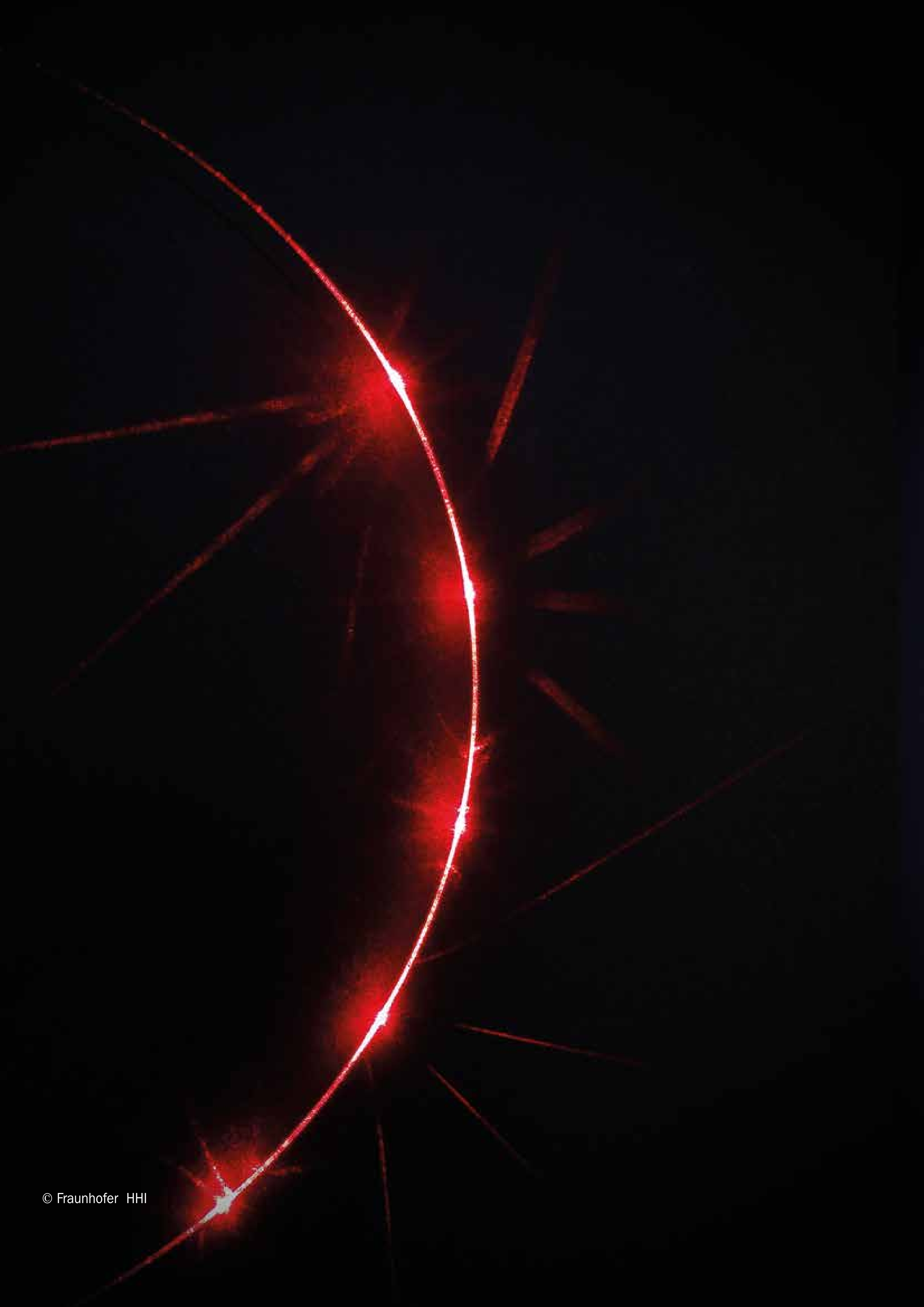
Photonics in Germany

2017

Optische Technologien in Deutschland



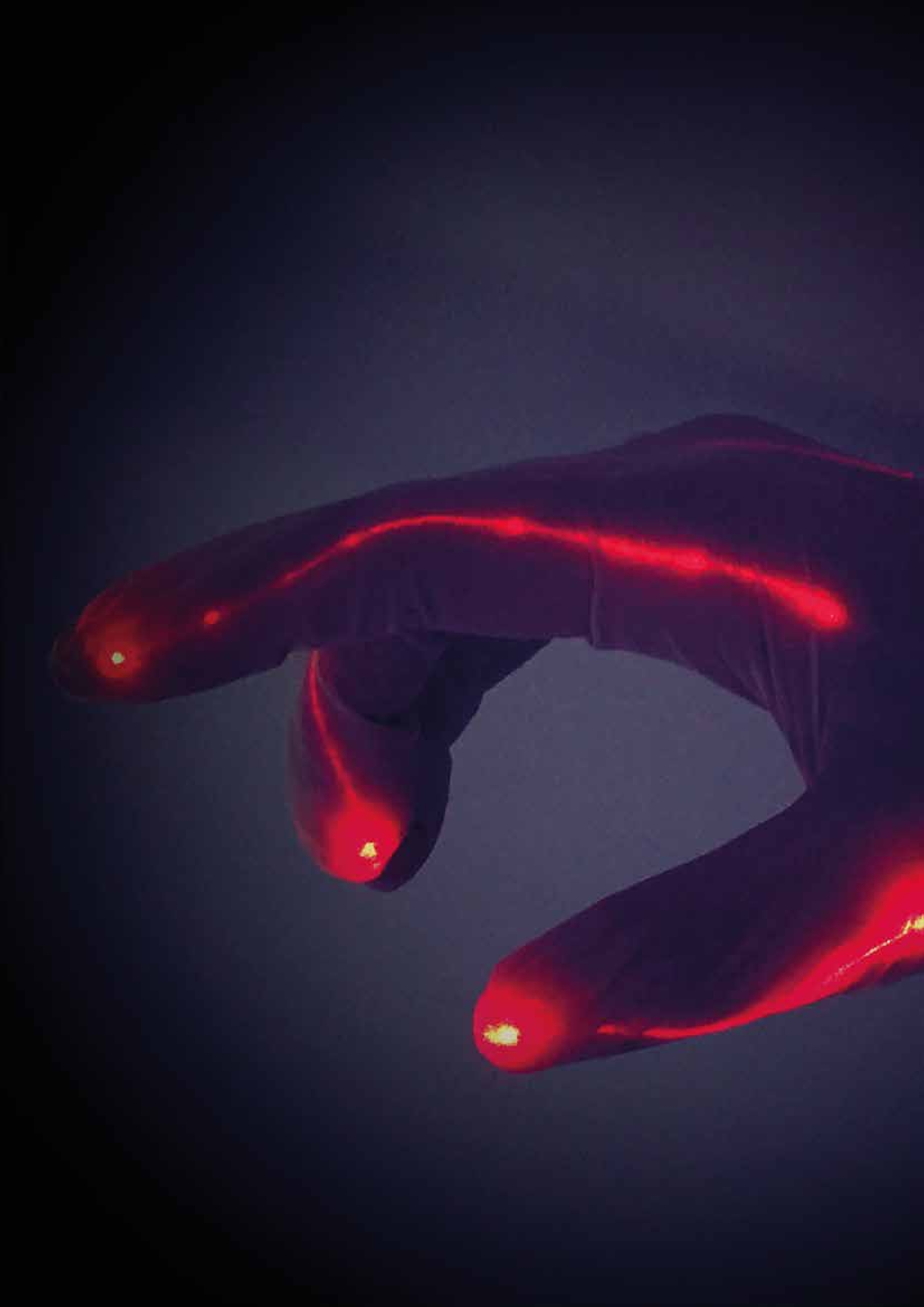
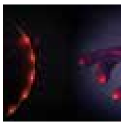
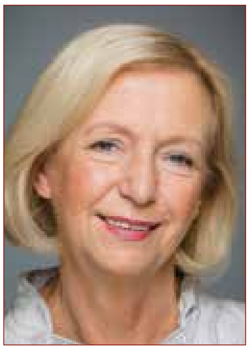


Table of Contents



Inhaltsverzeichnis

Preface



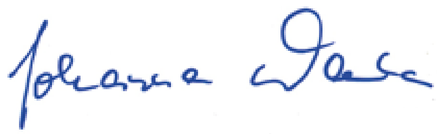
Prof. Dr. Johanna Wanka
Federal Minister of Education and Research
Bundesministerin für Bildung und Forschung

The Federal Government strives to safeguard the prosperity of our society in the long term. With the High-Tech Strategy, we have created a suitable framework for meeting global challenges such as climate change, mobility and security and expanding Germany's role as a leading country in terms of economic and innovation performance. Photonics and specifically technologies to control and exploit light are vital to reach this goal. In combination with other key enabling technologies, photonics plays an important role in achieving energy efficiency in manufacturing, eco-friendly lighting and enhanced medical diagnostics.

Extensive funding and sustained research efforts by German-based players have thrown the doors to photonics wide open in the past years. German businesses and research institutions count among the world's leaders in many areas of the optical technologies, for example laser technology, lighting or microscopy and imaging. Digital change is increasing the dynamics of innovation and international competition in photonics further. Photonics plays a key role in the digitalization of industry, providing a broad range of digital light technologies for cameras, sensors, scanners and even industrial 3D printers, to name but a few examples. Now it is about ensuring the successful development of these key areas.

In 2016, we assessed research and development in optical technologies in Germany in a mid-term review of the "Photonics Research Germany: Light with a Future" funding programme. We also formulated the challenges for the years to come: Our goal is to further strengthen the position of photonics, particularly in the areas of mobility and automated driving, medicine and diagnostics, smart home and smart cities and Industry 4.0. This requires that new business models are developed and linked to other major key enabling technologies. We also need to ensure that research and industry can draw upon highly skilled staff.

I am delighted that the present publication on "Photonics in Germany 2017" introduces both the "brains of light" and their innovations. May this help to excite the enthusiasm of many more people for photonics and bring together the driving forces of innovation in Germany and Europe.



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

Grußwort

Die Bundesregierung verfolgt das Ziel, den Wohlstand unserer Gesellschaft in nachhaltiger Weise zu sichern. Mit der Hightech-Strategie haben wir einen geeigneten Rahmen geschaffen, um globale Herausforderungen wie Klimaschutz, Mobilität oder Sicherheit zu lösen und Deutschlands Rolle als wirtschaftsstarke und innovative Nation weiter auszubauen. Die Photonik, also die Technologien zur Beherrschung und Nutzung des Lichts, ist dafür unverzichtbar. In Kombination mit anderen Schlüsseltechnologien liefert sie entscheidende Impulse für Energieeffizienz in der Produktion, für umweltgerechte Beleuchtung oder für eine bessere medizinische Diagnose.

Durch intensive Förderung und Forschungsanstrengungen in den vergangenen Jahren konnten die Akteure in Deutschland das Tor zur Photonik weit aufstoßen. Deutsche Unternehmen und Forschungseinrichtungen sind in vielen Bereichen der optischen Technologien – wie Lasertechnik, Beleuchtung oder Mikroskopie und Bildgebung – weltweit führend. Mit dem digitalen Wandel nimmt die Innovationsdynamik und der internationale Wettbewerb in der Photonik weiter Fahrt auf. Sie spielt zum Beispiel eine Schlüsselrolle bei der Digitalisierung der Industrie, denn sie stellt dafür eine breite Palette digitaler Lichttechnologien wie Kameras, Sensoren, Scanner bis hin zum industriellen 3D-Druck zur Verfügung. Es gilt, diese Zukunftsbereiche erfolgreich zu gestalten.

2016 – zur Halbzeit des Förderprogramms „Photonik Forschung Deutschland – Licht mit Zukunft" haben wir die Forschung und Entwicklung der optischen Technologien in Deutschland auf den Prüfstand gestellt und die Herausforderungen für die kommenden Jahre formuliert: Wir wollen das Zukunftsfeld Photonik weiter stark positionieren, vor allem in den Feldern von Mobilität und autonomem Fahren, in der Medizin und Diagnostik, für das intelligente Wohnen und in der vernetzen Stadt sowie in der Industrie 4.0. Neue Geschäftsmodelle sollen entwickelt und mit anderen wichtigen Schlüsseltechnologien verknüpft werden. Für Forschung und Unternehmen müssen wir zudem den Fachkräftenachwuchs sichern.

Ich freue mich, dass die vorliegende Publikation „Photonics in Germany 2017“ die „Köpfe des Lichts“ und ihre Innovationen vorstellt. Möge es dadurch gelingen, noch mehr Menschen für Photonik zu begeistern und die Kräfte für Innovation in Deutschland und Europa zu bündeln.

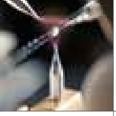
Prof. Dr. Johanna Wanka
Bundesministerin für Bildung und Forschung

Bundesministerium
für Bildung
und Forschung

Standort Deutschland

© Leibniz - IPHT / S. Döring


Location
Germany



Photonics in Germany is Open-minded

Photonics is high tech and, for good reason, considered one of today's key enabling technologies. But many are still finding it difficult to come to grips with photonics. It stands for a technology in itself and yet it is made up of many different industries. Light is what brackets all those technologies that generate, use or transform light.

Photonics is of extraordinary importance to the innovation and progress found in a very broad field of application industries. It provides the impulses and solutions crucial to future ecological and economic challenges – the efficiency of production processes, ecological lighting or improved medical diagnostics and therapeutics to name but a few. This is exactly why the last couple of decades saw it evolve into a globally competitive growth sector. In Germany, photonics companies are developing high-power lasers and supply sophisticated optical components or innovative image processing systems; which make them rank among the global market leaders in areas like production technology, machine vision or medical technology.

The success of photonics in Germany is not least attributable to the long-lasting and efficient interaction between excellent research, a highly productive economy and a dedicated support policy. Germany has taken the industry seriously at large and is globally construed as a synonym for innovation, best-in-class technology and high-level productivity. Thus, Germany's competitive industry has also become a model for other countries heading for (re-)industrialisation.

Challenges = chances

But challenges linger on all the same. Think of Industry 4.0 and the advancing digitisation of all industries, or the ever-increasing competition the strong German photonics industries are facing with their Asian counterparts: The industrial policy of the governments of China, South Korea and Japan are granting extremely high funds, focussing on topics and high technology relevant to the future and promoting shorter and shorter commercialisation cycles of their national innovations. This is evidenced by a strategic study initiated by VDMA and prepared by EAC (Euro Asia Consulting) in cooperation with the Federal Ministry of Education and Research (BMBF) and Spectaris. Even though German enterprises excel in their technological know-how and understanding of the processes involved, the Asian countries are rapidly advancing not only economically but also scientifically.

What is to be done? German enterprises must more seriously think about opening themselves up for cooperations with Asian partners. One approach to participating in the Asian research initiatives could be to become involved in the government-funded projects of Asian universities. German suppliers should also try to benefit from the growing demand and emerging Asian markets – see e.g. the ASEAN region and its new electronics-hub Vietnam – in order to better develop the sales potential and link themselves up with Asian interests. Politicians in Germany must see to research funding projects and strategies being given more focus and enhanced efficiency. The main thing, however, is to head for a faster commercialisation and, thus, economic success of the research results and innovations harvested from such funding programmes in Germany.

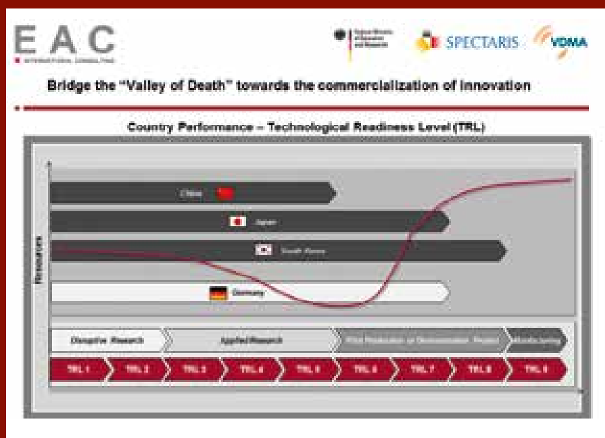
Be disruptive

Either side – industry and politics – is experiencing a great deal of change already. Politics is brushing up its agenda of photonics funding, giving it some highly up-to-date brilliance based on an open and creative interchange with the photonics community as well as other and quite different players. The BMBF supports for example the interlinking of photonics science and economy with various creative spin doctors, be they makers ("Make Light"), start-ups (Code_n new.New Festival), young talents (Photonics Academy) or the civil public (Open Photonics, Citizen Science). For this reason the ministry aims to acquaint as many people as possible with the ideas and notions of photonics, gain new partners, disrupt rigid processes and thoughts, and

Annika Löffler,
VDMA Photonics Forum

create room for innovation. Both politics and photonics enterprises are thus travelling a long and wide road to open-mindedness.

One of Germany's strengths is that its industry always sees beyond one's nose, opens up for new ideas, and keeps questioning its own actions. This is the only way of turning change into progress and ensuring that the German photonics industry is becoming a reliable and steady innovator. The proof of this dedication is the traditionally high 9-10% level of spending on R&D. At the Lasys trade fair 2016 in Stuttgart, VDMA for the first time backed up this process by making its stand a meeting place of young start-ups and makers on the one hand and established companies and young talents on the other. All parties were very interested indeed and established companies were very ready to learn from the unconventional input from the start-up scene. An enormous synergetic potential and a wealth of impulses for the future of photonics is emanating from this mutually "fertile" experience and openness for new ideas. The entire German photonics community of associations, enterprises, institutions and politicians should keep sharing this joint approach, feel and act towards these strengths, and generate innovations for the future of photonics.



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

Recent Trends in the Federal Programme on Photonics R&D

The optics community in Germany has a long tradition. And yet it is live and well. In 2016, the German photonics community set the agenda for the second half of the BMBF programme on photonics research.

Optical technology is most relevant to many advances in science, ranging from fundamental research in physics to life sciences. And in industry, the digital transformation is driven by light: optical sensing and imaging, computer vision and optical communication, materials processing and 3D printing are examples for this. Takeovers and financial investments follow this same trend.

We would like to induce new ideas to photonics. Makers work on what may be possible with photonics. There are „open photonics“ projects under way now which may open up new possibilities for everybody to apply photonics to their own projects. When the new.New festival of the international Code_n startup competition in Karlsruhe gathered some Top 50 international startups in September in Karlsruhe, nearly half of them were from photonics. So, to our best knowledge, the list of „photonics in Germany“ is set to grow further.

Photonics is paving the way for breakthrough innovations in medicine. Endoscopy for example uses fibre optics to get light to the point where surgery takes place and it uses fibre optics to get the image out. The next step will be devices such as this 3 lens camera with a diameter of just 125 micrometers. It has the focal length of about 3 mm and was 3D printed with a new 3D printing technology using femtosecond lasers developed by the startup Nanoscribe from Karlsruhe.
Source: University of Stuttgart, 4th Physics Institute

A display technology of the future will be the Picobeamer, a chip element including 3 laser diodes in the colors red, green and blue. Picobeamers will be cheap and versatile. They can project their information on any surface because of the superior depth of field of laser beamers. Connected with a sensor they will be interactive.
Source: Bosch Sensortec GmbH

MinR Dr.
Frank Schlie,
Bundesministerium
für Bildung
und Forschung

Aktuelle Entwicklungen im Programm „Photonik Forschung Deutschland“

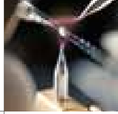
Die senseBox Photonik ist ein Do-It-Yourself-Bausatz für eine Sensorstation, mit der Bürgerinnen und Bürger sowie Schulen Umweltdaten über Klima, Luftqualität, Verkehrsaufkommen, Lärmbelästigung und vieles mehr selbst messen können. Die gemessenen Daten werden direkt an eine Internetkarte gesendet und als Open Data live online gestellt. Bürger können so eigene lokale Umweltforschungsfragen stellen und ganze Messnetze aufbauen.
Bildquelle: VDI Technologiezentrum, Frank Nürnberger

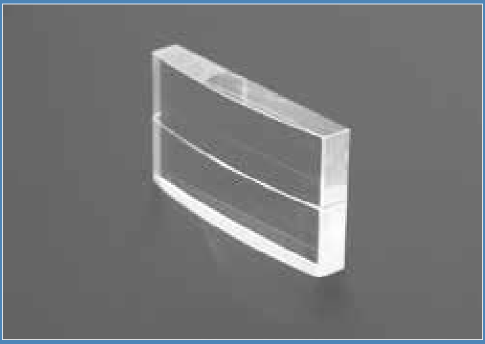
Das Netzwerk der Optik in Deutschland hat eine lange Geschichte. Und ist zugleich lebendig wie nie. 2016 hat die Photonik-Community in Deutschland ihre Forschungsagenda aktualisiert. Damit gehen wir in die zweite Halbzeit des BMBF-Photonikprogramms.

