainly utilized for semiconductor applications and advanced research, as silicon and compound semiconductor direct write, mask making as well as integrated optics and several new emerging markets. Among standardized and proven systems, Vistec Electron Beam also provides and designs customized solutions according to special technology requirements.

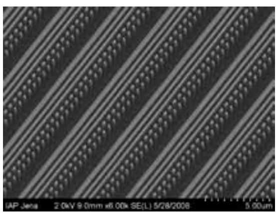
The company is located in Jena, Germany. Thanks to its location, Vistec Electron Beam benefits from the synergies between leading edge research institutes, universities, equipment and supplier companies as well as key semiconductor manufactures in the neighboring area.



Courtesy of Frounhofer IOF



3D chiral structures through CP (Courtesy of Friedrich-Schiller-Universität/IAP)



Near IR Spectrometer Grating (Courtesy of Fraunhofer IOF)

Vistec Electron Beam also maintains service and support centers in Europe, USA and Asia Pacific.

Optical technologies and applications are getting more and more important in our daily life. Electron-beam lithography, with its high resolution capability and flexibility, is one of the technologies allowing manufacturing optical elements with new optical properties. However, from an equipment manufacture's point of view, special requirements including positioning optimization and accuracy of critical structures dimensions, along with high throughput, longtime stability and the capability to handle large data volumes are linked with optical applications.

Prototypes and different production applications for optical elements with excellent properties can be produced by use of Variable Shaped Beam.

Examples include: waveguides as well as passive and active optical elements which are used in network technology, telecommunications, high speed data processing and data communication. Another example are gratings, used in high performance optical set-ups such as spectrometers.

To further serve nano-optical applications, a new feature called Cell Projection (CP) can be implemented as an option in all recent Vistec SB systems.

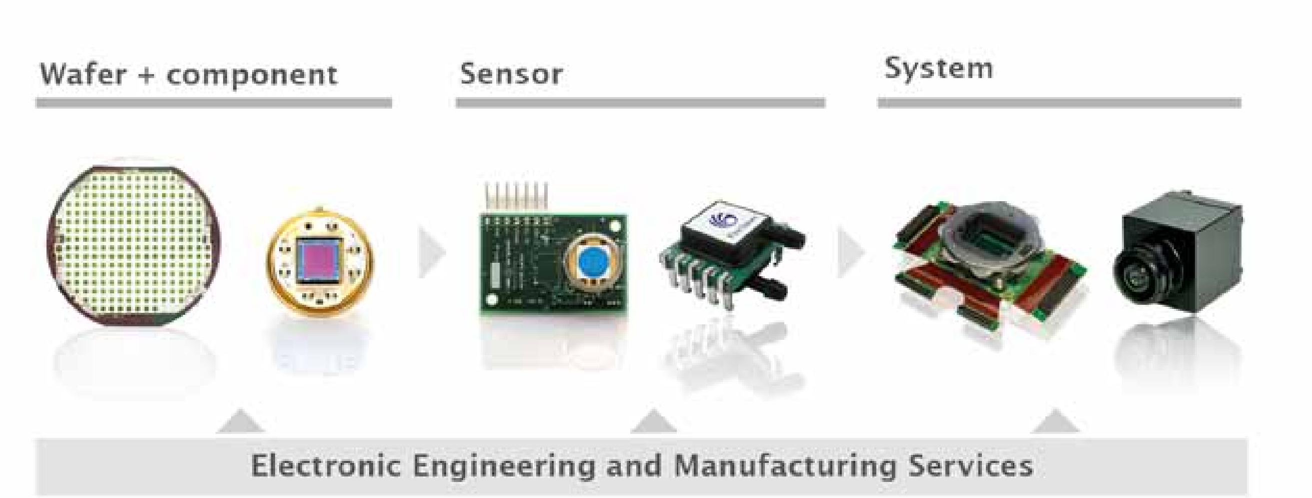
CP is a writing principle where more complex patterns than standard VSB shapes (rectangles, slants, and triangles) are coded in a stencil mask and are exposed as a single shot. This allows a higher throughput.

CP in combination with VSB is available in two configurations: first, as a basic configuration with up to 20 mini-reticles and secondly, in an advanced configuration with more than 20 mini-reticles.

Due to its high resolution capability and flexibility, electron-beam lithography is one of the technologies enabling the cost-effective manufacturing of elements with new optical properties. Therefore, CP mainly applies in nano-optical applications, in plasmonic, photo-crystal, metamaterials or silicon photonics.

Vistec Electron Beam GmbH
Ilmstr. 4
D – 07743 Jena
Germany
Phone +49 (0)3641-7998-0
Fax +49 (0)3641-7998-222
Mail electron-beam@vistec-semi.com
Web www.vistec-semi.com

First Sensor



First Sensor is a leading supplier of sensor solutions in the Medical, Industrial, Mobility, and Electronic Engineering & Manufacturing Services (E2MS) fields. First Sensor develops and manufactures high-quality, customer-specific sensor solutions for the detection of light, radiation, pressure, flow, level and acceleration. The company produces in-house and along the value-added chain from component to system level. Employing 790 people, the company is represented at six locations in Germany and also operates sales and production sites in USA, Canada, Singapore, UK, France, Denmark, Sweden and the Netherlands.

OUR COMPETENCE – YOUR SUCCESS

Sensor solutions are the basis of intelligent technology, and therefore they are always the first step on the path to innovation. First Sensor is your partner on this journey. We are one of the world's leading providers for developing and producing customized sensor solutions for OEMs, system suppliers and equipment manufacturers. We provide you with custom, high-precision solutions in certified top quality. That's what First Sensor stands for.

SENSOR SOLUTIONS FROM A SINGLE SOURCE

We provide you with tailored sensor solutions along the entire value chain – everything made under one umbrella. We are happy to give you advice on which sensor exactly you need for your application or if a customized solution might offer you a better total cost of ownership.

OPTICAL SENSOR SOLUTIONS

First Sensor has a large selection of high-sensitivity, high-speed and low-dark-current photodetectors optimized for ultraviolet, visible and infrared light as well as ionizing radiation. Package solutions include surface mount (SMD), through-hole (THD) and metal can type (TO) devices.

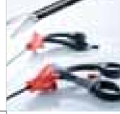
- PIN photodiodes
- Avalanche photodiodes (APD) and arrays
- Position-sensitive diodes
- Quadrant photodiodes
- Wavelength-sensitive diodes
- InGaAs detectors
- Detectors for ionizing radiation
- Silicon Photomultipliers

STRATEGIC PARTNER FOR DEVELOPMENT AND PRODUCTION

As a specialist in the development and production of sensor systems, we have been enabling long-term differentiation from the competition for many years. We provide all the expertise, technology and capacity this requires:

- Design, simulation, development and engineering
- Production processes
- Functional testing and calibration
- Qualification
- Serial production

First Sensor AG
Peter-Behrens-Str. 15
D – 12459 Berlin
Phone +49 (0)30-6399-2399
Fax +49 (0)30-6399-2333
Mail contact@first-sensor.com
Web www.first-sensor.com



More Precision
Optical Measurement Technology

MICRO-EPSILON

Micro-Epsilon is a medium-sized family-run company with headquarters in Ortenburg (Germany). For more than 45 years Micro-Epsilon has continuously offered reliable, high performance, unique solutions particularly when high precision measurement or inspection is required. The product range covers sensors for the measurement of distance and displacement, sensors for IR temperature measurement and color detection, as well as systems for dimensional measurement and defect detection.