Optische Verfahren sind vielfach relevant für die Wissenschaft, von der physikalischen Grundlagenforschung bis zur Medizin. Und in der Wirtschaft wird die digitale Transformation durch Licht bewegt: Sensoren, Bildverarbeitung, Datenkommunikation, Materialbearbeitung und die Fertigung ganzer Bauteile aus dem Pulverbett sind dafür Beispiele. Akquisitionen und Investitionen folgen dieser Logik.

Wir wollen die Impulse für die Photonik weiter entwickeln. Maker zeigen uns, was mit Photonik möglich ist, bei den BMBF-Wettbewerben „Light Cares“ und „Open Photonik“. Auf dem new.New Festival zum internationalen Code_n Startup Wettbewerb im September 2016 in Karlsruhe kam fast die Hälfte der Top 50 Startups aus der Photonik. Es sieht also alles danach aus, dass der Katalog der „Photonics in Germany“ auch in Zukunft weiter wachsen wird.

MinR. Dr. Frank Schlie
Bundesministerium für Bildung
und Forschung
Referat 513
Heinemannstrasse 2
53175 Bonn
Germany
Phone +49 228-9957-3259
Mail frank.schlie@bmbf.bund.de

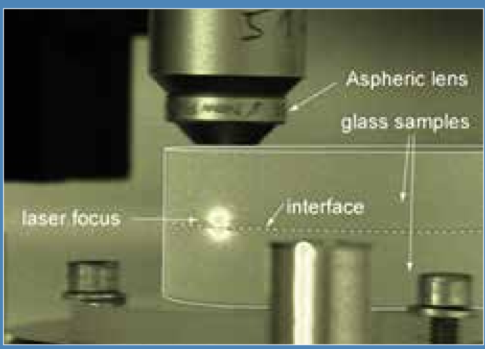




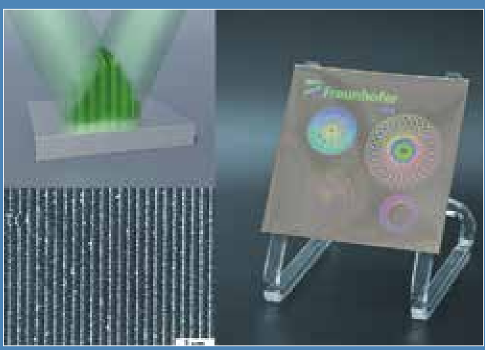
IGF-Projekt 18360 BR; © Fraunhofer IOF Jena

IGF-Projekt 18728 N, © Univ. Stuttgart IFSW & ITO

IGF-Projekt 18360 BR; © Fraunhofer IOF Jena



IGF-Projekt 18360 BR; © IAP Uni Jena



© Fraunhofer IWS Dresden

Pre-competitive Innovation Accelerator: The Promotion of Joint Industrial Research Programme

The German photonics industry is recognized around the world for its high-precision products of highest quality at the forefront of what can be realised. Since optical technologies commonly and still increasingly play a major role as a key enabling technology for many fields of industry, the impact of innovations in photonics for other industry sectors is often tremendous – and for small and medium sized companies (SMEs) potentially vital. Since the general trend towards a worldwide open market imposes an unprecedented competitive pressure, SMEs have to develop innovations in continuously shorter periods of time in order to remain competitive in the long term and maintain their market shares. The resulting question is, how the development and the probability of a more or less stable innovation output can be maximised.

To answer this question, we have to be aware of the main obstacle of brisk innovation activities: Particularly for SMEs, it is unlikely that companies invest in the further development of innovation ideas as long as the technological risk is still high and the amortisation of R&D expenditures is highly uncertain. As a minimum requirement, the industrial feasibility of a possible innovative product has to be proven before SMEs engage in developing innovation ideas further, assimilate a new technology, develop a prototype, and proprietary designs etc. Clearly, the innovation path, i.e. the way from the emergence of a not yet fully matured innovation idea to the launch of the final innovation, can be long and costly. But at least the first steps can be covered by joint efforts reducing the individual expense.

The Joint Industrial Research Programme ("Industrielle Gemeinschaftsforschung", IGF) by the German Federal Ministry for Economic Affairs and Energy (BMWi) has been developed over a number of decades and promotes precisely that. It is Germany's longest-lived promotional programme. Since 1954, more than 210,000 research projects have been funded by the BMWi within this programme. Some 10.5 billion Euros have been channelled to boost new developments and innovations, and thus the innovative strength of German SMEs. More than 50,000 companies, most of them SMEs, are involved in an SME research network through 100 research associations that cover all sections of the German industry.

The research associations are member of an umbrella organisation, the German Federation of Industrial Research Associations ("Arbeitsgemeinschaft industrieller Forschungsvereinigungen", AiF). Both are non-profit organisations with honorary boards. Neither the AiF nor the research associations receive public funding. The AiF is financed solely by its member associations, which in turn are financed by the industry – and for the industry.

Dr. Markus Safaricz,
SPECTARIS,
Head of Research &
Innovation

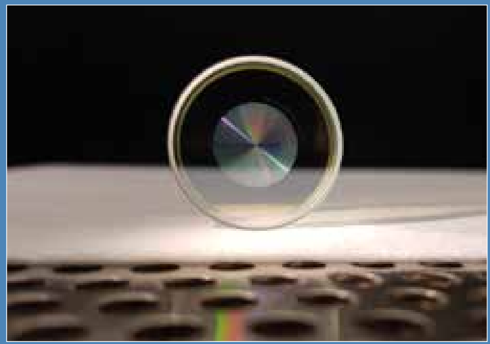
The industrial companies define common research interests in cooperation with scientists from a network of more than 1,200 research institutes, comprising university departments, institutes of technology, institutions of research communities and independent institutions. The most promising subjects are formulated into research proposals and submitted to the AiF. In their role as honorary peer reviewers, several hundred experts from industry and science review and evaluate the applications. On that basis, the AiF recommends the best projects to the BMWi for funding.

The IGF research in the field of photonics tackle pressing challenges of widely spread subjects: projects cover aspects of detection, optical sensor technology, optical spectroscopy, optical metrology, laser-assisted precision mechanics, optical functionalisation of surfaces, laser-optical medical technology, diagnostics by optical methods, 3D visualisation, monitoring etc. Filling gaps in knowledge in these fields often results in pioneering solutions for increased product quality requirements or are the basis for new methods of medical treatment.

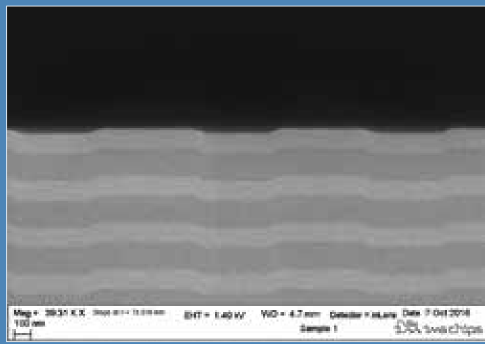
All funded projects are supervised by a consortium of interested company representatives to ensure the practical relevance. Although the majority of the consortium members have to be from SMEs, also big enterprises have access. It is this transdisciplinary cooperation between science and industry that is the key to a successful technology transfer. Regular meetings during the entire project run time ensure the steady, efficient and quasi-simultaneous transfer and discussion of intermediate data and results. Beyond that, the fact that the pre-competitive industry consortia of IGF projects often consist of an appreciable number of companies, accounts for a significant multiplier effect. The results of each project are published and, thus, are made available to even more companies.

The IGF contributes to the training of young scientists in fields of industrial research. This and the fact that it effectively reduces the amortisation risk of the SMEs' innovation activities make it to one of the key drivers of a constantly high German innovation output. The IGF guarantees the maintenance of Germany's recognised innovative strength in a globally competitive environment.

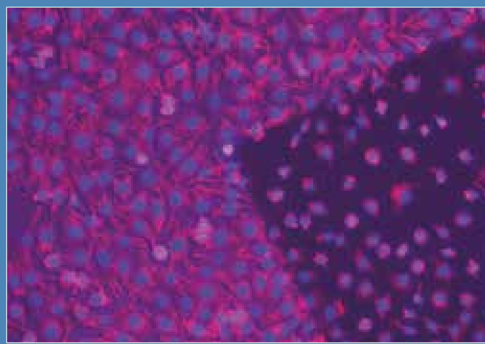
SPECTARIS Deutscher Industrieverband für optische, medizinische und mechatronische Technologien e. V.
Dr. Markus Safaricz
Werderscher Markt 15
10117 Berlin
Germany
Phone +49 30-41 40 21-39
Mail safaricz@spectaris.de
Web www.spectaris.de



IGF-Projekt 18728 N, © Univ. Stuttgart IFSW & ITO

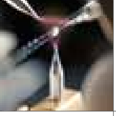


IGF-Projekt 18728 N, © Univ. Stuttgart IFSW & ITO



IGF-Projekt 17957 N; © Fraunhofer IFAM Bremen

IGF-Projekt 17957 N; © Fraunhofer IFAM Bremen



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; being driven by strong German companies, internationally renowned R&D institutes and generous government support.

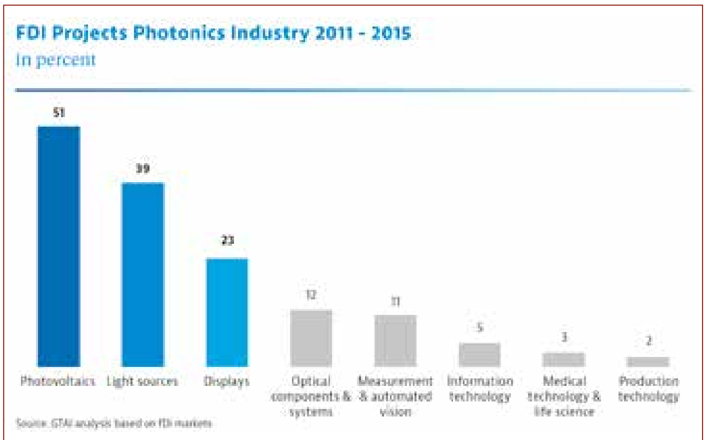
But just how attractive is Germany's photonic sector for international investors? In which fields are foreign companies investing in in Germany? Are foreign direct investment (FDI) projects being carried out in areas where the domestic industry has existing strengths? And how have the results changed compared to my last report?

The data suggest that the lion's share of FDI projects were a result of an international investment boom in photovoltaics in Germany between 2008 and 2012 – largely due to the country's progressive Energiewende ("Energy Transition") policy. However, a rapid drop in prices - caused by international competition – has caused investment in this segment to stall in recent times. Of 51 PV projects in total, only 15 were carried out during the period 2013 – 2015. Somewhat surprisingly, displays and light sources also showed up in the top three sectors. Let's examine these two categories in more detail.

Around half of all projects in the PV sector were established for the purpose of sales, marketing, support, or distribution activities. About one in seven were manufacturing projects - significantly down from two years ago. Significant investments are nevertheless still being made in PV manufacturing in Germany.

Most of the projects carried out in the light sources and display segments were in the areas of sales and marketing, support, or distribution activities. No foreign companies invested in display manufacturing projects between 2011 and 2015. This is hardly surprising: Display production and a large part of the corresponding value chain moved to Asia long before the period examined. 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 relatively unknown Asian companies looking to gain a foothold in Europe.

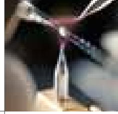
Germany is attractive as a manufacturing location in the light sources business, with more than one fifth of FDI projects investing in production activities. Both displays and light sources are largely destined for consumer markets. It can be seen that most of the FDI projects were primarily attracted to the large German consumer market, as opposed to establishing projects to serve world markets from a manufacturing base in Germany.



Source: GTAI analysis based on FDI markets

It is striking to note that 4 out of a total of 12 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 sciences, and measurement and automated vision have seen relatively few international investment projects compared to the levels of domestic production. Possible reasons include barriers to entry such as rigid regulations (e.g. in life sciences) or specific strengths of the German industry making these segments unattractive to new entrants.

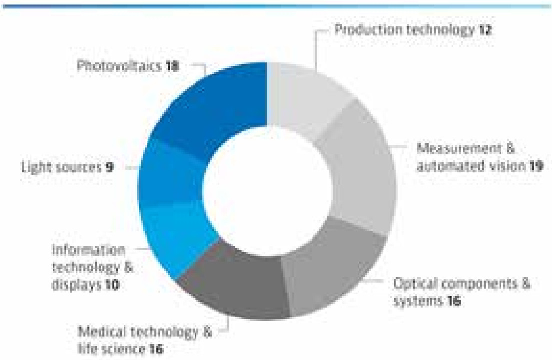


Max Milbredt,
Manager Investor Consulting
Electronics & Microtechnology
Germany Trade and Invest

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

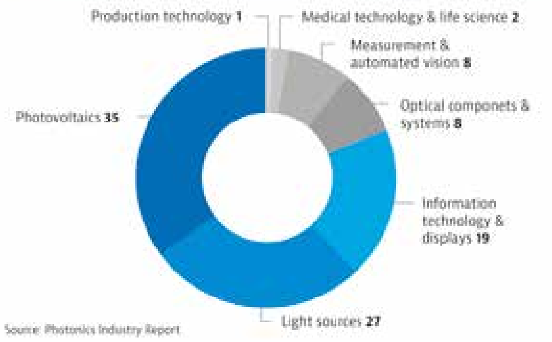
To return to our initial questions, it is clear from examples like these that Germany's photonics sector is attractive to international investors. The German consumer market for lighting and displays remains especially attractive for foreign investors. Germany's inherent strengths in medical technologies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

Domestic Production Germany 2011 – 2015
in percent



Source: GTAI analysis based on FDI markets, December 2016

FDI Projects in the German Photonics Sector 2011 – 2015
in percent



Source: Photonics Industry Report

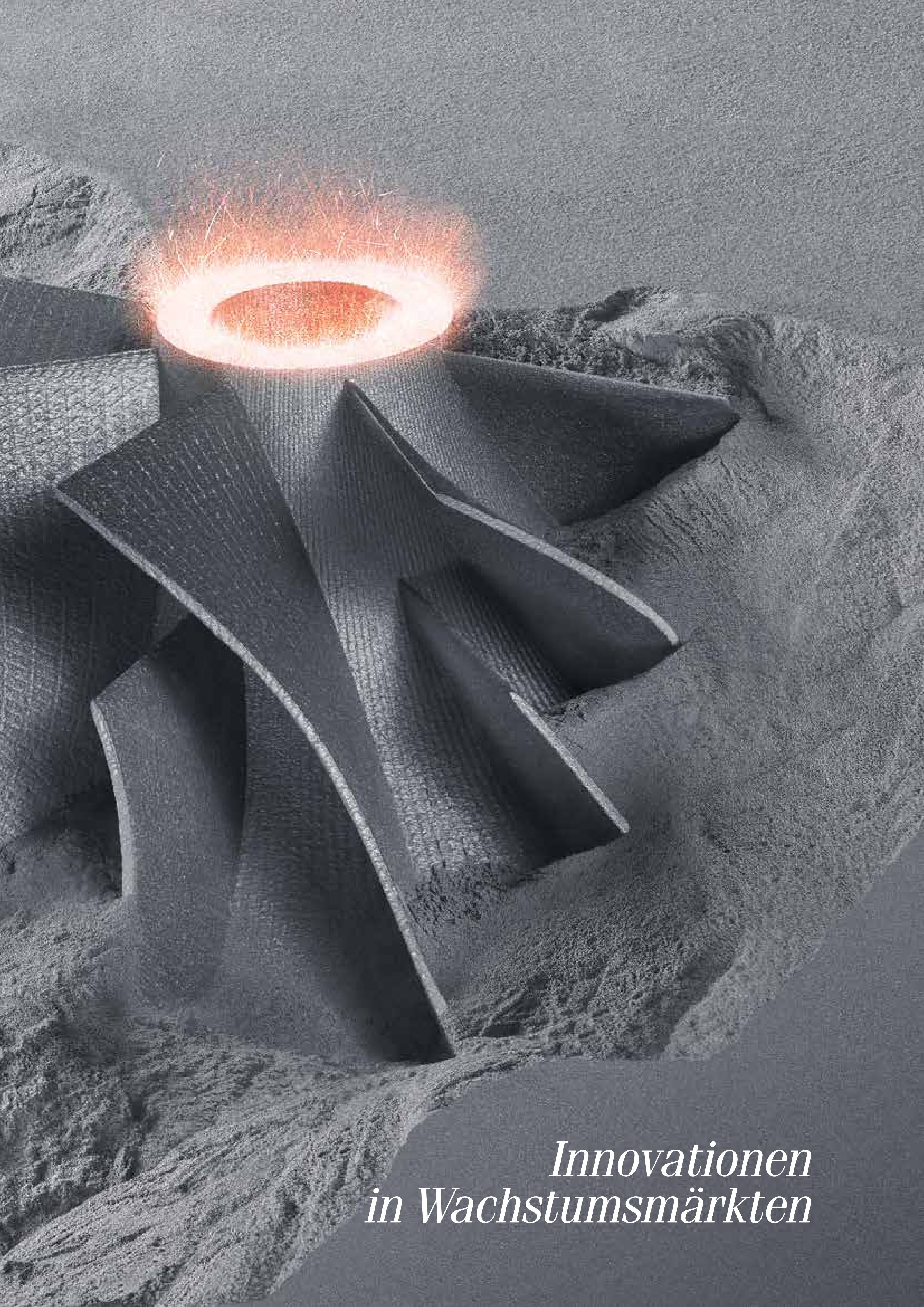
About Germany Trade & Invest

Germany Trade & Invest provides free 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).146 FDI projects were identified for the six-year period from January 2011 to December 2015.

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

Innovations in Growth Markets



Innovationen in Wachstumsmärkten

There's No Digital Revolution Without Optics and Photonics

Exploring the mutual influence of two key technologies

Digitalization has become a part of nearly all industries and economic sectors, and optics and photonics are certainly no exception. On the other hand digitalization has only been possible thanks to optics and photonics, because one of the key processes in the production of electronic circuits is optical lithography or photolithography. The ongoing improvements in the resolving power and the stability of this process – along with many others in semiconductor manufacturing – are formulated in Moore's Law, which states that the number of transistors on an integrated circuit doubles every 1-2 years. Gordon Moore based his famous law from 1965 on the number of transistors on ICs available at the time, about 50-60. This figure has grown exponentially over the past 50 years: a modern NAND chip has more than 100 billion transistors. This exponential increase in the computing capacity over long periods of time has ensured that the necessary hardware is available for digitalization.

Digitalization is now a crucial cornerstone for optical and photonic systems in industrial, research and consumer applications. And the trend is accelerating. From instrument control all the way to processing and analyzing sensor and image data: none of this would be possible without algorithmics and the accompanying electronics. But the inverse also holds true: no matter if it's sensors in Industry 4.0 production scenarios, wearables, self-driving cars, augmented reality (AR) or virtual reality (VR), all of these technologies make use of optics and photonics. So we can safely state that optics and photonics are an essential part of the digital world.

A glimpse into the future

To explore the current and future interaction of the two key technologies ZEISS organized in June 2016 the Symposium "Optics in the Digital World". There international scientists tackled four key trends in digital optics, discussed the state of the art and identified requirements for further development. These four trends are:

- Computational imaging
- Machine learning
- Large data
- Augmented and virtual reality

Computational imaging (CI) refers to the extension or even the partial substitution of optical functionality through software components. The basis for this technology is a set of innovative image acquisition methods for a better collection of the information contained in light as well as intelligent signal processing for extracting this information. For example: the ZEISS LSM 880 Airyscan acquires image information from previously unusable light, providing higher resolution and substantially increased sensitivity. CI technology is particularly promising in the fields of medical imaging and traditional microscopy, e.g. for phase contrast images, 3D reconstruction or multi-spectral imaging.

Fig. 1: ZEISS Symposium: Technology of the future: Immersive microscopy

Fig. 2: ZEISS Symposium: The ZEISS President and CEO Professor Michael Kaschke welcomes about 200 guests in Oberkochen

Dr. Michael Totzeck,
Director of Innovation
Management
Manufacturing
at ZEISS Corporate
Research and Technology
and ZEISS Fellow

Looking through mounds of data

According to the IDC, a research company, the quantity of data in the digital world currently doubles every two years. For the year 2020, they forecast 44 zettabytes (i.e. $44 \cdot 10^{21}$ bytes) of digital data. New developments in high-performance computing, cloud computing and in algorithmic are essential for coping with these amounts of data. Processes such as random forests, CNNs and SVMs identify important data and filter out less important information. The use of apriori information makes this task significantly easier for all processes.

Learning algorithms are particularly well-suited for analyzing large quantities of data without a known underlying model. These are based on e.g. multilayer neural networks (also known as 'deep learning') and currently enable tasks like language recognition and textual translation on a smartphone. They are also used for images, such as for facial recognition or identifying cells. The incredible progress of this artificial intelligence was suddenly in the spotlight this year when the computer program AlphaGo beat Lee Sedol, the Go world champion, at Go. Go is more complex than chess by several orders of magnitude. It's worth remembering that the human world champion was already beaten at chess by a computer back in 1996.

Machine learning is combined with computer-supported image processing, also known as computer vision, for image data. Computer vision makes it possible to identify people, animals or things via functions such as image segmentation and object recognition. It is also used with self-driving cars to ensure that they identify pedestrians and other vehicles in time. The next significant development could be a new generation of robots which independently modify and change decision-making processes in-line with the situation.

Blurring the digital and real worlds

Whereas virtual reality (VR) makes the virtual world as immersive as possible, augmented reality (AR) links digital and real content. The current boom in these technologies can be traced back to progress made in optics as well as computer hardware and software. Depth sensors such as

Fig. 3: ZEISS Symposium: Partners from science and industry in discussion. David Bohn, Microsoft, Professor Laura Waller, UC Berkeley, Dr. Stefan Kampmann, Osram,Professor Michael Kaschke, ZEISS, Professor Ingmar Posner, Oxford University, Dr. Jochen Peter, ZEISS (from left)

Kinect from Microsoft facilitate 3D reconstructions, for e.g. the real-time capture of movements and gestures. New technologies, including transparent OLEDs or bidirectional OLEDs, make new system designs possible, and progress in the miniaturization of optical components will enable compact HMDs with small form factors.

Summing up: the workshops conducted at the ZEISS Symposium "Optics in the Digital World" demonstrated that the mutual influence of optics, photonics and digitalization is a significant force driving forward innovation. All signs indicate that this will also be the case in the future.

The results of the workshops are summarized in three whitepaper which are available at http://www.zeiss.com/corporate/en_de/innovation-and-technology/zeiss-symposium.html.

ZEISS Gruppe
Eva Reitze
Carl-Zeiss-Strasse 22
73447 Oberkochen
Germany
Phone +49 7364-20-3407
Mail eva.reitze@zeiss.com
Web www.zeiss.de

How Do We Teach Cars to See?

Sensors for self-driving cars and the mobility of the future

Today's cars feature a host of different sensors to make them smarter and safer – all the while keeping responsibility with the driver. Cameras support assistance systems for example in automatically maintaining the lane on the highway, determining obstacles on the path and in some partially automated vehicles initiating the braking process. However, these cameras have technical limitations, the worst of which being the very limited dynamic range in comparison to the human eye. These limitations have an impact on the detection and recognition of objects. Poor lightning conditions, strong backlighting from the sun or bad weather conditions like rain and snow can lead to degraded perception, other vehicles or persons being registered too late or not at all by the systems.

Once we shift towards truly self-driving vehicles, the vehicle's understanding of its surroundings needs to be bulletproof under any condition – especially considering urban driving. Since in city traffic a large number of objects must be registered by the optical components and a higher accuracy in the prediction of movement of persons or vehicles is decisive for the safety of all road users, the further development of the systems is indispensable and promises significant benefits in terms of traffic safety and efficiency.

Another novel sensor used for car perception is the laser scanner, also referred to as LiDAR. The rotating combination of multiple laser beams registers a three dimensional 360° image in real-time within a radius of 100 to 200 meters around the vehicle. These scanners have already been successfully deployed on the roofs of autonomous vehicles from Google and other manufacturers. To contrast the capabilities of cameras and LiDARs we examine a situation that occurs in the city traffic: when a previously obstructed pedestrian enters the road between parked vehicles, the autonomous car has to analyze and recognize this within a fraction of a second. It must recognize parts of the body of the pedestrian and, on the basis of the movement towards the path of the vehicle, it must initiate the braking action. A human driver is normally able

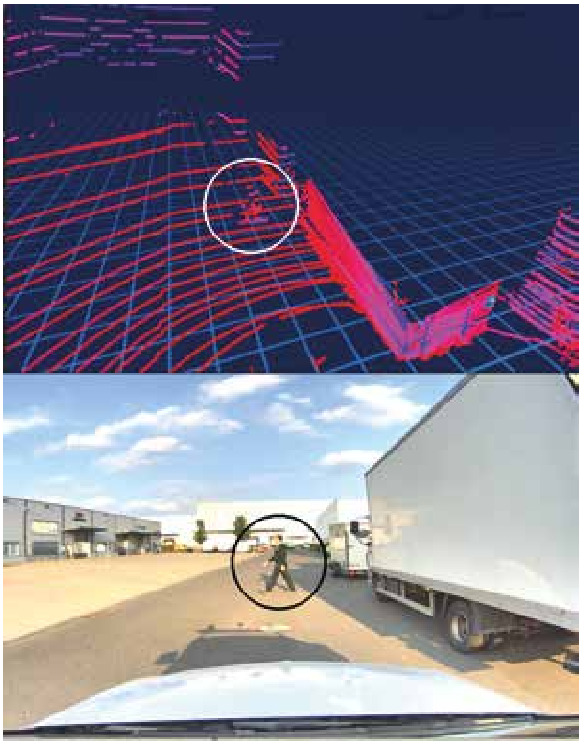


Fig1: LiDAR-scanner (top) in comparison with front camera (bottom): Both sensors recognize the pedestrian on the road.

to recognize a pedestrian as a person, even if he notices only a part of the body for example the head, with most of the person covered from view by the car in front of him.

If a camera records a pedestrian between vehicles, with the help of image recognition, the head of a pedestrian for example can be differentiated from a vehicle. From this information, it is inferred that it must be a person who is in the process of stepping onto the road, so that the car can react promptly. In case of poor weather conditions like back lighting, rain or snowfall, there is a possibility that the objects or persons may not be recognized accurately. Poor contrast or strong shadows may also make the recognition challenging. Significantly more reliable in positioning of objects and persons are the LiDAR systems. The positions of obstacles or road users are tracked by laser beams in

Dr. Ilja Radusch,
Director Business
Unit Smart Mobility
Fraunhofer FOKUS

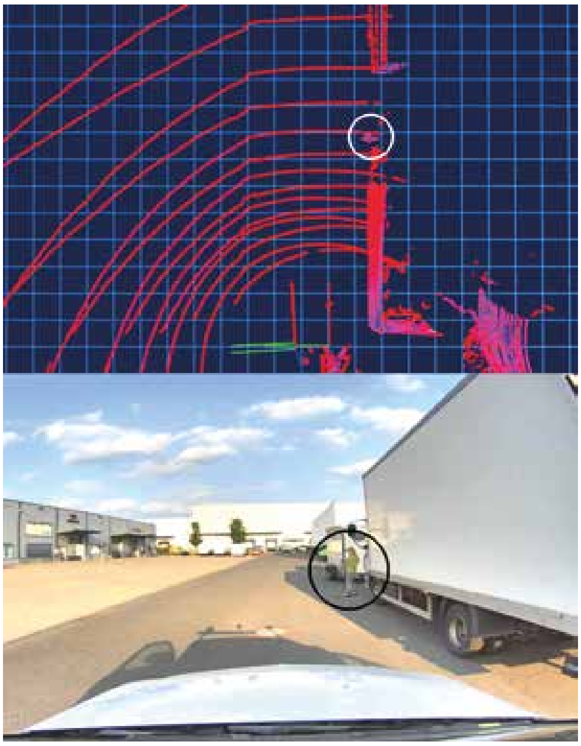


Fig2: LiDAR (top) only recognizes the pedestrian between the cars in the top view of the 360° image. Strong shadows may make the recognition of the pedestrian challenging for the camera (bottom). FOKUS aims to achieve improved recognition accuracy by combining the images of these sensors.

3D with centimeter accuracy regardless of light conditions, even at night. Challenging environmental conditions such as rainfall or glare at dawn have less influence on the accuracy of the sensors. As LiDAR scanners are active sensors, they are in principle independent of the environmental illumination and thus much more reliable in terms of detecting objects compared to cameras.

On the other hand, it is difficult for a laser scanner to recognize the object in question, as LiDAR scanners have a far lower resolution compared to cameras. Based on the different ways they reflect laser beams, pedestrians and vehicles may still be distinguishable from each other when they are separated but close enough. If the pedestrian is partly obstructed by parked vehicles, the laser scanner must differentiate between two objects which are in the same position. With the current state of development, the pedestrian would be viewed as being part of the parked vehicle. The aim of the current research in this field is to ensure that even a portion of the body is recognized and thereby the systems recognizes that apart from a vehicle there is also a person in the vicinity.

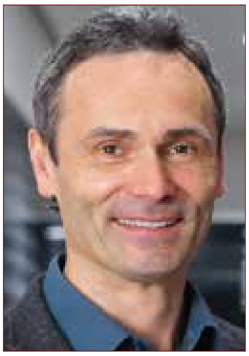
A current obstacle in the deployment of LiDAR scanners in autonomous vehicles is the cost of these systems. Even the small scanners with fewer laser beams are in a prohibitive price range for deployment in production vehicles. However for the deployment in autonomous vehicles, larger laser systems are required in order to receive a sufficient amount of information for the control of the vehicle. The development of solid state LiDAR systems aims to change this, yet this type of LiDAR is not currently available.

The business units Smart Mobility and Visual Computing at the Fraunhofer Institute for Open Communication Systems develop LiDAR and video analytics for tomorrow's smart self-driving vehicles. What FOKUS attempts, is offsetting the disadvantages of these optical components by fusing the information from LiDAR and cameras, given that both type of sensors have complementary features. By combining the high robustness against adverse weather conditions and the highly accurate distance measurement of the LiDAR with the high resolution, color and depth sensing capabilities of the cameras and camera clusters, FOKUS aims to achieve improved recognition accuracy and thus a safer driving for all.

Dr. Ilja Radusch
Fraunhofer-Institut für Offene
Kommunikationssysteme FOKUS
Kaiserin-Augusta-Allee 31
10589 Berlin
Germany
Phone +49 30-3463-7474
Mail ilja.radusch@fokus.fraunhofer.de
Web www.fokus.fraunhofer.de

New High-brightness Laser-based White Light Source for Vehicular Lighting Systems

Abdelmalek Hanafi, Ph.D. ,
Dynamic Laserlight
Program Management,
BMW Group



Dr. rer. Nat. Helmut Erdl,
Static Laserlight
Management,
BMW Group

ABSTRACT:

Modern vehicular lighting systems (VLS) are intended to improve safety on the road by providing the adequate visibility to the drivers under different driving conditions from within a compact housing, whilst simultaneously reducing the impact on the environment and meeting the consumer demands in terms of styling and low cost. Using **high-power GaN-based blue laser diodes** that pump a yellow phosphor in a remote position, BMW developed a new **high-brightness white point-like source** having a peak brightness of over 1000 cd/mm², which is 10 times higher than that of high-power white LEDs. By integrating this new light source in a VLS, BMW was able to double the range of the visibility while increasing the VLS's efficiency, keeping its size compact and fulfilling the required light fluxes and intensities.

This illumination method is not restricted to the automotive sector, but it can be generalized to sectors, where efficiency and compactness and/or specific lighting distributions are required.

1) SOLID-STATE SOURCES IN AUTOMOTIVE LIGHTING

Errors in the visual perception, namely during night-drives when the vision is limited, were found to be five times higher during night time and cause worldwide 1.25 million fatal accidents a year according to the World Health Organization reviewed in November 2016. Low illumination decreases both the depth of perception and the peripheral vision [1, 2]. Improvement of the night-time visibility using a better illumination pattern of the road contributes to enhance the perception in driving and the control of the vehicle for limited lumen flux respectively energy consumption. The inhomogeneous illumination patterns projected on the road are adequately engineered so as the recognition and the interpretation of the information, such as road marking, distance evaluation, presence person/animals on the road, is facilitated without dazzling the surrounding environment including the on-coming traffic. The international regulations on automotive lighting and signaling define minimum and maximum photometric specifications in each segment of the engineered illumination pattern. Dynamic illumination patterns, such as bending light, glare-free high-beam and marking lighting, are engineered to assist in different driving conditions.

Modern VLSs are intended to improve safety on the road by attempting to providing adequate visibility to the drivers under different driving conditions from within a compact housing, whilst simultaneously reducing the impact on the environment and meeting the consumer demands in terms of styling and low cost. The main objective is to make the driver conditions during night-time similar to that of the daytime ones. Assuming aberration free optics, the forward visibility is expressed in terms of the luminous intensity maximum of an *asymmetrical hot-spot* $\boldsymbol{I}_{hotspot}$ in the illumination patterns as follows [3]:

$$\boldsymbol{I}_{hotspot} = A\ N\ \eta\ L_s \qquad (1)$$

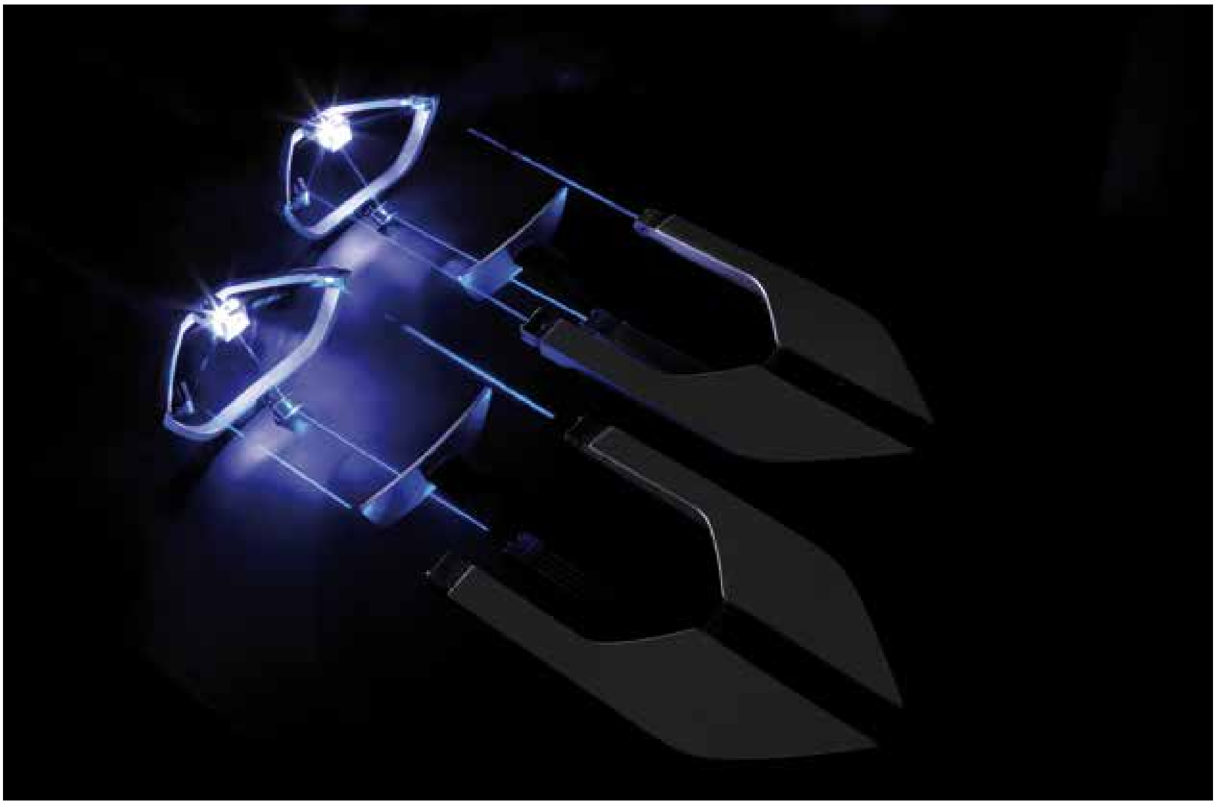
where L_s is the luminance of a lighting module (i.e. central LED chip), η is the absorption of the optical system, A is the aperture of a single lighting module and N is the number of contributing modules. One way to enhance the visibility of the drivers in the far-field is to use a large effective aperture $A_{eff} = A*N$. The separation in N sub-apertures by using multiple light sources creates the styling freedom, which is visible by the variety of the LED-headlamps existing on the road. However, a large emitting area A_{eff} per headlamp results in a decrease of efficiency for small lit apertures, limited by styling and package requirements. This impacts considerably the geometry and the weight of a headlight. Following this path, a new generation of VLSs based on LED chip array has been developed and brought to the market by different car manufacturers and their suppliers. It is based on a set (84 up to 1024) of individually addressable high-power white LEDs. These systems make use of the instant on/off switching and dimming capabilities of the LEDs to generate a given light illumination pattern. Despite the fact that these light-engines are electronically very demanding and thermally limited, standard static and dynamic illumination patterns could be generated without using mechanical actuators. Already implemented driver assistance lighting functions, such as marking light, could be realized using this technology. However, the photometric performances, namely the range of visibility, are extremely limited, since LED structures suffer from non-thermal drop in efficiency (known as *droop effect*) as the input power density is increased[4]. This loss is translated in terms of heat that has to be dissipated. The cooling systems to remedy this drawback in such light-engines end up to be bulky and heavy.

To achieve new dynamic driver assistance functions with specific illumination patterns a resolution of 0.1° in the far field is needed[5]. Considering a 60mm focal length secondary optics free of aberrations, the minimum size of an LED chip would be 100 µm x 100 µm. Typically, the field of illumination covered by a a headlamp is ±30° x ±10°. To illuminate this field using this technology, an array of 120 000 (600 x 200) LED chips would be needed. This is not realistic if the high-luminance is taken into account.

2) LASER DIODE (LD) FOR VLS

Another way to increase the visibility is to develop a new white light source featuring high-luminance L_s, as highlighted in the equation above. Such a source would lead to the development of very compact VLS with high-performance and a variety of new lighting functions with high resolution and contrast. This can be achieved by exciting a yellow phosphor in a remote position – also termed *remote phosphor* configuration (see Picture 1) using high-power multimode blue edge-emitting laser diodes (LD)[7], whose respective emitting surface is 5000 up 10000 times smaller than that of the blue chip of a high-power white LED. The radiance of the LD is even 1'000'000 times higher than that of a blue LED.

Unlike LED, the efficiency of LD increases with high input power density. During the last five years, the wall plug efficiency (WPE) i.e. ratio of the radiant power to the electrical one, of blue high-power laser diodes has been considerably improved from 25% to reach 40% at an operating temperature of 25 °C. Thanks to the use of semi-polar/m-polar GaN, thick multi-quantum wells active region and efficient design and manufacturing methods of the LD i.e. chip-on-submount and package, more efficient LDs are to be expected to hit the market in the near future. Yet, VLSs are



Picture 1: Experimental setup showing a white light produced by two Cerium(iii)-doped Yttrium Aluminum Garnet (Ce:YAG) phosphor-chips in a remote position that are excited by high-power multimode 450 nm laser diodes (over 1 W).