Micro-Epsilon also presents a wide range of optical measurement technologies for displacement, distance and position that play an essential role in the increasingly automated production and inspection processes. As well as the miniaturisation and increasing functionality of sensors, smooth process integration is also a decisive factor in highly automated industrial production environments. Integrated sensors control the quality not only of the finished product but also the optimisation of production processes. The laser triangulation sensors belong to the group of optical standard measurement principles. For one-dimensional distance measurements there are laser sensors series optoNCDT available. Laser sensors in the optoNCDT series operate according to the triangulation principle. Laser sensors from Micro-Epsilon measure displacement, dimension,

distance and position. Laser sensors are also suited for measurements against special surfaces such as lustrous metals, high speed measurements or large stand off distances round off the range.

Laser scanners scanCONTROL carry out complex 2D/3D measurement tasks for the detection of profiles and contours. They use the laser triangulation principle for two-dimensional profile detection on different target surfaces.

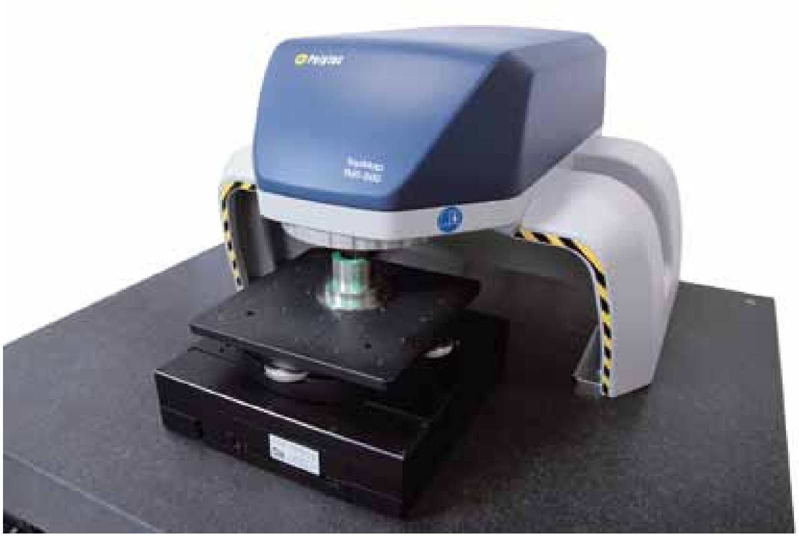
By using special lenses, a laser beam is enlarged to form a static laser line and is projected onto the target surface. A high quality optical system projects the diffusely reflected light of this laser line onto a highly sensitive sensor matrix. In addition to distance information (z-axis), the controller also uses this camera image to calculate the position along the laser line (x-axis). These measured values are then output in a two-dimensional coordinate system that is fixed with respect to the sensor. In the case of moving objects or a traversing sensor, it is therefore possible to obtain 3D measurement values.

Along with the triangulation sensors, Micro-Epsilon presents high end confocal chromatic sensors confocalDT 2451/2471 for. The controller achieves measurement rates of 10kHz using a white light LED and 70kHz using a xenon light source due to a very good signal-to-noise ration. Due to a comfortably designed web interface the total sensor configuration can be effected avoiding any additional software. The data output is effected via Ethernet, EtherCAT, RS422 or analog output. The confocalDT 2451/2471 are applied in challenging measurement tasks regarding the distance and thickness measurement.

MICRO-EPSILON Messtechnik GmbH & Co. KG
Martin Löw, BBA
Marketing Communications
Königbacher Str. 15
D – 94496 Ortenburg
Phone +49 (0)8542-168-0
Fax +49 (0)8542-168-90
Mail Martin.Loew@micro-epsilon.de
Web www.micro-epsilon.de

Measurements with Light

Optical Measurement Solutions for Vibration Analysis, Surface Topography Inspection, and Industrial Speed & Length Sensing



Polytec has provided high-technology, laser-based measurement solutions to researchers and engineers for over 40 years. We are committed to supplying the most precise and reliable optical instruments and sensors available for non-contact measurement, setting Polytec apart from the competition as the gold standard in the design and manufacture of vibrometer and velocimeter systems. Our innovations answer many pressing challenges in manufacturing and engineering.

Polytec develops and manufactures high-quality measurement systems for the analysis of vibration, length, speed and surface topography to solve our customers' application challenges in research, development, manufacturing quality and process control.

The applications range from micro system technology to large scale mechanical engineering, for example in the automotive sector, aerospace industry, medical technology, biomedical sciences, etc.

Besides laser technology, Polytec manufactures optical spectrometer systems and components for various applications in process analytics covering the full spectrum from OEM products to turnkey solutions.

Another focus of the Polytec business is the distribution of opto-electronic components and modules as well as complete measurement systems and special lasers for various applications. Polytec focuses on machine vision, fiber optics, sensing, optical telecommunication, optical radiation measurement, spectroscopy, semiconductor and photovoltaics, laser as well as on electro-optical test systems.

Optical Vibration Measurement

Polytec manufactures a wide range of laser vibrometers that are the acknowledged gold-standard for non-contact vibration measurement. No matter your measurement need, whether standard single-point or differential measurements, the determination of rotational or in-plane vibrations, the visualization of microscopic vibrations or the creation of a deflection shape for an entire surface, there is a Polytec system to provide the answer.

3D-Surface Profiling

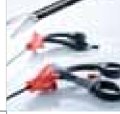
Polytec is addressing the surface metrology market with innovative, high-precision 3D profilometer technology that works on rough, smooth and stepped surfaces without contact. These products are based on scanning white-light interferometry, also called coherent or vertical scanning interferometry or coherence radar. With their large vertical range and nanometer resolution, they are ideal tools for determining flatness, height differences and parallelism of large surfaces and structures, including soft materials.

Speed & Length Sensors

Polytec Laser Surface Velocimeters (LSV) measure speed and length of moving surfaces accurately and without contact on coils, strips, tubes, fiber, film, paper, foil, composite lumber and almost any other moving material, including hot steel. Polytec's LSV systems are designed to perform continuously in harsh environments. The LSV control processor is easily interfaced with your process through its digital or analog interfaces.

Polytec

Polytec GmbH
Dr. Heinrich Steger
Polytec-Platz 1-7
D – 76337 Waldbronn
Phone +49 (0)7243-604-0
Mail h.steger@polytec.de
Web www.polytec.de



TRIOPTICS – Leading Manufacturer of Optical Test Equipment

TRIOPTICS GmbH is an internationally orientated company with headquarters in Germany. We are focused on optical measurement technology for lenses, lens systems and camera modules.

Mission

- to be the worldwide technology leader in optical test equipment
- to market products that are recognized as excellent in engineering and design

Our sales are globally positioned with subsidiaries in China, France, Japan, Taiwan and the USA and distributors in India, Israel, Korea, Russia and the UK.

Products

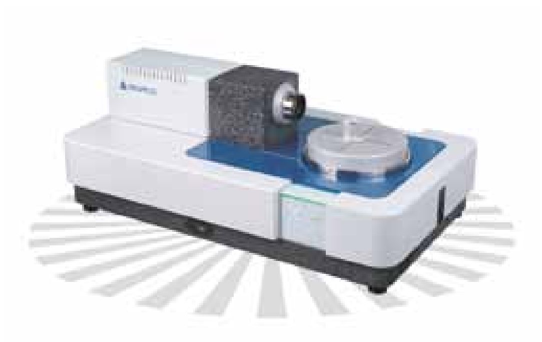
ATS – The first alignment turning station with fully integrated measurement technology for production of lenses in mount.

ImageMaster® is the most comprehensive line of MTF equipment for complete characterization of lenses and optical systems. It covers the complete spectral range from UV to IR.

The **ProCam®** product range covers the entire spectrum of assembly and final testing of camera modules and complete cameras from the R&D phase to mass production. ProCam® is an ultra-accurate measurement and production solution.