LARP 3 (Osram)	µLARP + (Osram)	Gigawhite (Nichia)	Sugar Cube (BMW/SLD)
			
• 500cd/mm², 160lm @25°C, CW • Transmissive remote phosphor • Integrated product safety measures • Monolithic configuration • Active cooling • Cost: high	• 500cd/mm², 188lm @25°C, CW • Transmissive remote phosphor • Product safety measures not integrated • Monolithic configuration • Active cooling • Cost: moderate	• 325cd/mm², 258lm @25°C, pulsed • Transmissive remote phosphor • Product safety measures not integrated • Monolithic configuration • Active cooling • Cost: moderate	• over 1000cd/mm², 531lm @25°C, CW • Reflective remote phosphor • Integrated product safety measures • Fiber-based configuration • Passive cooling • Cost: moderate (design to cost)

Table 1: Different laser-based white light engines

located in the vicinity of a combustion engine or electrical batteries, where temperature could reach up to 85 °C. Furthermore, the temperature inside an LED headlight could reach a peak of 110 °C as the junction temperature of an LED is about 150 °C. High-power multimode blue LDs have, however, lower junction temperatures ranging from 90 °C up to a maximum 110 °C. The remote-phosphor configuration (see Picture 1) consists in operating the LD and the phosphor units separately and under different temperature conditions. The LD unit is adequately placed in the headlight, where an efficient convection heat exchange with the cooled air flow generated by the vehicle movement takes place. By operating the LDs at the appropriate operating temperature i.e. under 60 °C and forward current, which lies between the threshold current and the rollover current, the conversion efficiency is maximized namely in a continuous wave driving mode. The robust ceramic phosphor unit together with its secondary optics is placed inside the headlight, where the temperature is high. The usage of a robust optical fiber cable between the two assemblies allows a high flexibility and modularity in the package design. Additionally reflective configuration of the phosphor that enables the local cooling is used to avoid quenching for high luminance. The heat is dissipated through the thickness of the phosphor chip (~ 100 µm), rather than radial dissipation (~ 500 µm), provided the adequate choice of the substrate that takes into account the coefficient of thermal expansion compatibility of the assembly. This reflective configuration permits, furthermore, the recycling of the back-scattered part of the light in the phosphor chip after the reflection at the interface level between the phosphor and the substrate. Under these conditions, the phosphor has to be optimized (composition/doping, grain size, grain distribution and density, thickness) to generate the desired luminance, while fulfilling the color requirement defined by the regulations. As a result, a peak luminance of over 1000 cd/mm², a luminous flux of 530 lm (see Table 1), a conversion efficient of more than 290 lm/Wradiant and a quenching temperature higher than 190 °C were achieved. The FWHM of the emitting spot is 375 µm x 275 µm. This new source is Lambertian and has a broad spectrum. The conception of the LD and phosphor units takes into account the thermo-optical stability to ensure a stable functioning when operated at high temperature.

Picture 2: High-Beam Laser-Light Booster in BMW i8

Picture 3: Marking lighting to assist drivers to detect not only pedestrians but also animals (e.g. deer) at an adequate distance

3) LIABILITY: SAFETY

An important aspect related to the use and integration of high-power laser diode in VLS is the eye and product safety. The light emanating from high-luminance sources could cause eye damages. Therefore, BMW took stringent measures to protect drivers, pedestrians and wildlife in terms of the conception, use and implementation of these new high-luminance point-sources. Similar to Xenon-based headlights, the high-beam laser-light booster is activated according to the cruising speed of the vehicle (e.g. above 40 km/h) after the activation of the main LED-generated high-beam. This intended to avoid any misuse such as having a direct close look at the system in a static position of the vehicle. Being used to generate high-beam lighting and glare-free high-beam functions, the on-coming traffic and traffic ahead is detected to switch it to the low-beam or adaptive driving beam. Furthermore, this new point source is composed of Class 4 high-power blue LDs. As such, its package was constructed to avoid leakages of the high-power coherent blue pumping light. It is also equipped with monitoring photodiodes that detect failure modes of the LDs, phosphor and the optics not only in normal situations but also in crash situations and under degradation-induced effects. The booster will be automatically switched off if a single failure mode is detected.

4) RESULTS AND PERSPECTIVES

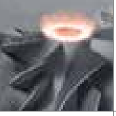
Such a high-luminance white light source was used not only to extend the range visibility in the BMW i8 vehicle (see Picture 2), but also to enhance the visibility contrast in the BMW 7 series. The maximum visibility range tolerated by the European ECE regulations is about 600 m, which corresponds to an illuminance of 344 lx at 25 m. In fact, we used LED to generate a broad illumination pattern of 64 lx illuminance and the LD-based quasi-collimated white light to generate a spot in the far-field of 290 lx illuminance. This performance has to be achieved from within a compact package (30 mm aperture of the optics) and be stable in the defined operating temperature range.

The development of new laser-based lighting functions, such as driver-assistance dynamic lighting functions shown in Picture 3 require high-luminance light sources and high resolution in the far field. MEMS-based scanning mirrors are extremely compact with high scan frequencies (kHz) and could be robust enough when integrated in the appropriate package. The main challenge ahead is to find out the appropriate configuration and optimal driving method to use the high-power (higher than 4 W) radiating beam(s) from a laser diode in combination with the MEMS-based scanning mirrors for the free patterned illumination purposes, namely in the automotive sector. An alternative to the laser scanning technologies could be the combination of optical phase modulation technologies and laser diodes. Their ability to accurately control the phase of a beam would enable free patterning of light distributions in the automotive lighting sector. In this case, coded patterns would be programmed to create dynamic light distributions without the need of any high scanning frequencies.

REFERENCES:

1. B.L. Hills, “Vision, visibility, and perception in driving”, Perception 9(2), 183-216 (1980).
2. W.N. Charman, “Vision and driving – a literature review and commentary”, Ophthalmic Physiol. Opt. 17(5), 371-91 (1997).
3. J. Jiao and B. Wang, “Étendue Concerns for Automotive Headlights Using White LEDs” in *Third International Conference on Solid State Lighting 234*; Proc. SPIE 5187, 234-242, (2004).
4. C. Weisbuch, “Droop in LEDs: Origin and Solutions”, DOE SSL R&D Workshop – Tampa Jan. 28th, 2014.
5. J. Aulbach, “Licht im Verkehrsraum. Ein- und Ausblicke” in Haus Der Technik- Tagung Automobil-Beleuchtung (2014).
6. J. J. Wierer, J. Y. Tsao and D. S. Sizov, “Comparison between blue lasers and light-emitting diodes for future solid-state lighting”; Laser Photonics Rev. 7, No. 6, 963-993 (2013).
7. S. Nakamura, S. Pearton and G. Fasol, “The Blue Laser Diode; the Complete Story”, Springer, ISBN 3-540-66505-6, (2000).

BMW Group
Licht und Sicht – EK-511
Forschungs- und Innovationszentrum
Knorrstrasse 147
80788 Munich
Germany
Phone +49 151 601 21125
Mail Abdelmalek.Hanafi@bmw.de
BMW www.bmw-muenchen.de



Laser Microwelding Ensures Reliable Contact of Batteries

The demand for powerful, yet compact, energy storage systems is increasing as both the number of smart devices and the trend towards electric mobility grow: sought-after are lithium-ion battery cells in cylindrical or prismatic design and in pouch-cell construction. The Fraunhofer Institute for Laser Technology ILT has developed the corresponding joining techniques for these battery cells: Micro welding with fiber lasers has proven itself for generating contacts for them.

The challenge often lies in the hybrid construction with different materials, for example, when aluminum, copper and steel are used. What is needed from laser microwelding is, therefore, customized hybrid joining processes: for 18650 battery cells, aluminum or copper cables need to be connected with steel; for pouch-cell batteries, aluminum and copper contacts need to be connected with each other.

This joining technology has succeeded, for example, with 18650 battery cells, which are preferably used in notebooks or laptops. They consist of cylindrical steel housings with 200 µm thin walls and are welded to relatively thick aluminum or copper wires. The heat input must be very brief and targeted very carefully so that the steel casing and the plastic seals remain intact. Fraunhofer ILT uses a 1 kW single-mode fiber laser with a wavelength of 1070 nm. The welding time depends on the desired weld geometry: in general, this deep welding process takes less than 200 ms.

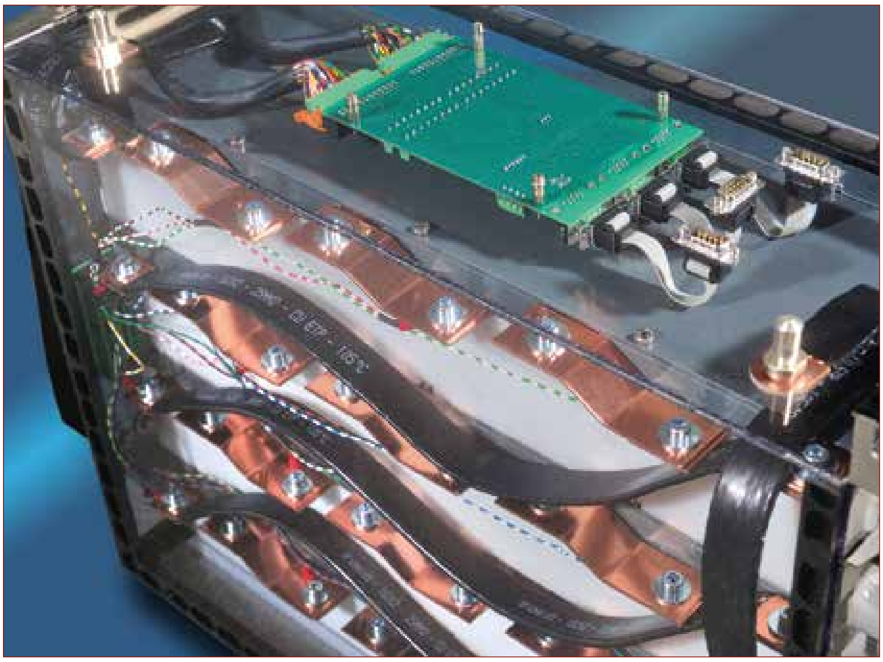
The joining of prismatic battery cells was tested in an industrial project. For this project, these lithium-ion batteries sit in a cell case made of aluminum. The outwardly guided aluminum pole connects a so-called busbar. In laser welding, the spatial power modulation has proven itself useful in that it can superimpose circular, oscillating movement in the linear feed. The method enables a constant weld and joint width. Thanks to the modulation, the weld pool geometry can be set specifically and the temperature gradient of the bath controlled accurately.

This method was also used for joining battery packs, which, among others, were developed within the joint project »Fraunhofer System Research for Electromobility«. That battery pack was built up out of 18650 cells in a modular construction. The aim was to interconnect the anode of one cell to the cathode of the other. Conventional welding and soldering methods were out of the question because

Joining of prismatic battery cells with spatial power modulation
Picture: Fraunhofer ILT, Aachen

Dr. Alexander Olowinsky, Head of the Micro Joining Group at the Fraunhofer ILT

Johanna Helm, M. Sc., Research associate at the Fraunhofer ILT, Micro Joining Group



Battery pack from the joint project »Fraunhofer System Research for Electromobility«
Picture: Fraunhofer ILT, Aachen

there was a danger that the resultant heat would destroy the cells.

Thanks to the superimposition of the feed movement with a high frequency circular oscillating movement, the energy input during laser welding could be so precisely controlled that one could weld into the 200 µm thin metallic cell wall and not damage the underlying plastic. This approach allows a modular construction and simplifies the assembly of blocks to form modules and battery packs.

This laser microwelding process continued to be developed within a research project funded by the BMBF [Federal Ministry of Education and Research]: »Robustness for Bonds in Electric Vehicles (Robe)«. Ultrasonic laser bonding originated out of a cooperation between the company F & K Delvotec GmbH and the S & F Systemtechnik GmbH. This combination of laser microwelding and wire bonding basically connects the best of both worlds because classic wire bonding reaches its limits at a maximum of 0.5 mm thick aluminum wires (max. current <35 A).

The process can be used to join current-carrying wire bonds of aluminum or copper on DCB substrates and copper terminals in the power electronics sector. Compared to conventional ultrasonic wire bonding, laser bonding allows one to join wider and thicker ribbons – this new process is more robust and reduces the demands on surface finish, cleaning processes and freedom from vibration of the workpiece. It also enables the bonding on new surfaces and with new materials. After the first prototype (400 W NIR laser, 1070 nm wavelength) was developed, the first series-produced machines will be built that can laser-bond batteries of virtually any size.

Dr. Alexander Olowinsky
Head of the Micro Joining Group at the Fraunhofer ILT
Phone +49 241 8906-491
Mail alexander.olowinsky@ilt.fraunhofer.de

Johanna Helm, M. Sc.
Research associate at the Fraunhofer ILT,
Micro Joining Group
Phone +49 241 8906-8382
Mail johanna.helm@ilt.fraunhofer.de

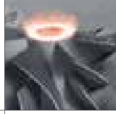
Fraunhofer Institute for Laser Technology ILT
Steinbachstr. 15
52074 Aachen
Germany
Web www.ilt.fraunhofer.de

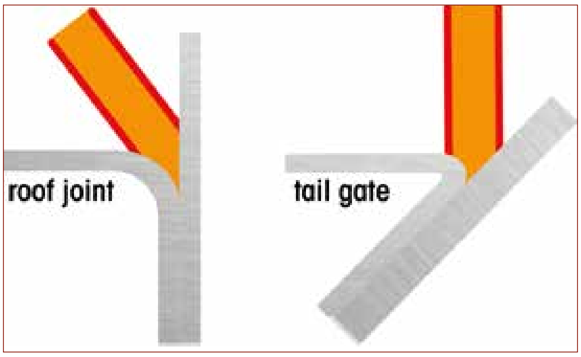
Triple Spot Module Optimizes Laser Brazing Hot-dip Galvanized Sheets

Dr. Axel Luft

Today, laser brazing is one of the firmly established methods for joining galvanized steel sheets in the series production of automotive bodies. Specifically for this application, developed brazing optics are moved along the joint by means of robots. The laser beam is transported by a fiber to the optics, and copper silicon wire ($CuSi_3$) is melted within the brazing process. The key to the success of laser brazing technology, besides a stability that is similar to a weld, is mainly to do with the high aesthetic quality of the joints: laser-generated brazing seams are known for their smooth, clean surfaces and junctions to the joining parts. This is visually appealing, as it almost completely spares post-processing and makes an immediate painting following the cleansing possible. Laser-based brazing enables such a unique impression of the joint, and unlike conventional joining techniques, cover parts and their storage and assembly can be saved.

However, recently the laser brazing technology could not meet, at least partially, the expectations placed in it. Automobile manufacturers have increasingly moved towards using hot-dip galvanized sheets in the body. Hot-dip galvanizing is more corrosion-resistant than the classical electro galvanizing. Thus, the changeover offers technical and economic advantages. Due to the new surface features of the sheets, laser brazing does not reach the usual results. In areas close to the joints, spatters increasingly occur, especially micro spatters that can hardly be recognized at the beginning, but clearly appear after painting. The quality of the joint itself decreases; it is rougher and often shows the so-called “wavelets” at which the lot exceeds the provided joint. These procedural difficulties have pushed automobile manufacturers to seek solutions from their distributors. At the time, we had already carried out laboratory tests with a rectangular spot instead of a round “single” spot. To produce a rectangular spot in a brazing optic, a so-called “homogenization module” is put into a Scansonic ALO_3 brazing optic. Such homogenizers have already been used for years by Laserline to create rectangular spots for hardening with laser powers at up to 10 kW. The actual idea of braze hot-dip galvanizing with higher quality had preoccupied Thorge Hammer from the technology planning and development at Volkswagen Wolfsburg. We were supposed to create a rectangular spot with a recess and in which a wire should be supplied. This first geometry, however, did not lead directly to the required success. But, we were able to build upon those first experiences, and within a year we developed with several iteration stages the present triple spot module or the so called “OR spot” module (optimized rectangle spot). In this solution, there are two smaller front spots positioned at the main spot that ablate the galvanization at the edges of the brazed seam. The main spot melts the lot, directly following a separate process, and creates the required joint. By the ablation of zinc at the edge-area of the joint, the process is calmed, such that spatters and wavelets can almost be completely prevented. In doing so, smooth and clean joints can be created. The approach in favor of a beam distribution in three beams by means of a triple spot module within the brazing optics has many beneficial properties. In order to calm the brazing process, as described above, an exact arrangement of the spots to one another is necessary on the one hand, while on the other hand an exactly adjusted distribution of the laser power to the three spots is necessary. But, depending on the application, e.g. roof or tailgate, or different joint geometries, different power distributions towards the three spots are necessary. The patented Laserline triple spot module offers the advantage of a stepless adjustable power distribution between the main spot and the front spots on the one hand, and between these leading front spots on the other hand. Furthermore, with this module the space between the front spots can subsequently be adjusted. The position of the module within the tactile brazing optics directly behind the integrated swivel axis also has a special meaning. Since its introduction, the tactile brazing optics, patented by Scansonic and has been in use for quite some time now, makes a significant reduction of seam errors possible. The robot has limited path accuracy and components, while clamping techniques do not always bring the joint into exactly identical positions. The wire is used as a seam-tracking sensor by the optics, and the frontal telescopic arm is swiveled for seam tracking. After the swivel axis, the laser beam is redirected at a 45° mirror, and follows the

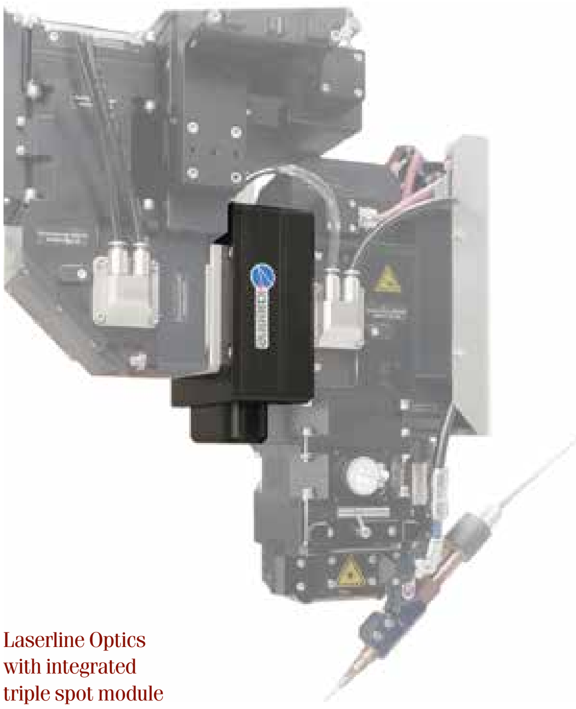




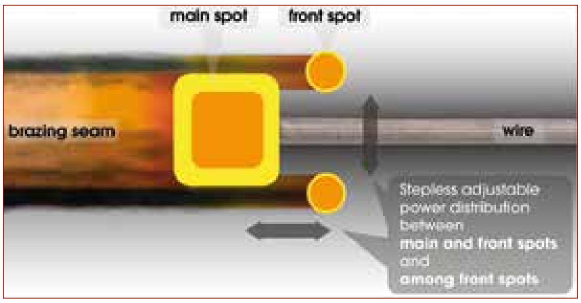
Laserline different triple spot brazing applications

wire. Because of the integration of the module behind the swivel axis, the created triple spot is always correctly oriented towards the wire. Therefore, the brazing process with robot and optics can be programmed as usual. If a triple core fiber, which is also available on the market, is used to create a triple spot, the swivel axis must be left out. When using a swivel axis, and because of the 45° mirror, the front spots would turn around the axis of the main spot, which would lead to process fluctuations. With the triple spot module, you also do not need special fibers or lasers. Laserline diode lasers are used for brazing by almost all big automobile manufacturers around the world. Standard lasers are diode lasers with a beam parameter product of 60 mm mrad. We have developed the triple spot module for exactly these lasers. That means, standard lasers with up to six exits can hitherto be used. Furthermore, standard fibers can be inserted via "plug and play". The concept remains advantageous when an older system should be equipped with triple spot modules. In most cases, a 60th standard laser is already in use, so it only needs a revision of the Scansonic optics. If further improvements at the modules can be achieved, already-installed modules can be exchanged easily with newer ones. Because of the huge variety of positive features, the triple spot module, which was not introduced until the beginning of 2016, has already entered the automobile production. As of October 2016, the module is already integrated into series productions of five cars. At the moment, extra modules for more systems are ordered. The triple spot concept offers a solution for brazing hot-dip galvanized sheets – easy and robust – with usual quality and production technique.

Laserline GmbH
Dr. Axel Luft
Fraunhofer Straße
56218 Mülheim-Kärlich
Germany
Phone +49 2630 964-0
Fax +49 2630 964-1018
Mail axel.luft@laserline.de
Web www.laserline.de



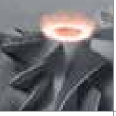
Laserline Optics with integrated triple spot module



Laserline triple spot concept new

Laserline triple spot brazing process

Laserline triple spot brazing result



Hybrid Processing of Glasses: The Benefits of Combining Plasmas and Lasers

Dr. Christoph Gerhard,
Verw.-Prof.
HAWK Hochschule
für angewandte
Wissenschaft und Kunst

Lasers have become essential and versatile tools in modern manufacturing and especially in the production of micro structures. However, precise laser micro structuring of transparent media such as optical glasses has turned out to be a challenging task. On the one hand, high machining quality is achieved when working at quite low laser energy since in this case, thermal impact is reduced. On the other hand, optical glasses feature a high laser ablation threshold and thus require the application of high laser energies due to the high transparency and insufficient near-surface absorption of incoming laser irradiation. Besides the use of ultraviolet or infrared lasers, a number of promising techniques have been developed in the last decades. Such methods are mainly based on the deposition of absorbing coatings on the glassy work piece surface.

A novel approach which was investigated in the last few years in the frame of the Lower Saxony Innovation Network for Plasma Technology (Niedersächsischer Innovationsverbund Plasmatechnik, NIP) is to increase the absorption of glassy work piece bulk material by means of plasma treatment at atmospheric pressure as shown schematically in Figure 1. Here, indirect dielectric barrier discharge plasmas, a.k.a. DBD plasma jets are used since such plasmas feature (i) high degrees of efficiency and (ii) very low gas temperatures which roughly correspond to ambient temperature. The heating of the treated glass is thus significantly below its softening temperature. For plasma formation, hydrogenous process gas mixtures are applied. The involved hydrogen molecules are dissociated and excited within the plasma volume by means of electron impact. The resulting hydrogen species, e.g. atomic hydrogen or radicals, feature high chemical reactivity and can react with the glass surface in different ways: First, oxygen vacancies and oxygen deficiency centres are formed due to the reaction of hydrogen provided by the plasma with oxygen from the glass-forming glass oxides, e.g. silicon dioxide. Further, hydrogen is implanted into the glass bulk material, leading to the formation of hydroxyl groups and a

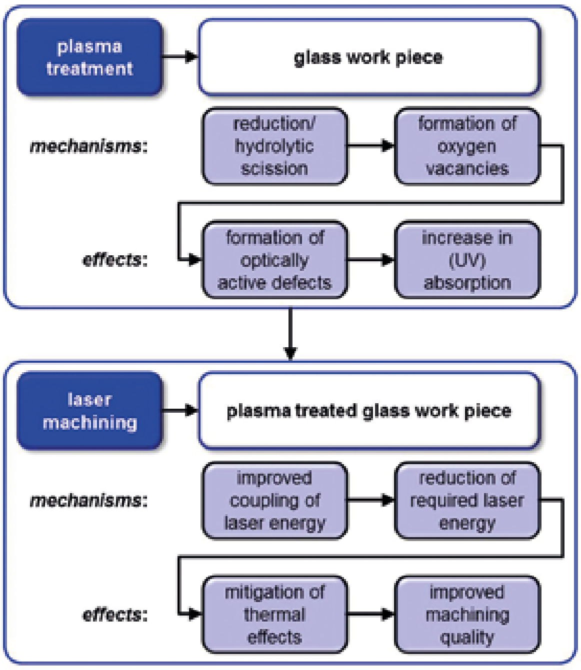


Figure 1: Schematic diagram of plasma-assisted laser ablation of glasses including the main process steps, mechanisms and effects

cracking of bonds within the glass network due to hydrolytic scission. In the course of this process, so-called E'-centers (i.e. unpaired electrons within the silicon dioxide network) can occur.

These plasma-induced effects generally represent optically active defects. As a result of such modification of the glass network, its absorption increases in the wavelength range from approx. 170 to 370 nm where the degree of absorption depends on the plasma treatment duration. In the case of fused silica, this increase amounts to 1 % at a wavelength of 193 nm (= argon fluoride excimer laser irradiation) per minute of plasma treatment. Consequently, the laser fluence, i.e. the laser energy per area given by the diameter of a focussed laser beam, required for abla-

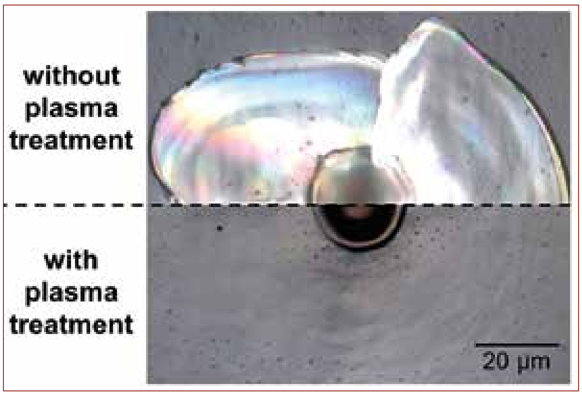


Figure 2: Comparison of laser-drilled holes in multicomponent glass without (top) and with (bottom) plasma pre-treatment, the latter showing an improved contour accuracy due to the mitigation of cracks and chips

tion is reduced by a factor of approx. 4.5 after plasma treatment for 15 minutes. Since thermal effects are now significantly reduced, a number of improvements of the machining quality can be obtained: In addition to a decrease in laser ablation threshold, the ablation rate, given by the amount of removed material per applied laser pulse, and the contour accuracy (see Figure 2) are increased. Further, both the formation of laser-induced debris and the surface roughness of laser-machined surfaces are reduced.

Finally, the latter parameter can even be improved by plasma post processing. For this purpose, direct dielectric barrier discharge plasma using inert process gases is applied. In this configuration, the work piece represents an essential component of the discharge geometry. The plasma is thus ignited directly on the glass surface, resulting in the formation of high electric field strengths on roughness peaks. Selective material removal is then obtained by plasma-physical mechanisms as for example the de-excitation of metastable plasma species and the accompanying transfer of energy at roughness peaks. In addition to surface smoothing this post processing step allows final surface cleaning by removing organic contaminations which could occur during laser processing.

One has to consider that both plasma pre-treatment for increasing the UV absorption and plasma post processing for surface smoothing can be realised using the same plasma source. This plasma source was developed in the frame of the NIP and can easily be switched between the two described modes of operation.

The above-listed economic and technical advantages show that the introduced approach represents an interesting and powerful alternative method for plasma-assisted high-quality laser based machining of optical glasses. Here, the structuring of micro lenses, lens arrays or fibre end faces as well as the realisation of achromatic micro lens doublets shall be mentioned exemplarily. It was further shown that laser machining of technical glasses such as photovoltaic cover glass can be improved by plasma pre-treatment. Thus, a number of potential applications for this technique in medical engineering, optical telecommunication and energy harvesting can be cited.

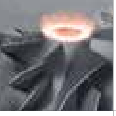
In addition to the sequential process as described above the combination of lasers and atmospheric pressure plasma sources can also be performed simultaneously. This allows increasing the machining efficiency during drilling or cutting of glasses, metals, and ceramics and was also shown to be suitable for enhancing laser-based modification of coatings and surface cleaning. To summarise, it can be assumed that most probably, a variety of currently not considered applications for laser-plasma-hybrid materials processing will be found in the future.

Acknowledgements

This work was funded by the European Regional Development Funds (EFRE) and the Workgroup Innovative Projects of Lower Saxony (AGiP) in the frame of the Lower Saxony Innovation Network for Plasma Technology (Niedersächsischer Innovationsverbund Plasmatechnik, NIP).

Dr. Christoph Gerhard, Verw.-Prof.
HAWK Hochschule für angewandte Wissenschaft und Kunst
Fakultät für Naturwissenschaften und Technik
Von-Ossietzky-Straße 99
37085 Göttingen
Germany
Phone +49 551-3705-220
Mail christoph.gerhard@hawk-hhg.de
Web www.hawk-hhg.de/naturwissenschaften

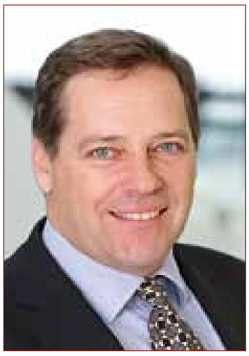
Anwendungszentrum für Plasma und Photonik des
Fraunhofer Instituts für Schicht-und Oberflächentechnik IST
Von-Ossietzky-Straße 100
37085 Göttingen
Germany
Phone +49 551-3705-376
Mail christoph.gerhard@ist.fraunhofer.de
Web www.ist.fraunhofer.de



Industrial Fibre Beam Delivery System for Ultrafast Lasers

New tools for laser machining applications

Dr. Björn Wedel,
CEO and co-founder
of Photonic Tools



Fibre optic beam delivery has been the key enabler for the wide industrial application of high power solid state cw lasers and in particular for the successful replacement of the CO_2 laser by the fibre beam delivered laser in the macro cutting applications.

The advantages – all resulting in a lower cost of ownership - are a simpler and more flexible laser installation and better serviceability of the laser application system. The laser source can be installed separately and independently from the application machine. The fibre optic beam delivery system enables routing e.g. through dynamically moved cable tracks or in a robotic cable management system. Additionally, servicing and maintaining the system is simplified by the easy exchange and setup of components requiring no or only very limited adjustments.

Since recently, flexible fibre beam delivery has become available for ultrafast lasers. In its core, this new beam delivery system employs micro structured hollow core fibres for the laser transport. The novel fibre material supports light propagation inside the hollow core (e.g. in gas, air or vacuum) enabling high laser power handling and drastically reduce nonlinear effects. Pico- and femto second laser pulses with peak powers reaching up to several hundreds of megawatts (and even close to gigawatts) can be guided through the fibre this way!

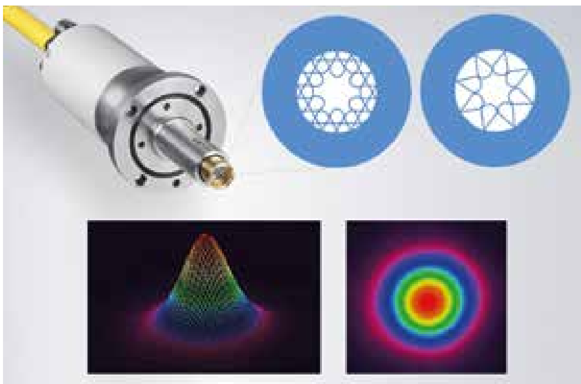


Fig. 1: Micro structured hollow core fibres and and transmitted beam profiles

The world´s first industrial fibre beam delivery system for ultrafast lasers

Photonic Tools has introduced the first industrial and commercially available fibre beam delivery system for ultrafast lasers. Applying decades of experience in the laser industry, the team behind Photonic Tools has managed the challenges of a launching a single mode laser beam efficiently into the micro structured hollow core fibre. The complete beam delivery system consists of a beam launching system (BLS), a laser light cable (LLK) with integrated fibre and a processing head, imaging the laser beam onto the workpiece.

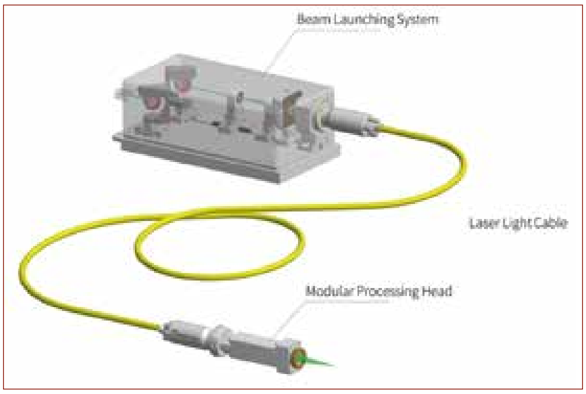


Fig. 2: Fibre beam delivery system for ultrafast lasers

The beam launching system (BLS) relays the beam exiting the laser source and focuses it exactly on to the tip of the hollow core fibre. The system is designed to perfectly match the various single mode beam parameters of the typical industrial ultrafast lasers to the fibre´s mode field diameter.

The fibre itself is packaged in a laser light cable with connectors on either end and an outer conduit protecting the fibre. The connector design features a window to create a sealed environment for the hollow core fibre which also enables evacuating the fibre structure or pressurizing it with noble gases. Integrated liquid cooling also allows for dealing with high average laser power.

The connector's flange type mounting sets a new standard in precision and easily detachable interfaces. At the same time, the o-ring seal offers a safe environmental protection for use in typical industrial manufacturing conditions.

The protective conduit is designed to withstand millions of bendings in robot or gantry applications. Also, fibre break and proper connection of cable and coupling unit are monitored according to industry standards.

Fig. 3: Laser light cable for ultrafast lasers

Performance of the ultrafast fibre beam delivery system

Given correct beam launching, the delivered beam quality at the output of the laser light cable can be regarded as single moded. An M^2 of 1.2 -1.4 is generally achieved. Fig. 3 shows the near field and the far field image of the laser beam transmitted by a typical micro structured fibre. Pulse durations down in the femtosecond range can be transmitted as well as average powers of several 100 W and pulse energies of several 100 µJ with typical transmission above 90 % for a 3 to 5 m long cable.

Fig. 4 reveals the full potential of the new technology giving a representative overview of the beam delivery performance of coupled industrial ultrafast lasers. Systems in the range of 3 to 200 W average power, 300 femtoseconds to 10 picoseconds pulse length and pulse energies between 3 and 250 µJ are shown.

Not only when operated statically but also when moving the laser light cable dynamically (such as with a gantry or robot system) the beam parameters and the near field beam profile at the output of the fibre can be preserved. The near field pointing stability could be confirmed to 1 – 2%.

For the dynamically moved cable the preservation of linear or circular beam polarization at the end of the beam delivery system could be established with a polarization extinction ratio of 25:1, which makes it suitable even for beam polarisation sensitive micromachining applications.

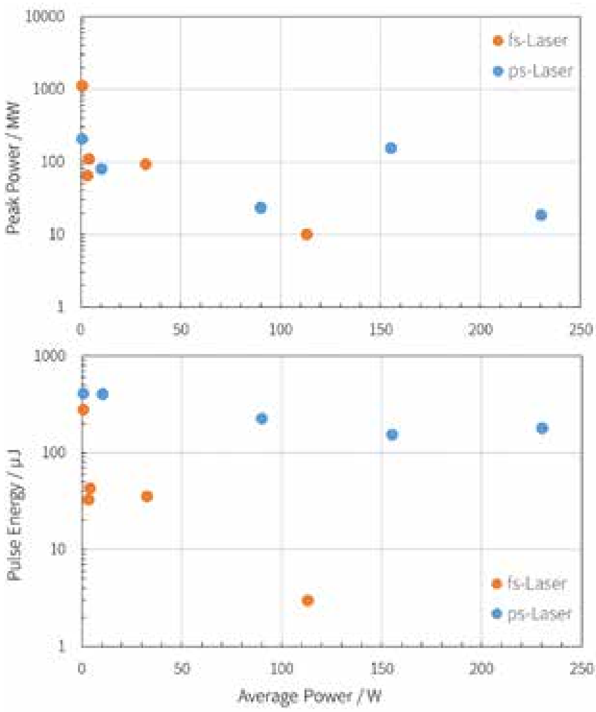


Fig. 4: Peak power and pulse energy of fibre beam delivered industrial ultrafast lasers

Outlook

Fibre beam delivery, time and energy sharing systems and modular laser processing heads will allow the simple and efficient integration of the ultrafast laser in advanced manufacturing systems. Additionally, by applying ultrafast laser physics in the technology the future ultrafast fibre beam delivery system will play a major role in the overall laser systems design. User adjustable pulse lengths and adapted wavelength spectra are just an example for adapting the laser focus to the application and the optimum laser beam material interaction.

PT Photonic Tools GmbH

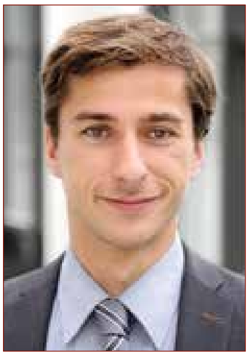
With a clear focus on increasing the productivity of industrial laser processes Photonic Tools provides state of the art beam delivery solutions, processing heads and system modules and components for industrial ultrafast and high power lasers.

photonic tools

PT Photonic Tools GmbH
Johann-Hittorf-Str. 8
12489 Berlin
Germany
Phone +49 30-639 278-000
Mail info@photonic-tools.de
Web www.photonic-tools.de

Etching Microstructures with Lasers for Electronics and Analytics

Dr. Arnold Gillner,
Head of the Competence
Area Ablation
and Joining at the
Fraunhofer ILT
© Fraunhofer ILT,
Aachen.



M. Sc. Christian Kalupka,
Research associate at the Chair
for Laser Technology LLT at
RWTH Aachen University and
Fraunhofer ILT, Micro and Nano
Structuring Group
Project Coordinator Femto DPP
© Fraunhofer ILT, Aachen.

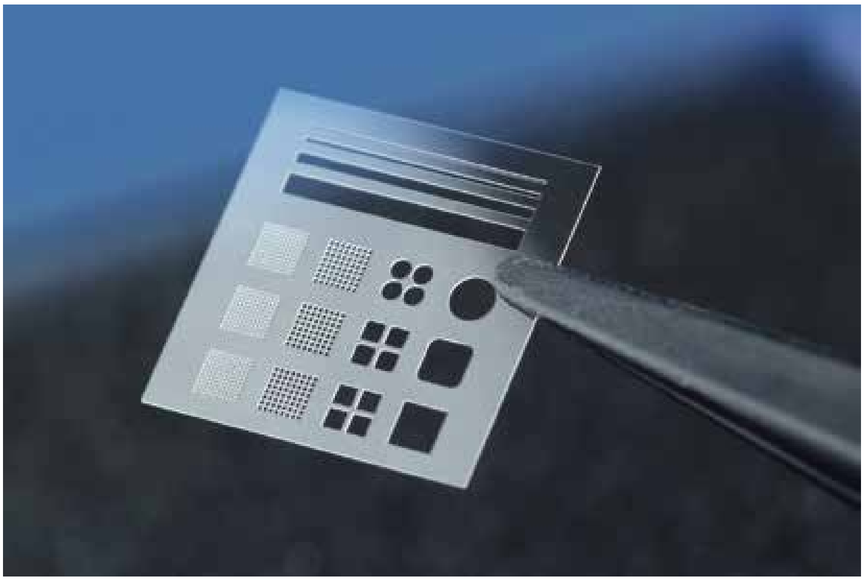
Industrial processes for the creation of microscopic structures are key for technologies such as microelectronics. A new technology developed within the Femto Digital Photonic Production project in Aachen combines laser irradiation and chemical etching to create holes and small tubes in thin glass. With it's inherently smooth surfaces this technology will enable not only new processes in microelectronics, but also microfluidic chips (lab on a chip) for biomedical applications.

This new method of Selective Laser-induced Etching (SLE) was born of a surprising phenomenon: irradiating glass in a particular way with a femtosecond laser has the effect of making the glass up to a thousand times more sensitive to subsequent wet chemical etching. Based on this effect a laser beam focused to a diameter of a few micrometers can be guided through a glass block and subsequently, a fine tube is etched through the volume of the glass. The method can be used to create the tiniest

Picture 1:
Structuring process for glass using direct laser ablation with ultrafast laser pulses.
© Fraunhofer ILT, Aachen / Volker Lannert.

of holes, to etch complete microfluidic systems into the glass, or to make cuts with extremely high surface quality.

Before this phenomenon can be harnessed in industrial processes, there are still many questions to be answered. Which materials are suitable? What are the optimum processing parameters? What type of processing technology is needed? And actually, what are the interaction processes?



Picture 2: With the SLE technique, holes with particularly smooth edges can be bored through thin glass. © Fraunhofer ILT, Aachen.

Answering these questions is the main aim of the Femto Digital Photonic Production (Femto DPP) joint research project. Since 2014, representatives of three research chairs at RWTH Aachen University and of the Fraunhofer Institute for Laser Technology ILT have been collaborating with six companies to study new phenomena that arise when processing transparent materials with ultrafast laser pulses.

The project is part of the initiative “Research Campus Digital Photonic Production” in Aachen, in which the Federal Ministry of Education and Research – BMBF supports large scale and long term cooperation between science and industry. Nine of those research campi have been established throughout Germany as public private partnership for innovation. Researchers from universities, research establishments such as the Fraunhofer institutes and companies are encouraged to work there “under one roof”.

The researchers of the Femto DPP project developed a demonstrator in which different materials and processing parameters can be compared. The SLE procedure was tested for several different glass materials, including quartz glass, sapphire, BOROFLOAT 33 and Corning Willow.

In the next phase of the project, lasting until 2019, understanding of the process will be deepened. Several experiments will be conducted at the Chair for Laser Technology LLT at RWTH Aachen University, with complex simulations running in parallel at the Nonlinear Dynamics of Laser Manufacturing Processes Instruction and Research Department NLD. The Chair for Technology of Optical Systems TOS will concentrate on optimizing the optics in the systems.