OptiCentric® covers a wide range of applications, either fulfilling centering measurement tasks or accomplishing important steps in the assembly and production process of optical systems. Recognized as industry standard for centering measurement, OptiCentric® provides outstanding accuracy and flexibility in applications for tiny endoscope and mobile phone lenses to precision optics used in microlithography and space applications.

ProCam® Align



PrismMaster® 300

OptiSpheric® is the industry standard for lens testing and qualifying optical components and systems.

WaveSensor® and **WaveMaster®** series measure the wavefront of aspherical and spherical lenses with Shack-Hartmann sensors.

The **TriAngle®** electronic autocollimator is ideally suited for standard angle measurement and alignment purposes in the laboratory, as well as for the production measurement of prisms and wedges.

PrismMaster® is the most accurate automatic goniometer featuring ultra-accurate angle measurements of prisms, polygons and other plano optics with accuracies higher than 0.2 arcsec.

SpectroMaster® and Spectrometer-Goniometers are used for high-precision determination of the refractive index and dispersion of optical glass and crystalline materials in the UV, VIS or IR spectral range.

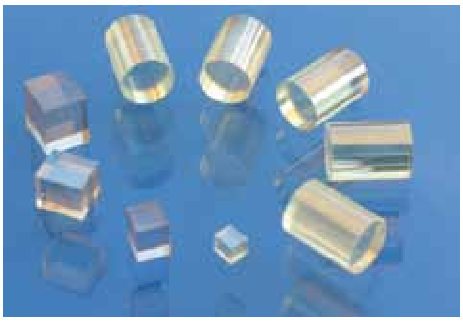
The **µPhase®** Interferometer measures the quality of spherical, aspherical and flat optics. It is compact and modular and measures optics and surfaces with reflectivities from 0.3% to 100%.

Furthermore, TRIOPTICS supplies standard optical test tools like spherometers, visual autocollimators, collimators, telescopes and dioptermeters.

TRIOPTICS GmbH
Hafenstr. 35-39
D – 22880 Wedel
Phone +49 (0)4103-18006-0
Mail sales@trioptics.com
Web www.trioptics.com

CRYSTAL GmbH – Your Partner for Optics and Crystals

We know about crystals..
...and we have been doing so for over 24 years. With a team of engineers, scientists and opticians, we manufacture crystalline components from our facilities in Berlin, serving leading companies in the photonic industry as well as in novel technology R&D. The emphasis on both branches, enable CRYSTAL to develop and supply individual and efficient solutions for customer requirements, regarding prototype- as well as series production.



Products and Services :

- **Optical Components**
  Windows, prisms, mirrors, lenses
- **Laser Components**
  Diffusion-bonded crystal composites
- **Substrates/Wafers**
  Single crystals for thin film application (epi-ready), bicrystals, standard sizes from stock
- **High-quality Single Crystals**
  Monochromators, scintillators, semi-conductors ferroic crystals
- **Assembly**
  Opto-electronic and opto-mechanic modules
- **Precision Processing of Crystals**
  Customised shapes and special crystallographic orientations
- **Crystalline Materials**
  Around 40 different materials available: Calcium fluoride (CaF_2), Sapphire (Al_2O_3), Barium fluoride (BaF_2), Rutile (TiO_2), Strontium titanate ($SrTiO_3$), Silicon (Si), Magnesium oxide (MgO) etc.

CRYSTAL GmbH
Ostendstraße 25
D – 12459 Berlin
Phone +49 (0)30-53 04 25 00
Fax +49 (0)30-53 04 25 25
Mail info@crystal-gmbh.com
Web www.crystal-gmbh.com

CryLaS – Crystal Laser Systems GmbH Leading Microchip and DUV Laser Technology

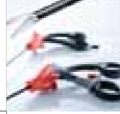
CryLaS is a globally reckoned manufacturer of diode-pumped solid-state lasers. CryLaS lasers are compact and robust, plug & play systems designed for OEM integration and use as stand-alone devices in lab environments and demanding scientific applications.

The product portfolio includes passively Q-switched microchip pulsed lasers from 213 to 1064 nm, and DUV cw lasers at 266 nm. Contained in sealed aluminum housings the lasers are suited for operation in a wide range of environmental conditions. Thousands of lasers are in industrial operation since many years.

CryLaS lasers combine excellent beam quality, long term stability, low noise and a very compact design with outstanding workmanship and superior product quality.

Located in Berlin, Germany, CryLaS serves customers in more than 35 countries worldwide. In addition to the experienced and technically capable direct sales and support team, CryLaS maintains a sales office in the US, and works with distributors in Asia and Europe.

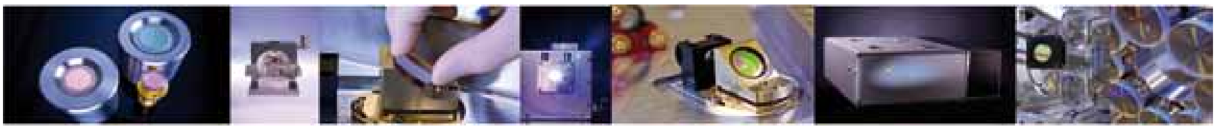
Crystal Laser Systems GmbH
Ostendstraße 25
D – 12459 Berlin
Phone +49 (0)30-53 04 24 40
Fax +49 (0)30-53 04 24 44
Mail info@crylas.de
Web www.crylas.de



Disk Laser Technology in Downtown Stuttgart

The disk laser was invented more than 20 years ago by Dr. Adolf Giesen and his coworkers at University of Stuttgart. Since then, commercial disk lasers in all power classes have become available.

Special purpose laser systems based on the thin disk laser technology with specifications, which are not readily available at the market, are built according to customer's demand.



Due to effective and homogenous cooling, the thin disk geometry allows for power and pulse energy scaling at high beam quality to much higher values than with rods, fibers or slabs. Disk laser technology is beneficial for medical applications, micro- and macro machining in the industry, as well as research fields like: Optical Parametric Chirped-Pulse Amplification, Extreme Ultraviolet generation, and Attosecond physics.

Dausinger + Giesen GmbH develops, markets, and sells disk lasers as well as key components and know-how in the field of disk laser technology

Mounting of thin laser crystals is the key technology for disk lasers. D+G offers pre-mounted disk laser crystals (e.g. Yb:YAG or materials like Yb:Lu_2O_3 or Yb:LuAG for high power femtosecond applications) tailored to customer's specifications. For power scaling, crystal diameters up to 25 mm with typical thicknesses of 200 µm – 350 µm are available.

Allowing – mainly – research groups to build their own laser, disk laser modules in various power classes are offered: The TDM 0.05, TDM 1.0, TDM 2.0, and TDM 30 (see figure) allow for maximum pump powers of 50 W, 1 kW, 2 kW, and 30 kW, respectively, for one single disk.

An example is our modular 50 W – 120 W laser system VaryDisk offering unprecedented flexibility in the choice of pulse duration from the femtosecond to the microsecond range. This laser was developed for process development in micromachining. One of the most important goals thereby is to find the optimum pulse duration for a given application. VaryDisk allows varying pulse duration keeping other parameters constant.

Another example is the GigaPulse laser system. D+G is currently developing a linear amplifier which will boost the pulses of the VaryDisk regenerative amplifier up to 750 mJ at ≥ 3 ps and 1 kHz.

Ample experience in macro and micro processing is used to foster the industrial application of disk lasers by feasibility studies and small series production in the application lab of D+G using VaryDisk and other modern lasers. Enduring on-site support of customers in their labs and production sites belongs since many years to the most demanded services of D+G.