A main challenge for the technology will be productivity. For this purpose the team works on multiple-beam systems as well as on smaller systems for micro-processing. The multiple-beam source uses a Spatial Light Modulator for the individual control of several similar beams. The required process technology is developed in collaboration with three laser source manufacturers (Amphos, EdgeWave and TRUMPF) and three system suppliers (4Jet, LightFab and Pulsar Photonics).

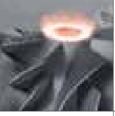
Part of the technology is already commercialized in LightFab GmbH, a start-up founded by former employees from the Chair for Laser Technology LLT at the RWTH Aachen University. It uses the SLE procedure to produce 3D precision parts made of quartz glass. Their machine - the LightFab 3D Printer - was honored with the Prism Award at Photonics West 2016.

The Femto DPP project partners see a multitude of potential applications for the technique already. Looking at microfluidics, it can produce not only channels in glass materials but also nozzles and other micro-components.

With regard to micro and consumer electronics SLE offers substantial advantages in drilling and cutting processes. Etching allows tension-free material ablation, which is advantageous for instance when manufacturing interposer structures in semiconductor technology. It can produce structures measuring under 10 µm. Currently, the team works on new systems with high laser power and multi-beam optics which hold major potential for reaching a high throughput.

Dr. Arnold Gillner
Head of the Competence Area Ablation and Joining at the Fraunhofer ILT
Phone +49 241 8906-148
arnold.gillner@ilt.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT
Steinbachstr. 15
52074 Aachen
Germany
Web www.ilt.fraunhofer.de



Optical Metrology – Enabling Technology for High Precision Fabrication

Christof Pruss

Metrology and inspection are vital parts of today's industrial fabrication, since it is an old wisdom that you cannot fabricate something reliably if you are not able to measure it.

Introduction

Contactless, high resolution in all dimensions and high measurement speed – the properties of optical metrology and inspection systems explain their considerable growth over the last years. One of the biggest fairs of optical inspection might be an indicator for this, showing this year again a visitor growth of 12% after a growth of 23% in 2014.

One of the most challenging fields in optical metrology is the testing of optical components themselves. Optics fabrication is not possible at all without appropriate metrology. The reason lies in the tight form tolerances of optical surfaces. Dictated by the wavelength of light only deviations in the range of fractions of a micrometer can be tolerated in imaging systems. For some precision systems the form tolerances even need to be down to the single digit nanometer range to meet current application's specifications.

The fabrication technology in this field is developing rapidly, fired by the demand for higher quality optical systems with extreme, application-driven build space. One example are head-up displays in cars that support the driver by displaying e.g. navigation information over the windshield. Other challenging fields are camera lenses for high resolution camera systems for image processing. Yet another field is optics for life science and vision, ranging from progressive glass spectacles to high end microscopes. All of these applications could not be realized with the traditional spherical lenses that have dominated optical systems for centuries. Instead, aspheric and freeform lenses have become a vital part of the optics designer's toolbox. These surfaces allow the same optical functionality with fewer surfaces and therefore are the basis for compact high-performance optical systems. Optics industry is on a transition from spherical optics to aspheric and freeform optics.

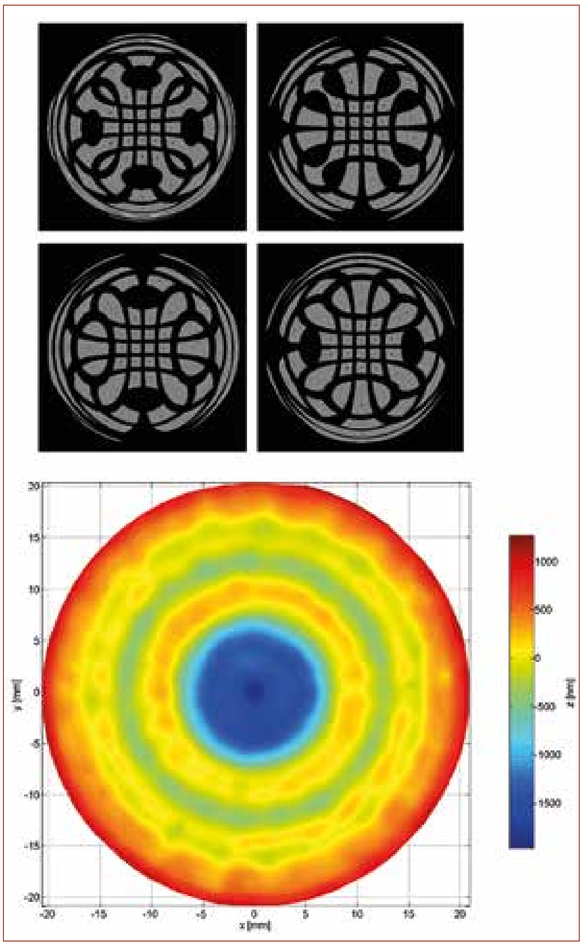


Figure 1: Deviations of a steep asphere from its design shape measured on a TWI. The inset shows the corresponding four raw interferograms that are captured within a few seconds. No movement of the test piece or the interferometer is necessary during data acquisition.

However, the advantages for optics design turn out to be the cause for major challenges in optics fabrication and testing. The high flexibility in optics design is achieved giving up the symmetry of the surfaces, which for the fabrication requires more axes and finer tools on the fabrication machines. Optics fabrication has developed rapidly over the last years to meet these demands, with German companies playing a major role in this field. New technologies like IBF (ion beam figuring), MRF (magneto-rheological finishing) or CCP (computer controlled polishing) or fluid jet polishing (FJP) enable nanometer-level surface figuring.

Testing of non-spherical optical components

Interferometry is the classic tool for form testing of optical surfaces, since its physical principle relatively easily allows sub-nanometer sensitivity. However, standard interferometers can tolerate only a few micrometers deviation from a spherical shape. Measuring steeper aspheric (literally: "non-spheric") lenses requires either a so called null optics, i.e. a tailored compensation optics that adapts the test wavefront to the asphere to be tested, or a lengthy stitching procedure where the asphere is measured in many subapertures or point by point. Both methods have their downsides, in one case the extra cost per new type of asphere, in the other case the measurement time of several to tens of minutes.

A new method that addresses the demand of optics industry for a flexible yet fast and precise metrology has been invented at the Institute of Applied Optics (ITO) at the University of Stuttgart [1,2], the so called tilted wave interferometer (TWI). It is based on a new illumination scheme that illuminates the surface under test (SUT) with many tilted wavefronts from different sides. This solves the so called vignetting problem: if the SUT's deviation from the best fitting sphere is too big, parts of the test wavefront of the interferometer are blocked before they reach the detector, so no information from those areas of the SUT can be obtained. In a TWI, this gap is filled by another wavefront from the ensemble of wavefronts, so the whole SUT can be measured at once. This explains the short measurement time even for freeforms of a few seconds only, a feature that is met by no other method on the market as of today. Figure 1 shows the resulting interferograms when measuring a strong asphere of about 600 µm departure from best fit sphere.

Thorough calibration, i.e. to determine and subtract systematic errors of the measurement device is a prerequisite for high accuracy. The TWI calibration not only covers the standard on-axis measurement of typical interferometers but also measurements in the field. This is the key for high precision and high flexibility [3] .

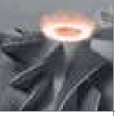
BMBF funding in the scope of the joint research project MESOFREI helped to take the next steps to commercialization together with the company Mahr GmbH. At the same time, the uncertainty of the method is investigated in close cooperation with the PTB (Physikalisch-Technische Bundesanstalt in Braunschweig and Berlin) [3]. In 2016, the TWI 60 was presented on the OPTATEC fair in Frankfurt, with an overwhelming response of the audience, showing the need of optical industry for a precise, fast and flexible metrology method in Germany as well as internationally. TWI has won the AMA Innovation Award 2014 and was nominated finalist in the SPIE Prism Awards 2015.

Figure 2: Testing a strong asphere on a Tilted Wave Interferometer (TWI) lab setup.

Figure 3: TWI 60 on the fair OPTATEC 2016 in Frankfurt

[1] J. Liesener; E. Garbusi; C. Pruß; W. Osten: Verfahren und Messvorrichtung zur Vermessung einer optisch glatten Oberfläche, DE Patent 102006057606, 2006.
[2] E. Garbusi, C. Pruss, and W. Osten, "Interferometer for precise and flexible asphere testing," Opt. Lett. 33, 2973-2975 (2008)
[3] G. Baer, J. Schindler, C. Pruss, J. Siepmann, and W. Osten, "Calibration of a non-null test interferometer for the measurement of aspheres and free-form surfaces," Opt. Express 22, 31200-31211 (2014)
[4] I. Fortmeier, M. Stavridis, A. Wiegmann, M. Schulz, W. Osten and C. Elster: Evaluation of absolute form measurements using a tilted-wave interferometer. Opt. Express, 24(4), 3393-3404, 2016.

ITO-Institut für Technische Optik
Universität Stuttgart
Christof Pruss
Pfaffenwaldring 9
70569 Stuttgart
Germany
Phone +49 711-685-66066
Fax +49 711-685-56066
Mail pruss@ito.uni-stuttgart.de
Web www.ito.uni-stuttgart.de



Surface Inspection 4.0

Research project enables the automation of complex measuring jobs.

Fig 1:
A robot holds the curved trim using vacuum suckers in order to move it in front of the ZEISS LineScan camera (faintly visible in the foreground on the left) on the inspection system. An elongated image of the surface is created using deflectometry technology
Source: ZEISS

Fig. 2:
The curved shape of the trim was a challenge for the project team.
Source: ZEISS

The degree of automation in today's production facilities is high and will only continue to grow. Not surprisingly, there is already considerable demand for automated measuring and inspection technology. This includes surface inspection where sight checks with the naked eye are still commonplace. Currently, a cutting-edge research project is overcoming several technological hurdles which have stood in the way of comprehensive automated surface inspection.

"In the factory of the future, measuring and inspection technology will steer manufacturing," explains Dr. Wolfgang Kimmig, Project Head in the Process Control & Inspection business area at ZEISS Industrial Metrology. Along with several colleagues and cooperation partners, Dr. Kimmig is currently working on automating the surface inspection of trims for vehicles as part of the 'Production Intelligence' project. The goal is that warnings like "Please clean press 3, a chip in the mold may cause rejects" will improve production monitoring.

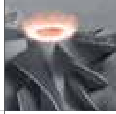
In addition to ZEISS, the Fraunhofer Institute for Physical Measurement Technology, the automotive supplier Fischer IMF and the software company Jedox AG are involved in this project which is supported by the German Ministry of Education and Research (funding code: 01IS15011) The primary task of ZEISS is to acquire measuring data, but this job is harder than it sounds. Although the team from ZEISS has already performed similar inspection tasks for other workpieces, it has required a lot of time and effort to realize the current project. The greatest challenges facing the project team were closely related to the optical technology used.

Light for defect detection

The deflectometry process, which forms the basis for inspection systems such as the ZEISS SurfMax, is already being implemented successfully. In order to identify surface defects, LED arrays illuminate the workpiece using different sinusoidal striped patterns. These are reflected on the surface of the inspection piece and captured by a camera which shoots multiple images in direct succession.

Using these raw images, the software generates not only a gray-scale image with pure brightness information, but also the gloss and tilt information of the surface. The benefit: a chafe mark, for example, that is barely visible in the gray-scale image can be easily identified in the glossy image. The tilt image, by way of contrast, reveals points of impact or scratches. Special software evaluates the images automatically. The criteria and limit values are stipulated in advance.

"Even the most experienced visual inspector does not come close to analyzing the surface as precisely as a measuring machine using deflectometry," says Kimmig. In the case of the ZEISS SurfMax, the curved arrangement of the LED arrays also enables the illumination of dented surfaces. Moreover, the high light intensity ensures short



Judith Schwarz

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

Fig. 3: Performing surface inspection using deflectometry enables an informative evaluation because tilt and glossy images are captured in addition to the gray-scale image. For example: a dent (image) is highly visible in a tilt image. Source: ZEISS

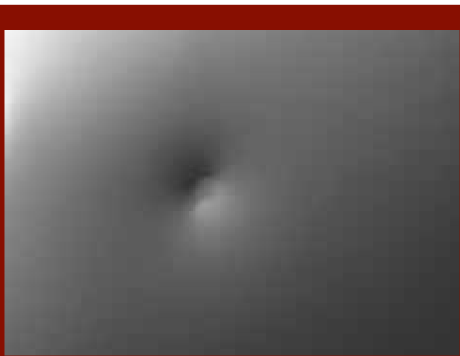
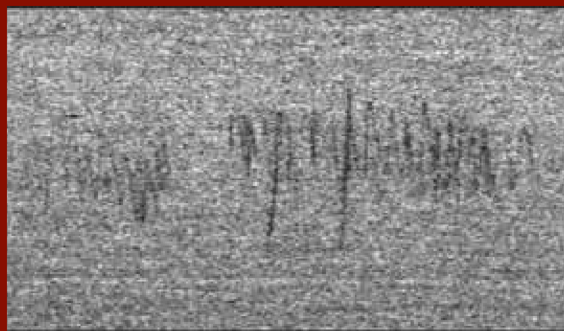


Fig. 4: A chafe mark which is hardly visible in the gray-scale image is clearly visible in the glossy image. Source: ZEISS



illumination times, meaning images are captured quickly – the prerequisite for use in the production cycle.

Not a job for a standard robot

While operators successfully inspect the surfaces of cylindrical sockets and knee joints using the ZEISS SurfMax, the system cannot simply be used as-is for metal trims. The machine reaches its limit when confronted with strongly curved trims which are 3 to 10 cm wide and 1 to 1.20 m long. The reason: the inspection system used up until now was limited to four axes, meaning it simply was not possible to completely inspect this type of component.

The project team at ZEISS decided to use a robot which would move the test object being inspected in front of the permanently installed ZEISS LineScan camera and rotate it accordingly. This way the entire surface could be imaged. However, this solution presented three difficulties: first, the developers needed to know the exact speed of the robot in order to achieve a sharply defined, informative image; second, this speed needed to remain constant so that no striped-shaped artifacts would appear on the image; and third, the trim – in spite of its curved shape – needed to be in the camera's focusing range during the entire scan, i.e. the camera needed to offer the appropriate focusing range while still maintaining the right distance from the workpiece. A standard robot designed just to quickly transport a component from A to B simply could not perform these tasks.

Adapting others' experience and expertise

The developers benefited from their colleagues producing lenses at ZEISS who faced similar challenges. Even when using robots to polish lenses, it was ultimately necessary to know the exact position and speed of the robot at any given moment. Vibrations were equally disruptive in both areas of application. On the basis of these experiences, Kimmig's team selected a suitable robot and was able to tailor the deflectometry technology to the workpieces with the robot's help.

Currently, the robot and test instrument are at the ZEISS site in Oberkochen, Germany where the first 30 trims have already been scanned. Soon the project team will install the system directly at the trim manufacturer's site. Then it will be faster e.g. to identify the press with the chip in it.

Dr. Benjamin Viering
Head of marketing and business strategy
Business unit Industrial Metrology
Carl Zeiss Industrielle Messtechnik GmbH
ZEISS Gruppe
Carl-Zeiss-Straße 22
73447 Oberkochen
Germany
Phone +49 7364-20-2144
Mail benjamin.viering@zeiss.com
Web www.zeiss.de/imt

Silicon Photonics-Based Transceivers for Exascale Data Centers

Jörg-Peter Elbers, Danish Rafique, Benjamin Wohlfeil, ADVA Optical Networking

The steady increase in digital information which needs to be stored and processed is a primary driver for data center (DC) deployments at global scale. Data centers are growing in number and – more critically – in size. Five years ago the largest data center in the world was Google's Mayes data center featuring an area of more than 90.000 m² or 13 football pitches. Today, the SuperNAP in Las Vegas has more than twice that size, scaling both the number of data center fabric ports and the interconnection requirements. Data center interconnects (DCIs) can be separated into two classes: Intra data center interconnects link individual data center switches to form a single distributed data center fabric. They are migrating from copper cables to optical fibers and support 100 Gb/s bandwidth over distances up to 2 km. Inter data center interconnects extend the data center fabric over multiple data center locations to allow a geographic distribution of networking, compute and storage functions. Employing dense wavelength division multiplexing (DWDM), they offer multi-Tb/s fiber capacities over metro distances ranging from a few tens to a few hundred kilometers. Figure 1 shows a typical data center architecture comprising a data center fabric with multiple-switch stages along with the associated intra- and inter-DC links.

Optical transceivers for DCI will be a 2.1 Billion US$ market by 2019 (IHS) [1]. Next-generation data center interconnects do not only require higher capacities but also dramatic improvements in equipment density, power consumption and cost-efficiency. Following the example of the semiconductor industry, a high level of integration in transceiver design and a high degree of automation in manufacturing are indispensable for achieving these goals.

To address these challenges, the Silicon Photonics Enabling Exascale Data Networks (SPEED) project was started in November 2015 [2]. Sponsored by Germany's Federal Ministry of Education and Research (BMBF) and coordinated by ADVA Optical Networking, the project creates a platform for development, manufacturing and packaging

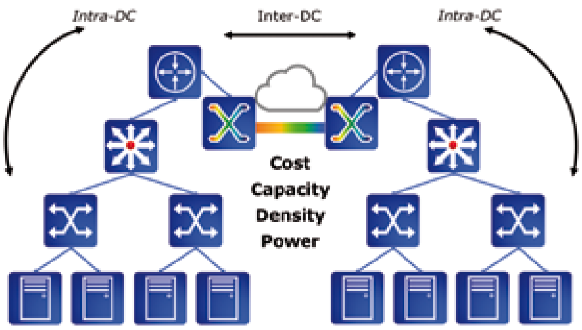


Figure 1: Typical data center architecture

of application-specific electro-photonic integrated circuits (ePICs) on silicon. ePICs combine electronic and optical functions on a single semiconductor chip, delivering better performance, smaller footprint and lower cost than competing solutions. Target applications are board-mount optical transceivers for ultra-high-speed data center interconnects.

Manufacturability, testability and low-cost packaging have been priorities right from the beginning of the project. SPEED aims at establishing a value chain for the development of ePICs in Germany. Project partners include AEM-

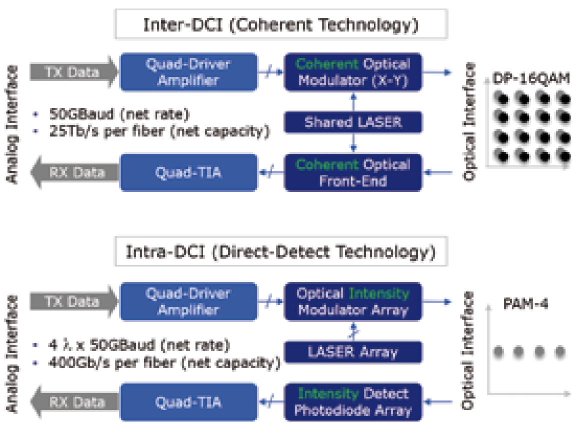


Figure 2: Intra- and inter-DC transceivers targeted in SPEED. DP: Dual Polarization, PAM: Pulse Amplitude Modulation, QAM: Quadrature Amplitude Modulation, X-Y: Orthogonal polarization states

Jörg-Peter Elbers

Danish Rafique

Benjamin Wohlfeil

tec, Finetech, Fraunhofer HHI and IZM, Innovations for High Performance Microelectronics (IHP), Paderborn University, Ranovus, Sicoya, TU Berlin, and Vertilas. In line with the emerging IEEE 802.3bs 400 Gigabit Ethernet standard and leveraging IHP's SiGe:BiCMOS and Silicon Photonics platform technologies, the project will develop two novel 400 Gb/s transceivers: a multi-wavelength direct-detect solution for intra-data center and a single-wavelength tunable coherent device for inter-data center interconnects (Fig. 2).

Figure 3: Test chips used in the SPEED project (left: direct detect chip – courtesy of Sicoya, right: coherent receiver chip – courtesy of IHP)

Test chips containing key building blocks are already available (Fig. 3).

Traditionally, Indium Phosphide (InP) was the material of choice for photonic integration due to its ability to generate light – a crucial property that is missing in silicon photonics, where the indirect band gap of the material makes it unsuitable as light source. On the other hand, silicon benefits from a mature fabrication technology facilitating large scale integration with high yield. To obtain best performance and lowest cost, a combination of the electro optical integration capabilities in silicon with the light generation and amplification properties of InP is highly desirable.
Achieving this goal is the objective of the DIMENSION (Directly Modulated Lasers on Silicon) project [3], which started in February 2016. Funded by European Union's Horizon 2020 program, DIMENSION brings together a consortium of research and industry partners from four European countries and aims at incorporating active III-V materials directly onto silicon photonics chips - either by wafer bonding or direct epitaxial growth. The DIMENSION project is coordinated by TU Dresden and involves partners from Germany, Switzerland, Greece and the UK. Research centers included are Innovations for High Performance Microelectronics (IHP) and Athens Information Technology (AIT). Industrial partners in the consortium are ADVA Optical Networking, Optocap and IBM Research – Zurich.