DAUSINGER+ GIESEN GMBH

Dausinger + Giesen GmbH
Rotebühlstraße 87
D – 70178 Stuttgart
Phone +49 (0)711-907060-550
Fax +49 (0)711-907060-99
Mail info@dausinger-giesen.de
Web www.dausinger-giesen.de

LASOS

For worldwide photonics

In the last centuries laser technology has become one of the key technologies in nearly all fields of industry and science. Many modern applications in manufacturing and research are only possible due to the unique properties of laser radiation.

Jena in Germany, especially notable for its history in the development of optical technologies, is home to the facilities of LASOS. After moving into a new building LASOS has increased its production and is now developing and manufacturing lasers and laser systems in a 3000 qm² facility space equipped with the latest measuring and confectioning systems to serve customers with highest requirements on quality and reliability.

LASOS laser manufacturing practices are also guided by many years of industry experience, drawing on the expertise of Siemens and Zeiss. We are a leading manufacturer of gas and solid-state laser products for OEM equipment, particularly in the biophotonics, measurement technology and laser-supported image exposure sectors, with a special focus on the client specific production of laser modules and subsystems. Covering a range from UV to visible and near infrared with outputs up to several hundred mW our laser technology is in use for many innovative applications in microscopy, spectroscopy, flow cytometry, metrology and holography.

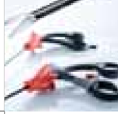
LASOS laser technology helps to

- Detect cancer and other diseases
- Encrypting the DNA to improve health care
- Inspect the quality of our daily food
- Analyze emissions to help protecting our environment
- Inspect component parts to assure constant quality
- Measure small length variations in construction sites

and many more.

With the closed chain of development, design and manufacturing LASOS is able to adapt customer's requirements and to deliver customized solutions including laser modules, optomechanical systems and fiber technology up to complete system solutions. LASOS has become the world's leading supplier of laser technology for confocal microscopy.

LASOS Lasertechnik GmbH
Franz-Loewen-Str. 2
D – 07745 Jena
Phone +49 (0)3641-2944-0
Mail sales@lasos.com
Web www.lasos.com



Omicron-Laserage Laserprodukte GmbH
Flexible Laser and LED Light Sources for Industry and Science

Omicron develops and produces innovative laser systems and LED light sources. Important developments are compact high-performance and pulsed diode lasers, LED and laser light engines as well as laser beam combiners. With these developments, Omicron is one of the leading manufacturers for demanding applications in biotechnology, microscopy, microlithography and many more.

Innovative Products

LuxX+

The lasers of the “LuxX+” series have got several new functions: With fast, direct digital modulation capability of >250MHz and analogue power modulation >3 MHz and full modulation depth >500 kHz, the lasers have got unique modulation speeds. The “LuxX+” is available in more than 20 different wavelengths in the range of 375nm to 1550nm with an output power of up to 500mW.

BrixX ps® Picosecond Pulsed Diode Laser

The “BrixX ps” series of diode lasers can be pulsed in the picosecond range, as well as being operated in “continuous wave” (CW) and modulated mode. The compact laser modules with completely integrated driver electronics, high precision temperature regulation and beam shaping optics can emit ultrashort pulses down to 50 picoseconds, pulses in the nanosecond range and fast analogue and digital modulated CW emission. The light output can be either free-space or fibre-coupled. The modules have got an electronic shutter function which can switch the emission on and off at a bandwidth of more than 500kHz. In pulsed mode the repetition rate can either be triggered by an external synchronization signal, or it can be generated by the internal, programmable frequency generator with up to 100MHz.

Multi Wavelength Solutions

The SOLE® laser light engines and LightHUB® compact beam combiners represent a new era of Omicron products. The SOLE® light engines are compact laser sources with up to six lasers, coupled in up to two single mode fibres. The SOLE® systems offer fast analogue and digital modulation for each laser line and fast switching between the individual wavelengths. The LightHUB® compact beam combiners are able to steadily combine the laser beams of up to six diode or DPSS lasers into a co-linear beam, which can then be used in free-space or fibre coupled applications.

The Omicron LedHUB® is a high power LED light source for Biotech, industrial and analytical applications. With up to 6 wavelengths between 365 and 840nm it can be used in applications like widefield microscopy, optogenetics, chemical analysis, forensics etc. Key features are the modular principle, field-upgradability, fast switching between the wavelengths and high speed analogue modulation.

Omicron-Laserage Laserprodukte GmbH
Raiffeisenstrasse 5e
D – 63110 Rodgau
Phone +49 (0)6106-8224-0
Fax +49 (0)6106-8224-10
Mail mail@omicron-laser.de
Web www.omicron-laser.de

rofin

Your Industrial Laser Partner

Light, when used as a manufacturing tool, is fascinating: it offers a virtually infinite potential of applications in materials processing. Whether CO_2 lasers, solid-state lasers, fiber lasers, ultrashort pulse lasers or diode lasers, ROFIN provides all of the decisive key technologies and covers the entire spectrum of industrial lasers. The product portfolio ranges from industry standard laser beam sources to compact all-in-one system solutions – we offer the optimal solution for almost every application task.

The application areas for ROFIN lasers are as broad as the product range. ROFIN lasers are used for production in automotive industry, machine tool industry, manufacturing of electronics and semiconductors, in photovoltaics and also in jewelry design as well as medical device technology.

M³ - Macro, Micro, Marking

Our company is structured by the application areas of the laser technology: Macro, Micro and Marking. Whether it is the use of high-power lasers in harsh industrial environments, filigree laser applications in the µm-range or the laser marking on different materials – with these three core competences ROFIN optimally meets all customer requirements in the field of laser technology.

ROFIN Macro – The Power of Light

With output powers from 500 watts up to several kilowatts, the ROFIN Macro group is typically affiliated with applications in the sheet metal industry. However, high-power lasers are also used in many other production processes, such as the manufacturing of wine glasses, the cutting of wood for die boards, as well as the processing of tubes and profiles – the list of possible applications is essentially endless. Thanks to clean cut edges, securely welded seams and flexible contouring, high-power lasers provide manufacturers with perfect production tools that not only enable high processing speeds but also innovative product design.

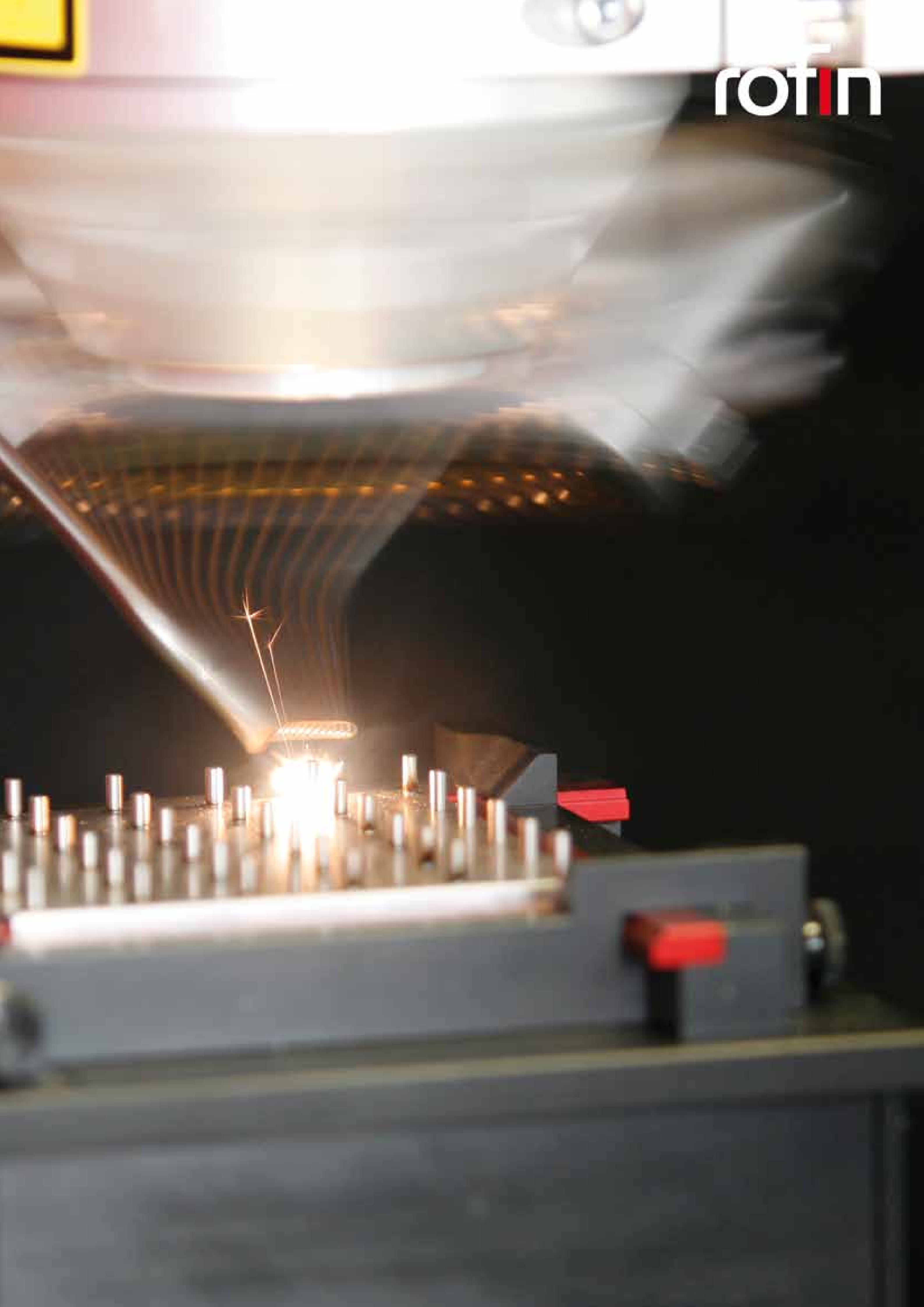
ROFIN Micro – Focus on Fine Solutions

Laser micro-processing is defined by high-precision applications and the processing of minuscule, delicate parts down to the micrometer range. The continuously growing field of applications includes fine cutting, spot and seam welding, micro drilling, structuring and perforating. Due to the ongoing trend of micro manufacturing and the miniaturization of electronic components, the ROFIN Micro group continually enhances its product portfolio with new laser technologies and system solutions to meet these ever increasing needs. Laser micro-processing is not only used in high-tech product manufacturing processes – the spot-welding of pacemakers, the fine-cutting of medical instruments and medical implants like stents, and the micro-structuring of solar cells, for example – but also in the production processes of everyday goods, such as the spot-welding of eyeglasses and batteries.

ROFIN Marking – The Mark of Excellence

Whether it's metal, plastic, glass, ceramic, wood or semi-conductors – nearly all materials can be marked by a laser. Millions of pieces and products are laser-marked every day around the globe, from animal ear tags to pacemakers and from microprocessors to driver licenses. In the smart card industry, lasers are often used to mark cards such as ID cards, mobile phone SIM and media cards, as well as credit cards. The result is an abrasion-proof mark that does not require any additional sealing or label sticking. Lasers provide a permanent and forgery-proof technique for marking a virtually unlimited quantity of organic and synthetic materials. Whether sophisticated turnkey solutions or laser sources for integration purposes, the ROFIN Marking group offers one of the market's broadest ranges of customized and standardized marking solutions.

ROFIN-SINAR Laser GmbH
Berzeliusstrasse 87
D – 22113 Hamburg
Phone +49 (0)40-73363-0
Fax +49 (0)40-73363-4100
Mail info@rofin.com
Web www.rofin.com



Markets and Networks

Märkte und Netzwerke

Lasers and Photonics at the Biggest Show Ever – LASER World of PHOTONICS 2015 is industry and research flagship

The global photonics market is on an upward trend, the increasing importance of the key technology photonics is unabated – and with it the demand for exhibition space. With 1,130 exhibitors occupying 42,000 square meters, the last LASER World of PHOTONICS in 2013 was fully booked. To meet the need of the industry in 2015 the world's leading show LASER World of PHOTONICS 2015 has expanded by one hall to 55,000 square meters and now presents the biggest show ever in the show history of photonics.

From 22 to 25 June 2015 the international laser and photonics industry is meeting for the industry's flagship show at the fair ground of Messe Muenchen. Taking place in parallel is the international scientific elite's meeting at the World of Photonics Congress 2015 from 21 to 25 June 2015.

For more than 40 years, the world's leading trade fair has been the number one global market place for all matters pertaining to lasers and photonics. Dr. Reinhard Pfeiffer, Deputy CEO, Messe München GmbH said: "The photonics industry is an industry of the future and the driving force behind numerous other industries. We sense the need for the technology from the market growth, the growth in exhibitor numbers and from the fact the halls were becoming ever fuller. Therefore we upsized the LASER World of PHOTONICS 2015."

Outstanding forecasts: steady growth of photonics market

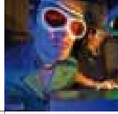
The global photonics market is indeed on a stable or even an upward trend. The economic indicators in Germany - according to the latest edition of the "Branchenreport Photonik" – pointed to long term growth again in the wake of subdued development in 2012 and 2013. Photonics is of strategic importance to the German government, which has identified it as one of the key technologies of the future in its high tech strategy.

In the remaining years to 2020, the biggest EU framework program for research and innovation, "Horizon 2020", with 80 billion euros of funding, aims to help small companies generate the ultimate in innovation, in photonics as well.

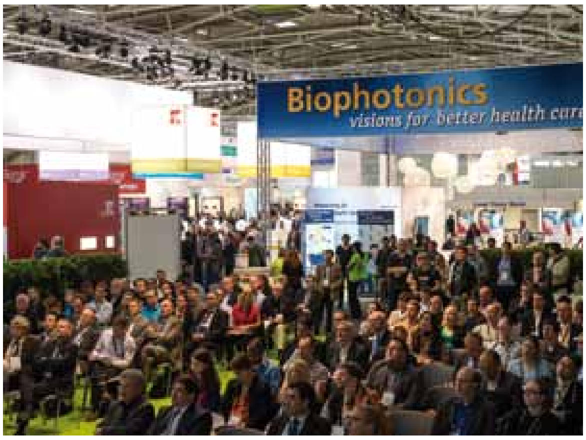
Dr. Reinhard Pfeiffer, Deputy CEO, Messe München

Three focus topics for all facets of photonics

The LASER World of PHOTONICS exhibition spans all aspects of the application of photonics – already established applications and industry newcomers and future markets alike. A new highlight and focus topic in 2015 is the "imaging" field. There is scarcely a single production sector nowadays capable of dispensing with industrial image processing, combining stringent quality control with optimal efficiency. There is a huge need for solutions. Their use is extremely diverse, for example in testing and measurement technology, optics, medical and photo technology, electronics and material processing.



Entrance West
Messe München



Messe München

"Laser systems for manufacturing" are already established but remain among the trade fair visitors' favorites. This largest focus topic showcases the entire gamut of laser applications in material processing and machining. The spectrum ranges from macro to micro material processing and on to additive manufacturing – also known as 3D printing. The laser is also increasingly the option of choice as a machining tool for lightweight construction solutions or hybrid material combinations. Twinned with robots and the appropriate system peripherals, laser systems cater for users' every conceivable wish, in automation matters as well.