SPEED and its companion project DIMENSION are driven by the vision that high-bit-rate optical transceivers in the future should be as easy to manufacture and deal with as electronic ICs today. By integrating the silicon photonics, electronics and active InP photonics on a common platform, the projects are poised to give data centers what they need to meet tomorrow's demands: Ultra-high bit rate transceivers which drastically improve equipment density, power consumption and cost-efficiency of next generation data center interconnects.

[1] http://news.ihsmarkit.com/press-release/technology/data-center-optics-market-40g-transceivers-ubiquitous-100g-accelerating
[2] http://www.advaoptical.com/en/newsroom/press-releases-english/20160323
[3] http://www.dimension-h2020.eu/

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

Li-Fi – Optical Wireless Communication

Dr. Frank Deicke,
Fraunhofer-Institut
für Photonische
Mikrosysteme IPMS,
Dresden

Light as a Transmission Medium

Using light as a communication tool, for example in beacons and lighthouses, has a long tradition in the history of mankind. With a speed of approx. 300,000 km/s, light is the fastest known transmission medium. Today, optical wireless communication has prevailed only in niche applications, while radio transmission technologies are dominating the broader market of wireless data communication. However, due to the ever-growing amount of data to be transmitted, radio-based wireless communication is increasingly reaching its limits. In addition to the limited bandwidth availability of radio systems, the so-called “Frequency Crunch” problem, implementation costs are growing exponentially with increasing transmission frequencies. Therefore, optical wireless communication known as Li-Fi (Light Fidelity) is experiencing a renaissance in particular due to the high achievable data rates, the relatively low production costs and the possibility to communicate in real time. Li-Fi communication will play an increasingly important role in both the industrial as well as in the consumer sectors in the upcoming years.

Li-Fi GigaDock

With the optical docking station ‚GigaDock‘ Fraunhofer IPMS developed Li-Fi devices addressing near-field data transmission in the range of a few cm. Transmission speeds of up to 12.5 Gbps are already realizable, being unachievable for RF connections. The future will bring data rates of more than 100 Gbps. Through narrow restrictions of the data connection with regards to range and field-of-view, up to 97% of the transmission capacity can be utilized for user data. In addition to high data rates and real-time capability, security issues play a major role in this application scenario. Eavesdropping on Li-Fi is practically impossible making it just as private and direct as a plug or cable connection. With no open contacts, the system remains fully closed on every side of communication. The transceivers can be miniaturized down to 2 mm edge length. A wireless energy supply is also possible at that operating distance.

Li-Fi HotSpot

The Li-Fi ‚HotSpot‘ developed at Fraunhofer IPMS allows for the installation of a private, high-speed network without imposing cables. The modules offer data rates of up to 1 Gbps, mechanical robustness, low energy consumption, data security as well as networking capability over a distance of up to 30 m. The Hotspot device has a small size, making installation and alignment easy and inexpensive. The data exchange is limited to a defined area and does not interfere with other Hotspots nearby, making it possible to use the full bandwidth of each Li-Fi link. Besides one-directional Li-Fi broadcasting, Fraunhofer IPMS Li-Fi technology offers the possibility of a real-time capable and bi-directional, “full duplex” communication.

Figure 1: Li-Fi HotSpot with 1 Gbps Ethernet connectivity.

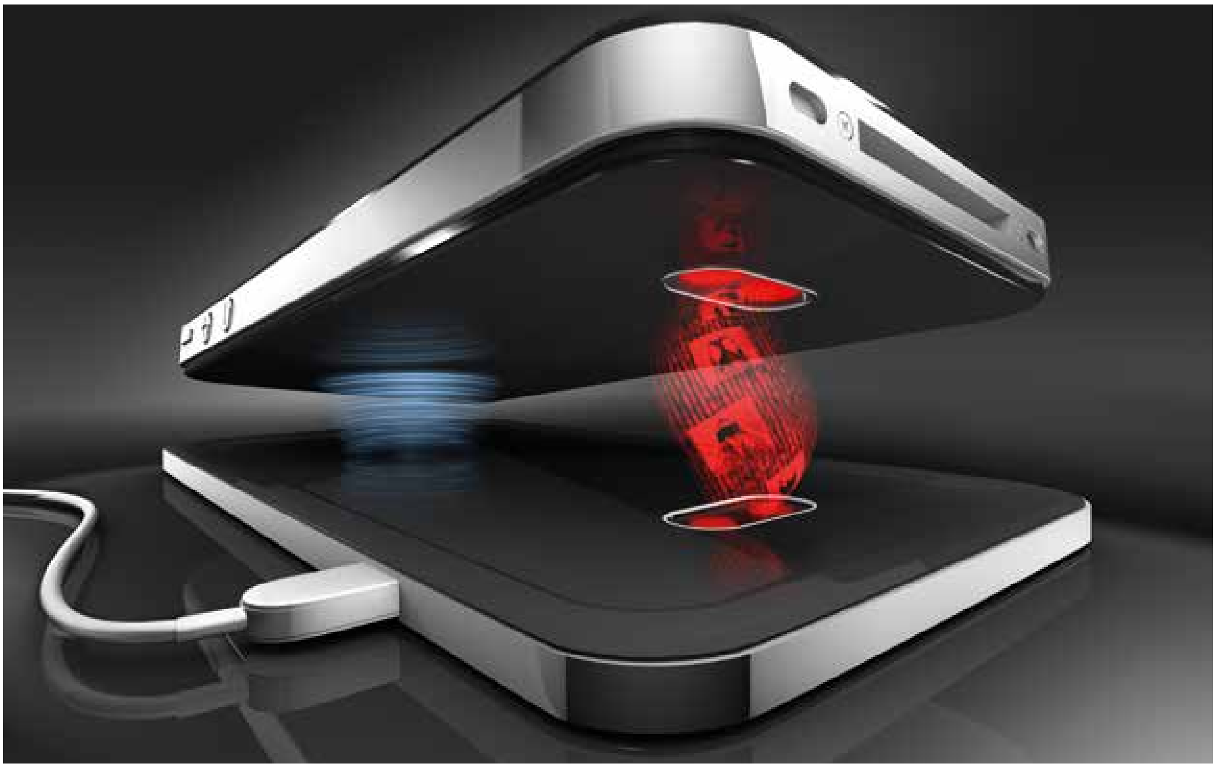


Figure 2: Li-Fi GigaDock, wireless energy and high speed data transmission with up to 12.5 Gbps.

Cable Replacement in Industrial Applications

With more and more sensors, machines and control units communicating with each other, industrial equipment is becoming increasingly complex. Harsh working conditions such as elevated temperatures, rotating machinery parts and mechanical vibrations as well as contamination with abrasion particles or corrosion results in strong demands to substitute the prevailing cable-based fieldbus systems. Wireless modules offer better reliability, longer lifetime and cost saving compared to cable connections or slip rings that are prone to wear and tear, particularly in movable or rotating tools. Its low latency makes Li-Fi communication perfectly suited for machine-to-machine interaction. It is easily possible to synchronize sensor and actuator data and, thus, to avoid collisions or to coordinate complex interactions between robot arms or different subsystems.

Fraunhofer IPMS Li-Fi technology allows for the expansion of existing infrastructure by adding an independent communication channel. This might be beneficial in areas where conventional technologies are already in use by other applications or the use of RF transmission is impossible due to strong electromagnetic interactions. The electrical interface communication for the Li-Fi module can be individually adapted to the given requirements of an already existing communication network, like Ethernet, Gigabit Ethernet, RS422, RS232, CAN or Profinet. The modules are designed to work in a plug-and-play manner without installation of additional software.

Data Security

The largest constraint of Li-Fi – the necessity of a line of sight – turns out to be a major advantage for data security, since interception devices would have to be directly installed in the transmission channel. Such an intrusion is very likely to be noticed allowing for a swift response. Therefore, Li-Fi communication combines the flexibility of wireless communication technology with the security of traditional cable-wired solutions.

Li-Fi Board-to-Board Communication

High-frequency signals are commonly transmitted between two circuit boards via HF connectors. To reliably send signals at higher data rates more complex and, therefore, mechanically fragile and expensive connector constructions are required. The miniature Li-Fi modules designed at Fraunhofer IPMS are meant to replace vulnerable HF connectors on printed circuit boards and thus ensure reliable board-to-board communication. This allows for higher flexibility with respect to interchangeability and installation of board modules. Furthermore, completely new opportunities arise for the form factor and miniaturization of systems and the galvanic decoupling of subsystems.

Dr. Frank Deicke
Fraunhofer-Institut für Photonische Mikrosysteme IPMS
Maria-Reiche-Straße 2
01109 Dresden
Germany
Phone +49 351-8823-385
Mail frank.deicke@ipms.fraunhofer.de
Web www.ipms.fraunhofer.de

Organic Solar Films – A novel and truly urban-fit source of energy

Fig. 1: Solar Glass Façade in Dresden North-East orientation to test low light behaviour 1 kWp

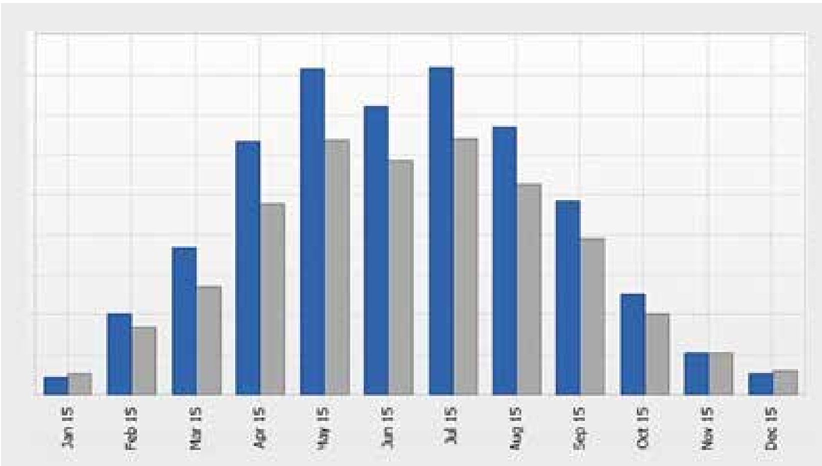


Fig. 2: Energy generating data for 2015. Blue: HeliaFilm® live Data. Grey:Calculated data of silicon façade using solar sensor data

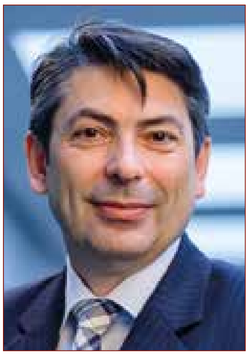
Current market situation

In order to bring solar power into the cities a new approach to photovoltaic power generation is needed, which is able to cope with a huge variety of building situations. Today mainly fossil fuels are used for heating, lighting and air-conditioning in urban buildings, that being responsible for 40 % of energy consumption and 36 % of CO_2 emissions in the EU. Moving forward, the EU has set a target for all new buildings to be nearly zero-energy by 2020. This situation and the urgent need for decreasing the carbon footprint call for new urban energy solutions. A major change in the electricity market is needed. Instead of centralized power generation from fossil fuels with a power distribution network, each building will produce its own power. The goal should be carbon neutral or even surplus electricity producing product solutions that can be fitted to both new and old buildings.

HeliaFilm®, a new solar film based on organic material can be the solution! With its extremely low weight and high flexibility in form, fit and function new applications in the building envelope are possible. In addition HeliaFilm® yields more energy per installed KWp than conventional solar cells. This is due to its unique inherent material properties, which allow better energy harvesting during cloudy days or hot climate conditions.

Solar Energy and the global trend of urbanization

Nowadays conventional solar technology has reached often grid parity cost level, which allows competitive prices compared to classical centralized fossil fuel electricity



Dr. Thomas Bickl,
Vice President Sales
and Product
Development
Heliatek GmbH

generation. One of the reasons why that competitive cost level has been reached is the standardization into similar module sizes and optical appearances with little flexibility for adaptation to other installation methods than solar farms or roof top systems. That leaves urban environments with all their various needs little choice to implement solar technology on a large scale in order to meet their future renewable energy targets. Considering the fact that by today already more than 50 % of the global population lives in cities - with numbers increasing – the world is looking for a solution of this problem. Heliafilm® can be the perfect solution for solving this problem.

Fig. 3: Fiber Concrete Façade in Linkebeek, Belgium. South orientation to test panel installation and show case to architects and designers

About Heliafilm®

Heliafilm® is a flexible solar film deposited on a PET substrate. Its photoelectric function is achieved through a carbon based layer structure invented and developed by Heliatek GmbH in Dresden. The company produces Heliafilm® that is ultra-thin, ultra-light and flexible and can be customized in colours, dimensions and transparency. The production of Heliafilm® is based on patented raw material and processes, which allows to directly translating market requirements into manufacturing specifications. Heliafilm® is effective in generating electricity also at low light levels, any orientation and at high temperatures, which will be further described below.

Unique product features of Heliafilm® are

- Flexibility – exhibiting a minimal bending radius of 10 cm
- Light weight – with an extremely low weight of 500 g/m²
- Thinness – with a total thickness of less than 1 mm
- Transparency - achieving up to 30 % transmission with 6 % efficiency

It allows enormous freedom of design with various sizes and colours on multiple building materials and applications. In addition Heliafilm® is a "Truly green" technology with no toxic materials in the production process and in the end-product, using only 1 gram of organic material per m².

Optimal Harvesting

The efficiency of inorganic solar cells based on e.g. crystalline silicon (c-Si), amorphous silicon (a-Si), cadmium telluride (CdTe) or copper-indium-gallium-diselenide (CIGS) decreases linearly with increasing temperature, and i.e. they all have a negative temperature coefficient.

In other words: During hot and sunny days the output of conventional solar cells is a lot less than their nameplate power would suggest.

However, the temperature behaviour of organic solar cells is widely independent of the ambient temperature. This leads to an optimal power production when fully illuminated and therefore to the mentioned harvesting advantage.

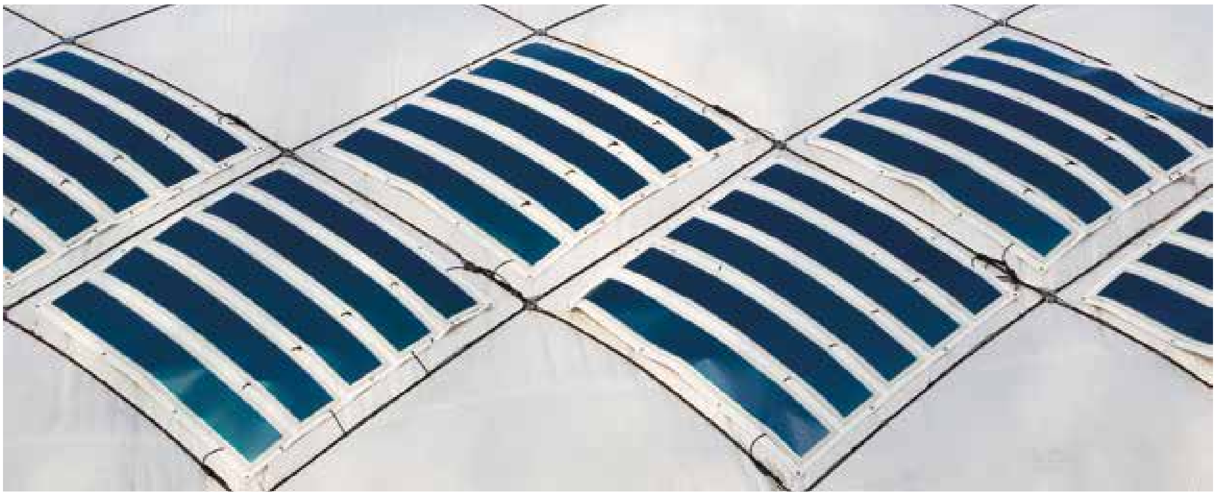


Fig. 4: HeliaFilm® on PVC – 1,5 kWp to support power needs for inflating the hall.:

In addition there is no need for a costly mounting structure that leads to a cooling ventilation air flow of the solar cells, which is always the case for crystalline technologies. The films can be directly mounted onto the building façade materials saving on cost and weight.

BiPV Applications

The company is deliberately not aiming on applications which can be easily fulfilled by silicon based solar modules but is focused on Building Integrated Organic Photovoltaic (BiOPV) where HeliaFilm's USPs provide a compellingly better solution. Every building could become a light-powered, self-sufficient energy harvester with HeliaFilm®. Heliatek is co-operating with international industry partners for applications in glass, concrete, fiber concrete, metal, PV membranes and other building materials.

Glass

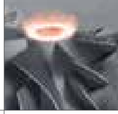
HeliaFilm® can be laminated between the layers of any glass thus fitting all building related applications. Example is a pilot installation in Dresden Germany (Fig. 1):

The data for this pilot show impressively how more energy can be harvested even in this no- optimal conditions: 21% more energy than an equivalent silicon installation (Fig. 2).

Fiber Concrete

HeliaFilm® can also be applied on top or embedded into concrete façades. An example on fiber concrete panels has been installed in Belgium to test fixation methods and also show the aesthetic integration into a design surface to architects (Fig. 3).

Fig. 5: Innogy plant with organic solar films by Heliatek



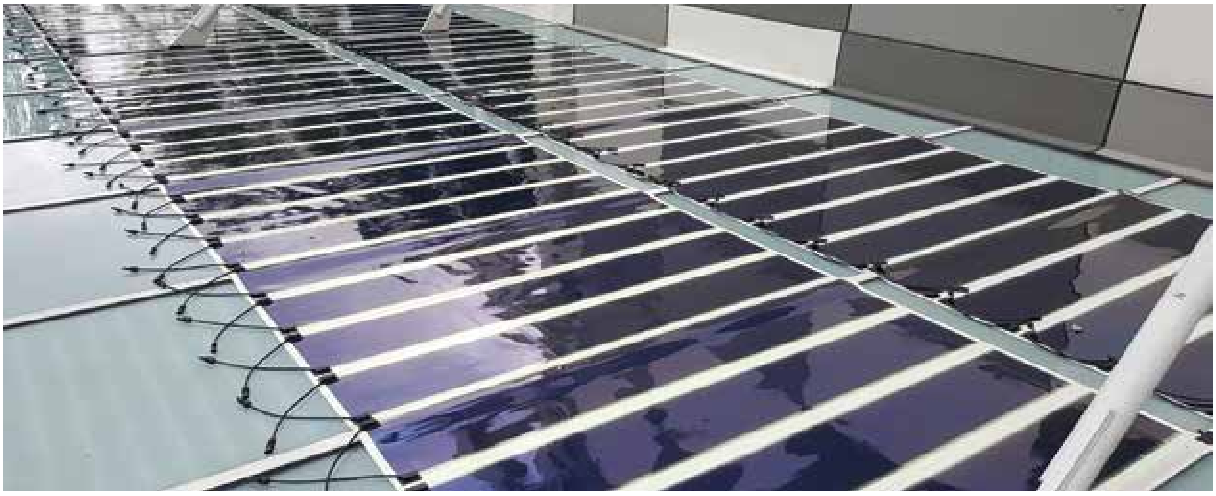


Fig. 6: Cleantech 2 building façade where HeliaFilm® has been installed on the roof and façade

Low Weight Structures

One of the major advantages of HeliaFilm® is its low weight and flexibility. A perfect application for exploiting these features are tents or other low weight architectural structures. A first pilot has been installed in Berlin, Germany (Fig. 4).

An additional benefit of Heliafilm® has been measured after the installation: it reduced racially the heat transfer into the tent structure, which allows for a cooler climate and less need for air conditioning.

Metal

Together with innogy the first biogas plant was covered with HeliaFilm®. Besides the production of bio-methane, the large façade of the fermenters is used for a pilot installation of the organic solar film by Heliatek (Fig. 5).