In the third focus area, "Biophotonics & medical technology", medical and scientific companies are showcasing solutions from spectroscopy and microscopy to therapeutic and manipulation processes.

Laser and optoelectronics, optical information and communication, optics and manufacturing technology for optics, sensors, test and measurement technology and optical measuring systems complete the exhibition portfolio.

The latest trends that will also been showed at the LASER World of PHOTONICS 2015 are Additive manufacturing, ultra-short pulse lasers or 3D X-ray microscopy.

World of Photonics Congress – Meeting of the International research elite

In 2015 the World of Photonics Congress, one of the three biggest scientific photonics congresses in the world, is entirely under the "International Year of Light and Light-based Technologies" banner.

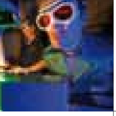
With its six conferences, the Congress is addressing all disciplines of the photonics sciences – from fundamental research to application-related areas such as optical measuring technology, lasers in manufacturing, biophotonics and biomedical optics as well as optical component manufacturing processes. International scientific societies such as EPS, OSA, SPIE, WLT and IEEE ensure the high scientific quality of the contributions. In 2013 around 3,500 international participants attended the Congress with its more than 2,800 lectures and poster presentations.

LASER World of PHOTONICS global network in Germany, China and India

The LASER World of PHOTONICS trade fairs and their congresses are the most important marketplaces for the worldwide laser and photonics industry. Messe München International has held LASER World of PHOTONICS in Munich every two years since 1973. LASER World of PHOTONICS CHINA is the leading regional trade show for optical technologies in China and takes place in Shanghai every spring. LASER World of PHOTONICS INDIA is a regional trade fair for optical technologies in India. It takes place every year in fall, rotating in Mumbai, Bangalore and New Delhi.

With a total of 1,860 exhibitors and more than 70,000 visitors in Munich, Shanghai and India, Messe München International is the world's leading trade show organizer for lasers and photonics.

Press contacts
Messe München GmbH
Claudia Huber
PR Manager
Messegelände
D – 81823 Munich
Phone +49 (0)89-949-21471
Fax +49 (0)89-949-97 21471
Mail claudia.huber@messe-muenchen.de
Web www.world-of-photonics.com



German Society of Applied Optics
Deutsche Gesellschaft für angewandte Optik e. V. (DGaO)

Involvement of the DGaO in the International Year of Light

The United Nations have proclaimed 2015 as the International Year of Light (IYL2015) to raise awareness of how optical technologies promote sustainable development and provide solutions to worldwide challenges in energy, education, agriculture, communications and health. The DGaO is happy to be one of the Gold Sponsors of the International Year of Light in order to promote the public interest in optics as one of the key technologies of the 21st century. Besides being a sponsor of national and international activities we warmly welcome our members to start local initiatives which can be financially supported from the DGaO. Details for financial support can be found on www.dgao.de.

EUV lithography illumination system (Source by Carl Zeiss AG)

Interface between optics experts from science and industry

More than 130 000 employees and an annual turnover of about 30 billion Euros make the optical technologies to be one of the most important fields for the future of German economy. The essential part to promote this area is the exchange of knowledge and experiences between photonics and optics experts from industry on one side and from research laboratories and universities on the other side. Since its foundation in 1923 the German Society of Applied Optics (DGaO) is committed to this task. Apart from different working groups and meetings on a national level, DGaO endeavors this interfacing idea more and more also on a European level.

Key-role to establish applied and close-to-industry research problems in Europe

As third biggest “Branch” of the European Optical Society (EOS), after the French and the British optical society, DGaO influences and supports optical technologies and science on a European level. Due to a very strong optics and photonics industry in Germany, DGaO plays a key-role in establishing applied and close-to-industry research problems in optics in a European context.

Preservation of the level of optics education and further training

Education and further training in the field of the optical technologies is another element, which especially in a European context becomes more and more important. Herein, DGaO considers itself to be partner and intermediary between educational institutions and institutions of further training on one side and the needs of the optical industry on the other side. The preservation of the currently very high level of optics education and further training, especially regarding the new academic degrees according to the Bologna process, is a great concern of DGaO.

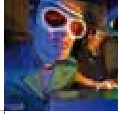
Transfer of new topics from science to industry

Optics and Photonics in Germany show very clearly how new technologies are transferred into innovative products in relatively short time. DGaO is devoted to further improve this by connecting people from science and industry. Some examples may show this rapid transfer from science to industry.

Production technology of optical elements is driven by the need for innovative optical elements like free form surfaces and diffractive optical elements which become more and more common in optical instruments covering very different fields from consumer illumination optics up to EUV lithography lenses.

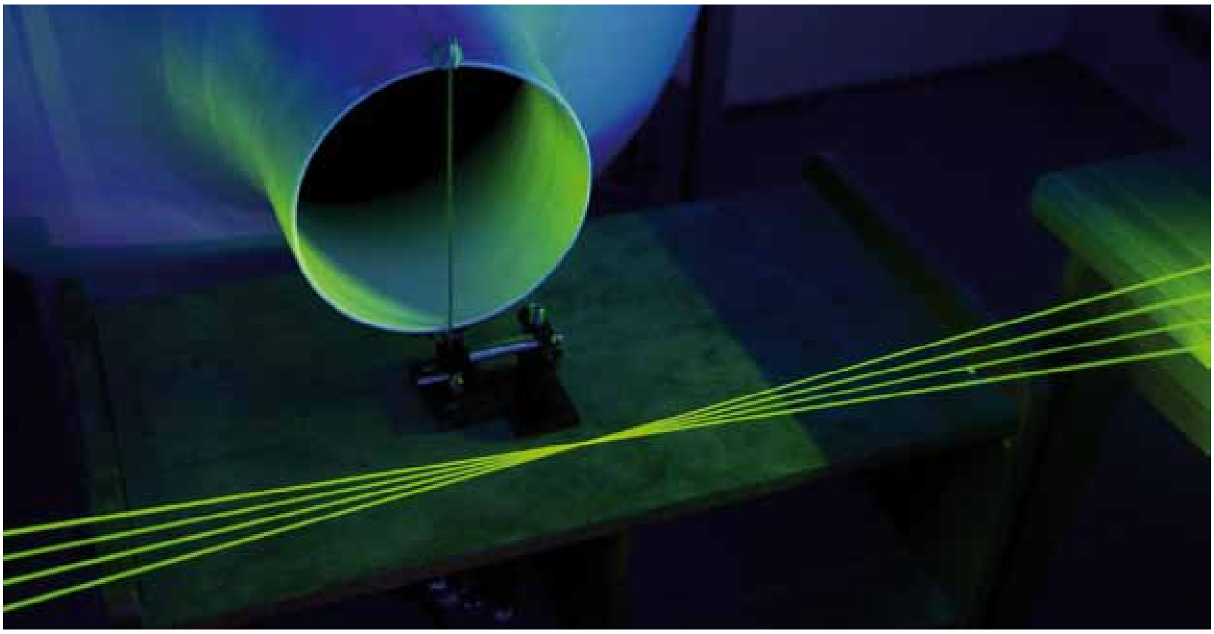
Ultra short pulse lasers have made two photon microscopy and lithography possible and are gaining growing importance. Frequency combs enable new types of optical measurement in spectroscopy and length measurement with extreme precision.

Micromechanical elements (MEMS), Microdisplays and light sources such as LEDs and OLEDs become part of



DGaO
Deutsche Gesellschaft für angewandte Optik
The German Branch of the European Optical Society

Highly resolved three dimensional measurements of flows using four adaptive laser beams with micron and microsecond resolution using 4 multiplexed laser beams of a frequency-doubled Nd:YAG laser. MEMS spatial light modulators enable undisturbed precise measurements. Credit of the photography : Berthold Leibinger Innovationspreis (Prof. Czarske TH Dresden)



classical optical instruments like microscopes. They also enable highly innovative systems using adaptive optics as demonstrated in the experimental setup for 3d airflow measurement from Prof. Czarske.

Annual Meetings

The Annual Meeting is the most suitable forum to discuss and address the topics mentioned above to the corresponding audience. Being frequented by several hundreds of scientists and engineers, this Annual Meeting typically takes place in spring in the week after Whitsuntide. The meeting is accompanied by a trade-show, where companies and organizations are invited to present their products or services for very moderate fees.

116th Annual Meeting of the DGaO in Brno

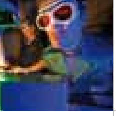
DGaO is happy that the international year of light goes along with the longstanding tradition to hold the DGaO annual meeting in a neighboring country as a joint conference together with the local optical societies. For 2015, we would like to invite you to Brno (Brünn) in the Czech Republic. The 116th Annual Meeting will take place from May 26th to 29th 2015 at the Brno university of technology. The conference will be held as a joint event of the Czech and Slovak Society for Photonics and the DGaO. The conference will mainly address the following topics:

- Precision Optics and Mechanics
- Optical and Photonic Systems Design
- Optical Metrology
- Microscopy
- Micro and Nano Photonics
- Optical Image Processing
- Biophotonics and Optofluidics

Short oral presentations (12 minutes) and poster presentations are invited, concerning all aspects of Applied Optics, and preferably the above mentioned topics. The meeting language is English. Submission of the contributions should be made before January, 18th 2015 on www.dgao.de.

Furthermore we warmly welcome applications for the now established DGaO Nachwuchspreis. Details can be found on www.dgao.de.

Dr.-Ing. Frank Höller
President of the German Society of Applied Optics (DGaO)
c/o Carl Zeiss AG
Carl Zeiss Str. 22
D – 73447 Oberkochen
Phone +49 (0)7364-20-4399
Fax +49 (0)7364-20-2692
Mail dgao-sekretariat@dgao.de
frank.hoeller@zeiss.com
Web www.dgao.de

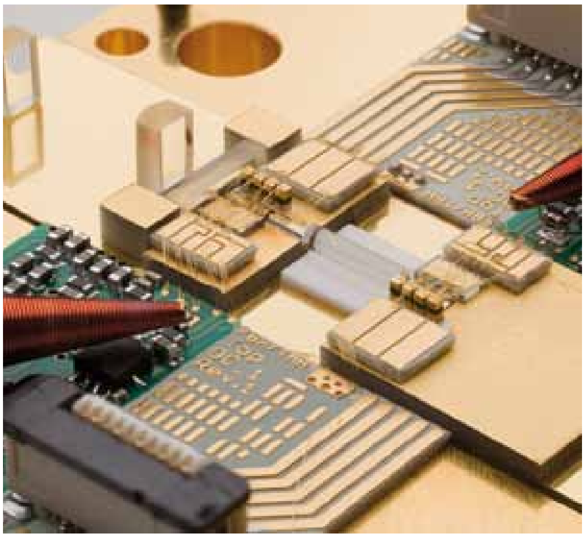


Photonics Cluster Alliance Berlin-Warsaw – Joint projects on GaN semiconductors launched

Since September 2012, the State of Berlin has supported a partnership between Berlin and Warsaw in the field of photonics in the project Photonics and Optoelectronics Network (PHOENIX). This alliance between Fraunhofer HHI, Berlin Partner, and OpTecBB, cooperating with the Photonics Society of Poland and the network Optoklaster, has the focus in the promotion of a transnational photonics R&D network between science and industrial stakeholders from both capital regions.

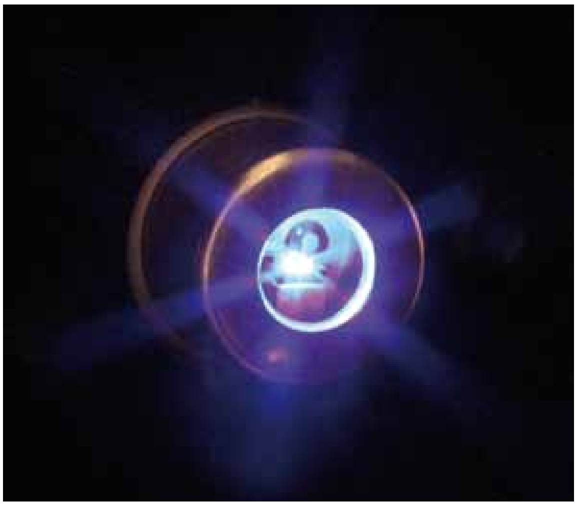
Based on their cooperation agreement the Berlin Senate Department for Economy and Technology and the National Centre for Research and Development of Poland released a call in January 2014 allowing companies and research institutes from Berlin and Poland to apply for joint R&D projects with regional funding. In this context, two transnational consortiums were granted in autumn 2014:

On the basis of the semiconductor material system (Al, Ga, In)N the collaborative project **BriVi** aims to develop violet-emitting laser systems. These are expected to combine so far unachieved properties: a stable, adjustable emission wavelength, that the systems are to feature narrow line width, high beam quality, and high optical performance (brilliance). Examples of new applications include those in spectroscopy with mercury atoms, laser lithography or diagnostics, and therapy. BriVi partners are the Ferdinand-Braun-Institut, eagleyard Photonics, the Institute of High Pressure Physics of the Polish Academy of Science (Unipress) and TopGaN Ltd..



Pulsed laser system including GaN transistors (FBH technology).
Source: © FBH/schurian.com

Within the framework of the **PioneerGaN** consortium, the partners are developing and realizing nano- and sub-nanosecond light pulses of very high intensity based on semiconductors. Due to increasingly available low-defect substrates from GaN volume crystals, there is now the possibility to develop and bring onto the market reliable, intrinsically vertical, normally-off GaN transistors. PioneerGaN partners are the Ferdinand-Braun-Institut, SENTECH Instruments, Ammono S.A. and the Wrocław Research Centre EIT+.



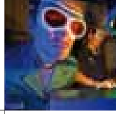
Blue-emitting GaN laser diode with 440 nm in TO housing.
Source: © Philipp Keshet

The quality of all proposals was convincing overall and in both partner regions there is a strong interest to continue German-Polish cooperation. As a result, in January 2015 a second bilateral R&D call was released.

Further information on PHOENIX can be found under http://photonics-bb.com/en/phoenix.

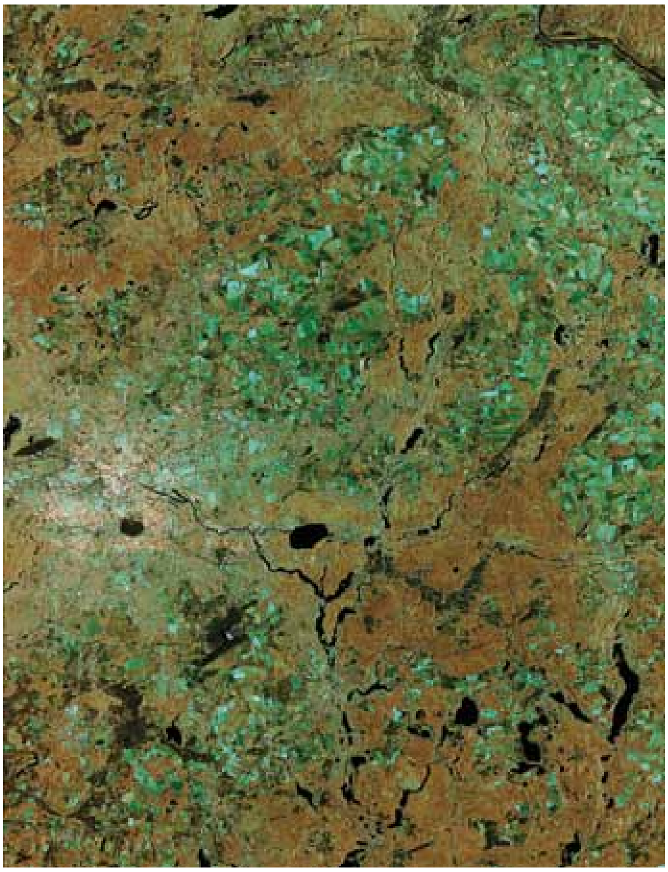
PHOENIX
Photonics & Optoelectronics Network

Gerrit Rössler
Cluster Manager Photonics
Berlin Partner for Business and Technology
Phone +49 (0)30-46302-456
Mail gerrit.roessler@berlin-partner.de
Web http://photonics-bb.com/en/phoenix



Ground Breaking Connections through Light made in Berlin

Aiming to further promote photonics and microsystems technology in Berlin and Brandenburg, in 2011 the Photonics Cluster was created. One emphasis lies on optical communication technology in which Berlin-Brandenburg is one of the leading sites: the German capital region combines leading global research institutions (e.g. Fraunhofer HHI, Ferdinand-Braun-Institut or Fraunhofer IZM) with major industry players (e.g. Corning, Finisar, Leoni, ADVA or Coriant), as well as a great number of small and medium-sized highly innovative companies (e.g. SHF, LUCEO or FOC). Beyond that, Berlin internationally proved its position as reference site in the field of free-space optical communication technology with successful participation in an ESA project in 2014:



Source: © Copernicus data/ESA (2014)

Milestone SpaceDataHighway

In November 2014, a research team, under the direction of the European Space Agency ESA and involving the participation of the Ferdinand-Braun-Institut and the Berliner Glas Group, came significantly closer to the aim of transferring high data volumes in real-time 24/7. For the first time, data have been successfully transmitted between a near-earth and a geostationary satellite over a distance of 40,000 kilometers. In the future, satellites flying in this low orbit will provide data for environmental and security surveillance, working as a kind of data highway in space. One of the first images delivered using this state-of-the-art technology was a satellite photograph taken over Berlin.

Both satellites – the Earth observation satellite Sentinel-1A (in orbit since April 2014) and the European communication satellite Alphasat (launched in July 2013) – are each equipped with a laser communication terminal (LCT) which contains several optical components and systems manufactured by the Berliner Glas Group. LCTs are the core pieces for optical communication between satellites, allowing for increasing amount of data to be transferred more quickly and more rapidly via light over long distances.

Equally, very small-sized laser modules from Berlin contributed to the success. The compact and extremely reliable laser diode benches from the Ferdinand-Braun-Institut are located in the heart of the capable laser technology. As pump sources for highly efficient solid-state lasers, these benches ensure frictionless communication in the LCTs. Sentinel-1 is the result of close collaboration between the ESA, the European Commission, industry, service providers and data users. It is an outstanding example of Europe's technological excellence.

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Gerrit Rössler
Cluster Manager Photonics
Berlin Partner for Business and Technology
Phone +49 (0)30-46302-456
Email gerrit.roessler@berlin-partner.de
Web www.photonics-bb.com/en/

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D – 10827 Berlin
Phone +49 (0)30-781 11 52
Mail trias-consult@gmx.de
Web www.optical-technologies-in-germany.de
www.microsystems-technology-in-germany.de

Layout
Uta Eickworth, 18334 Dammerstorf
Phone +49 (0)38228-15 99 77
Mail uta.eickworth@ymail.com
Web www.designcircle-berlin.de

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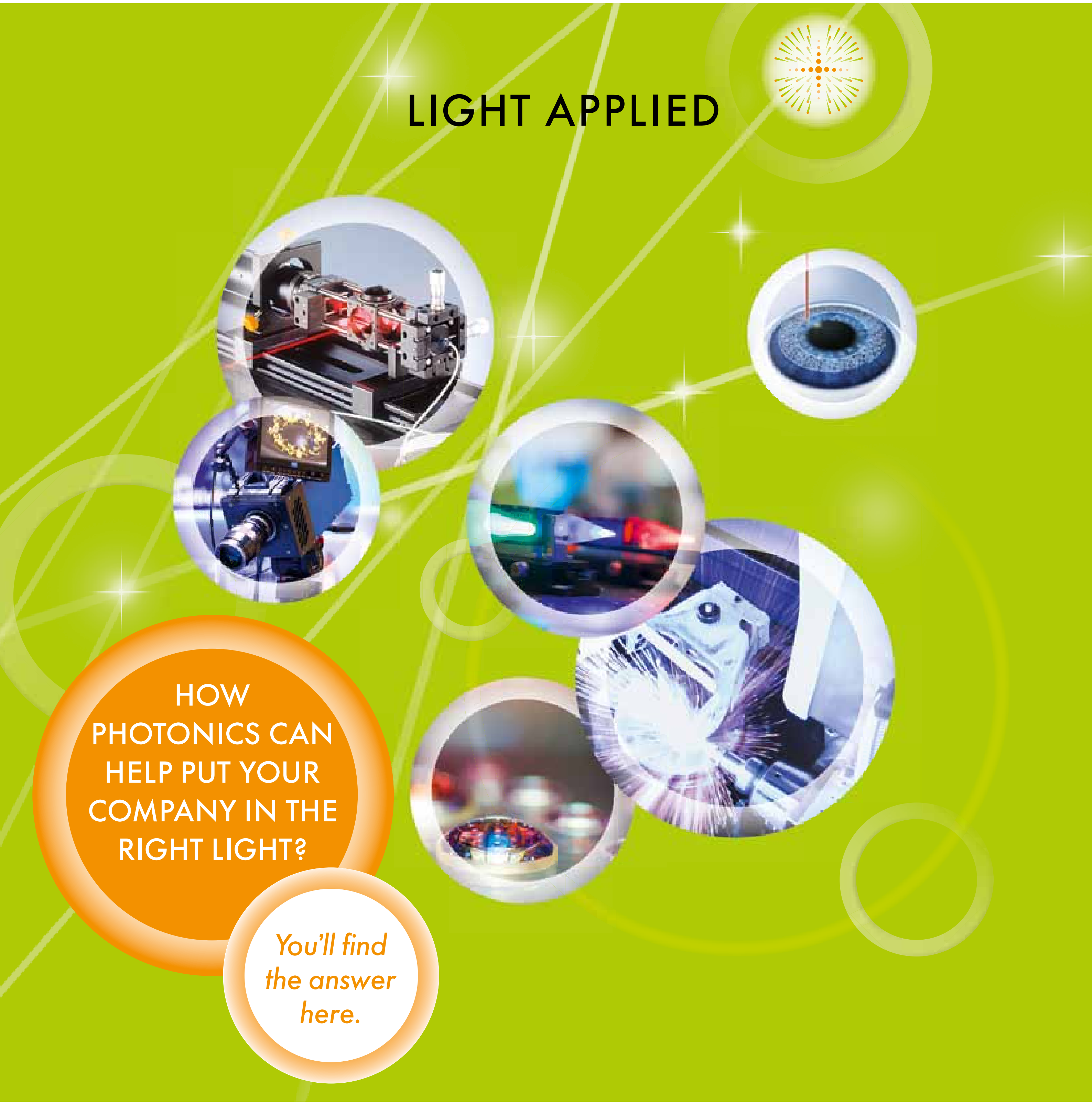

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