Singapore Pilot

Heliatek's partner, vTrium Energy, has been implementing this world's most powerful and Asia's largest BIOPV (Building Integrated Organic Photovoltaic) project. It will provide a test-bed platform and will be installed on 200 m² with a peak power of 10 kWp yielding an expected energy of more than 11 MWh per. The findings from this project will help to create a base for the future energy mix for Singapore. HeliaFilm® has been implemented with various building materials: within and on glass, on steel and on curved aluminium. Several versions of HeliaFilm® have been used: full power opaque and transparent (Fig. 6).

Outlook

Heliatek strives to work with industrial partners to supply electricity from every surface of a building at cost competitive levels.

Imagine a warehouse, where it will be possible to cover the whole roof plus the facades with HeliaFilm® . Due to its low weight there will be no restrictions with regards to weight. The films can be as long as the respective design, e.g. 20 m and more, which will lead to extremely low installation and balance of system cost.

Heliatek is uniquely positioned with the right product at the right time in the right markets achieving the three Ds – De-carbonising, De-centralising and Disrupting. As a result, Heliatek will provide zero-carbon power for everyone. As the Company says – the Future is Light.

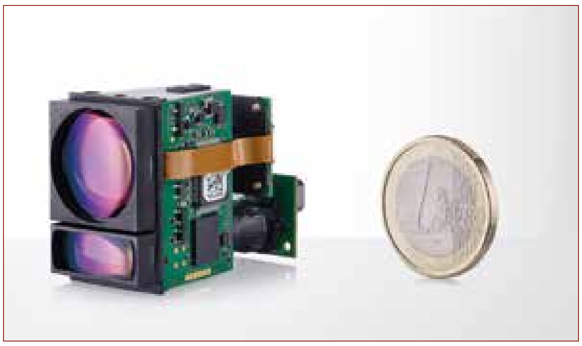
Dr. Thomas Bickl
Heliatek GmbH
Treidlerstraße 3
01139 Dresden
Germany
Mail sayhello@heliatek.com
Web www.heliatek.com

Sensory Safety Systems in Civil and Military Use

Precise surveillance and reconnaissance in combination with high performing measurement capabilities, for example the laser rangefinder, is no longer a capability which is only required in the defense market. Detection of objects or persons and their position supports consumer or industrial applications in automotive, public safety and smart home applications.

The Jenoptik Defense & Civil System division combines a set of sensors such as Long Wave IR (LWIR) modules with high-speed, high-resolution IR modules and a wide variety of laser rangefinders within surveillance devices for civil and military purposes. In conjunction with other sensors such as GPS, Digital Magnetic Compass and Direct View channel or CCD, the surveillance devices provide location data to determine the position or movement of an object.

For example, in civil-industrial-automation, uncooled LWIR modules are utilized in product development processes of devices containing highly integrated electronics, such as tablet PCs, notebooks and smartphones. In the development phase of such products it is rarely possible to foresee thermal problems based on theoretical calculations or simulations. Thermal cameras are a highly efficient test tool as they allow a two-dimensional-temperature distribution of the PCBs to be visualized with the highest available resolution up to 3 megapixels and point by point temperature measurement with highest accuracies to prove the design.



Source: Jeibmann Photografik

Source: DTS Control

Jenoptik LWIR modules are furthermore an accurate solution for machine vision and automation applications that require remote sensing technologies. The modules immediately identify thermal problems that would otherwise be undetected thanks to the highest thermal resolution and real-time interface capabilities.

Using a high-resolution thermal camera, the devices provide true night vision capabilities even in complete darkness. Unlike conventional I² image intensifier tubes that rely on some level of passive or active illumination such as night glow, thermal imaging modules based on microbolometer focal plane arrays (FPA) do not require any light at all. With the ability to image an object's heat signature based on emitted radiation, a thermal monocular's performance will not be affected by the level of available light and will

Jan Kutschera
Leader Product
Management Sensors

function in total darkness. Whatever the circumstances, a thermal monocular surveillance device will provide complete situational awareness, even on an overcast night or deep inside a cave or tunnel.

Laser rangefinder modules , available from high-speed (>30kHz), high-precision (1mm) up to long-range (20 km) extend the capability range of IR modules. Reduced size, weight, power and price are enabling factors for applications such as firing control for handheld weapons, thermal weapon sights, UAVs and hand held surveillance equipment.

Effective firing ranges of 1.5 kilometers and beyond with today's rifles require the shooter to have very accurate information about the range to the target to increase the first hit probability. The new Jenoptik DLEM 20 laser rangefinder is the ideal candidate for this kind of equipment as it is the most powerful sensor in its class weighing less than 33 grams. It is the worldwide smallest and lightest eye-safe class 1 LRF with a range capability of 2 km for a man-sized target and 5 km for extended targets.

In today's asymmetric warfare when enemy forces operate from behind protective barriers, the use of airburst ammunition against such targets is becoming more and more common. The "smart" airburst ammunition is programmed to detonate at a defined time after leaving the barrel, which could, for instance, put the high-explosive round just behind and above a brick wall where the target is hiding. Jenoptik laser rangefinders with a range accuracy of up to 0.5 m are already used in several systems worldwide.

UAVs are becoming more and more popular for reconnaissance tasks. Geolocation of observed targets becomes possible when the position and the heading direction of the UAV in combination with the range to the target are known. Due to the size and weight limitations of these kinds of UAVs, the battery capacity is the limiting factor of the achievable air time. Jenoptik laser rangefinders with a power consumption of less than 2 W during a measuring time of several hundred milliseconds are well suited to this application. The continuous range output with up to 25 times per second simplifies software design for the gimbal when implementing target tracking or speed measuring functionality.

Source: Fotolia

Detection, recognition and localization of targets, day and night, at distances up to 5 km is of increasing interest at a time when borders are again becoming more important.

Jenoptik civil laser rangefinders combine high accuracy of several millimeters with long range capability of up to 300 m. Crane control, docking procedures, warehouse position control, car distance, speed and shape measurements rely on Jenoptik products such as LDM 302, LDS 30 and LDM 50.

JENOPTIK I Defense & Civil Systems
Jan Kutschera
Product Management Sensors
Prüssingstraße 41
07745 Jena
Germany
Phone +49 3641-65-3046
Mail jan.kutschera@jenoptik.com
Web www. jenoptik.com

Freeform-based Monolithic Night Vision Objective

Dr. rer. nat. Ramona Eberhardt
R&D Coordinator
ƒo+ [freeform optics plus]
Fraunhofer IOF

Night vision technology literally allows one to see in the dark. Such equipment has evolved from bulky optical instruments in lightweight glasses through the advancement of image intensification technology. It might contribute a big share for the safety in everyday lives. Night vision cameras in automobiles, e.g., offer a higher level of security and driving comfort. Due to the complexity (multiple IR-lens elements, high adjustment effort) associated with high initial cost, however, they are primarily reserved for the military/civil aviation and are only available for the premium segment of the automotive industry.

The requirements

Thermal imaging technology now operates by capturing the upper part of the infrared light spectrum, which is not reflected as other wavelengths but emitted as heat by objects. For that, the emitted infrared light of objects in view has to be focused by a special lens, phase-scanned by an IR detector in order to generate a detailed temperature pattern, and displayed as various colors depending on the intensity of the IR emission. With respect to night vision objectives for the automotive industry, which means for application in driving cars, it is a challenge to generate such thermal imaging in rapid succession and with high resolution.

Typically, night vision cameras consist of multiple infrared lens components that bring about large adjustment efforts and limitations. In addition to technical and economic restrictions as integration time and system performance, product qualities are determined for the most part by costumers. They set limits for mass and assembly space in order to achieve a desired look causing that these quantities define the overall system. Furthermore, costumers expect a steady increase in performance of the optical components and system as well as solutions for a broad spectrum of wavelengths and thus, a wide range of applications.

The solution

In order to develop a powerful tightly arranged, costumer-oriented night vision objective in cooperation with the JENOPTIK Optical Systems GmbH, Fraunhofer IOF has therefore developed a compact freeform lens design consisting of just one single optical component to be integrated into the camera mount without significant effort. The work has been performed within the Regional Growth Core ƒo+ [freeform optics plus], funded by the Federal Ministry of Education and Research under grant number 03WKCK. Eight leading Thuringian Photonics companies and two prestigious research institutes have teamed up in ƒo+ in order to develop and market innovative freeform optical systems based on the new developed technological freeform platform.

Optical design of the freeform monolith

The material of the developed monolithic component is a novel infrared transmissive chalcogenide glass (IG4: $Ge_{10}As_{40}Se_{50}$) realized by the VITRON GmbH, which is characterized by excellent transmission and low tempera-

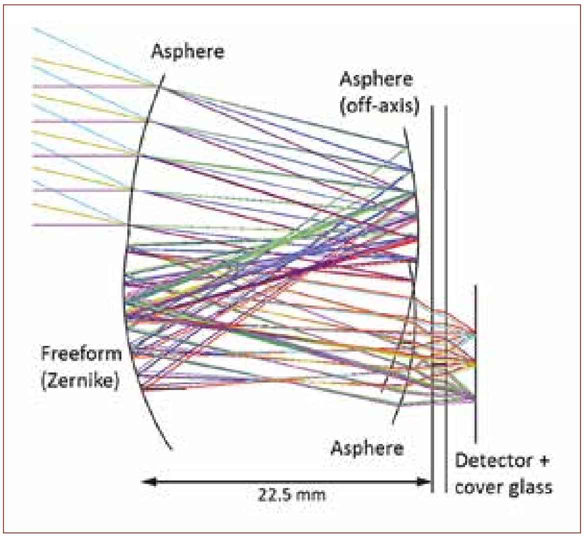
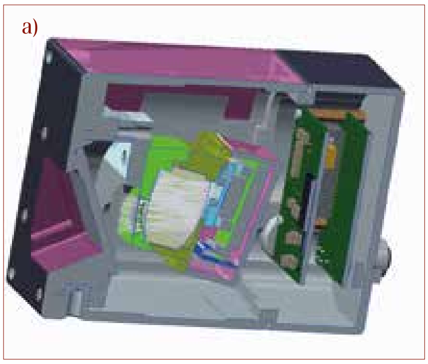


Figure 1: Optical design of the IG4 monolith.

ture dependence of refractive index and dispersion. The IR material is suitable for injection molding. Using pressed pre-forms, the material volume and the time of ultra-precision milling of the monolith as well are reduced, which results in a reduction of production process costs for mass production. Such properties offer an advantage in comparison to the typical IR material germanium.



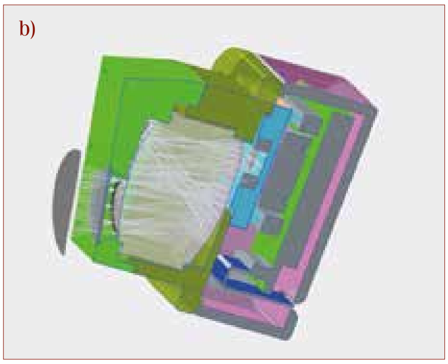


Figure 3: IG4 monolith in IR camera with freeform and one degree of freedom for adjustment (a) and in miniaturized IR camera (b).

The refractive index of the IG glass, however, is in the range of 2.6 and thus, comparably low for the IR wavelength range. For this, the requirements on the optical design are increased. The monolithic component is described by four optical surfaces, of which the entrance and exit surface are refractive, while the two remaining surfaces are metalized and used as mirrors. Compactness is achieved by a folded ray path, breaking the rotational symmetry. Thus, the imaging application requires the use of a freeform surface (cf. figure 1).

Freeform surfaces offer a huge variety of possible system geometries, while the number of existing starting configurations is very small. For this reason, the starting configuration for the monolithic design is built from aspherical surfaces enabling a perfect image for one monochromatic on-axis point. In particular, an off-axis parabolic mirror focuses the incoming light bundle of the pilot ray into an intermediate image plane, which is then imaged by an ellipsoid onto the sensor. With the help of a freeform surface described by a Zernike polynomial in Fringe convention, the optimized optical design reaches the desired field of view of 37° x 25° [1]. The spectral bandwidth is expanded from 8 µm to 14 µm. As a result, good image quality over the whole field of view with 17 µm pixel pitch is achieved together with an f-number of 1. The real intermediate image allows a compact lens volume of 2 cm x 2 cm x 1 cm [1,2], cf. figure 2.

Figure 2: Shape of the IG4 monolith with a compact lens volume of 2 cm x 2 cm x 1 cm.

Production concept of the freeform-based monolithic night vision objective

For manufacturing the IG4 monolith with the help of ultra-precision milling by the asphericon GmbH, the position of the surfaces is optimized in a way that two neighbored surfaces are machined simultaneously [3]. Thus, the design supports the calculation of a continuous tool path over the two neighbored surfaces on each side of the monolith. Furthermore, the rotational axes of these two surface compounds are aligned and thus, the monolith is produced as one turning work piece. This novel method reduces the manufacturing expense and efforts of the tooling adjustment significantly, cf. figure 3. IR cameras based on an IG4 monolith with freeform and one degree of freedom for adjustment (a) are feasible; even miniaturized and robust IR cameras in the order of about 5 cm x 5 cm x 5 cm (b) can be achieved.

For the freeform-based monolithic night vision camera, whose design is optimized for production costs, four optical surfaces on one substrate are machined, two fabrication steps are carried out for each side, and simple mounting and integration procedures are realized. The compact camera (Ge-freeform design) shows excellent images [2].

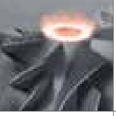
[1] Britta Satzer et al., Annual report of Fraunhofer IOF, Jena, 2015

[2] Public Workshop of the Innovative Regional Growth Core ƒo+ [freeform optics plus] as part of the OptoNet Workshop on Ultra Precision Manufacturing of Aspheres and Freeforms, Jena, 2016

[3] Patent pending No., 10 2015120853.9

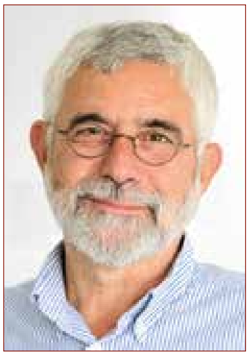
[4] http://www.fo-plus.de

Dr. rer. nat. Ramona Eberhardt
Fraunhofer Institute of Applied Optics and Precision Engineering IOF
Albert-Einstein-Strasse 7
07745 Jena
Germany
Phone +49 3641 - 807-312
Fax +49 3641 - 807-604
Mail ramona.eberhardt@iof.fraunhofer.de
Web www.iof.fraunhofer.de



FiberLab – Nerves Made Out of Glass for Human and Machine

Fraunhofer HHI



Prof. Dr. Wolfgang Schade
Head of Fiber Optical Sensor Systems Department,
Fraunhofer HHI

The Fiber Optical Sensor Systems department of Fraunhofer HHI located at Goslar has developed a multipurpose and powerful technology platform called *FiberLab*. This platform enables the design and production of novel fiber optic sensors and sensor networks for 3D shape sensing (*FiberNavi*), temperature, vibration and strain measurements (*FiberSens*), as well as chemical analyses (*FiberChem*) at the same time (Figure 1). Through the approach of a multifunctional sensor, the *FiberLab* platform allows designing tailored fiber optical sensor networks for applications in medicine, oil and gas industries, robotics and industry 4.0.

FiberNavi: The processing of the fiber optical sensor itself is done by femtosecond laser point-by-point direct writing. This technique does not only allow precise and direct writing of Bragg gratings into the core of a common optical fiber, but also direct writing of waveguides and Bragg gratings into its cladding (cladding waveguides (CWG)) without any modification of the fiber prior to laser processing. By choosing the exact laser parameters, the characteristics of the Bragg grating and CWG such as reflectivity, grating length, chirp, sideband suppression, waveguide diameter and grade of index modulation can be aligned precisely.

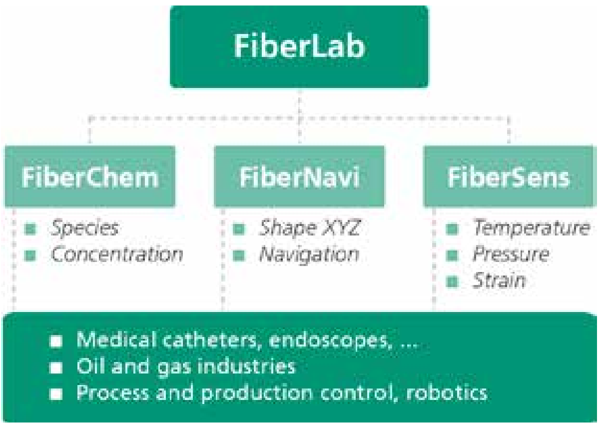


Figure 1: The technology platform FiberLab developed by Fraunhofer HHI.

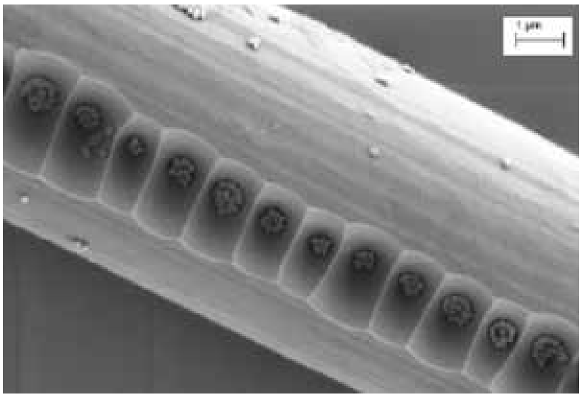


Figure 2: A FiberChem sensor produced by femtosecond laser assisted micromachining.

A 90° geometrical arrangement of CWG and Bragg grating in the cladding of the fiber allows a spatially-resolved detection of optical strain signals. Analyzing the Σ_x and Σ_y components of the strain at different positions across the fiber gives information on the 3D shape of the optical fiber. The core of the fiber only acts for data transmission, the 3D shape sensing is done by the CWG and Bragg gratings distributed across the length of the fiber. This new concept for fiber optical 3D shape sensing is patent pending by Fraunhofer HHI.

The accuracy of the 3D fiber optical measuring system is determined by three factors: (1) the spectral resolution of the interrogation system, (2) the distance of the CWG Bragg gratings with respect to the neutral bending axis, which is the core of the fiber, and (3) the number of CWG sensing elements. For a compact spectrometer in the near infrared spectral range (e.g. 850 nm) the spectral resolution is < 5 pm resulting in a resolution of the strain signal of about 8 µm/m (microstrain). Assuming the length of the active sensing fiber is 20 mm, the distance of the CWG Bragg gratings to the fiber core is 35 µm and the distance between each sensing segment is 5 mm, then the coordinate of the tip position can be determined with an accuracy better than 500 µm.

FiberChem: Besides 3D shape sensing, the technology platform *FiberLab* offers the possibility of measuring chemical concentrations by femtosecond laser assisted micromachining of the fiber. Here the adsorption of target molecules on the surface of the fiber at the position of a Bragg grating induces a change of the index of refraction and thus a shift of the Bragg wavelength. It has been shown that spots after interaction with the femtosecond laser pulses do have an enhanced etching rate for hydrofluoric acid compared to untreated fused silica. By this process a Bragg grating (e.g. located in the CWG) can be "opened" to the environment, allowing an interaction with surrounding molecules (figure 2). Deposition of gold nano-spheres coated by specific receptors can be used to enhance the effect by orders of magnitude. In that case an index change $< 10^{-4}$ can be measured by such a fiber optical sensor. Depending on the receptor and the target molecule this results in a detection limit down to ppt (parts per trillion).

Application example for a fiber optical 3D sensor: the Cyberglove

A very innovative example of the fiber optical 3D sensor concept developed by Fraunhofer HHI is the realization of a Cyberglove as human-machine interface for application in Virtual Reality or robotics. 3D fiber sensors are integrated in all fingers in a thin glove that allows the monitoring of the motion of a hand in real time (Figure 3). The Cyberglove can easily be combined with a camera based system for Virtual Reality projection. With this technique one can bring a real human hand into a Virtual Reality environment. Such a combination will find a very interesting application in the entertainment industry, as well as in intelligent manufacturing as proposed by industry 4.0.

About Fraunhofer HHI

Innovations for the digital society of the future are the focus of research and development work at the Fraunhofer Heinrich Hertz Institute HHI. In this area, Fraunhofer HHI is a world leader in the development of mobile and optical communication networks and systems, fiber optical sensor systems as well as the processing and coding of video signals.

Prof. Dr. Wolfgang Schade
Fraunhofer Heinrich Hertz Institute HHI
Fiber Optical Sensor Systems
Am Stollen 19H
38640 Goslar
Germany
Phone +49 5321-3816-8420
Mail info-fs@hhi.fraunhofer.de
Web www.hhi.fraunhofer.de/fs

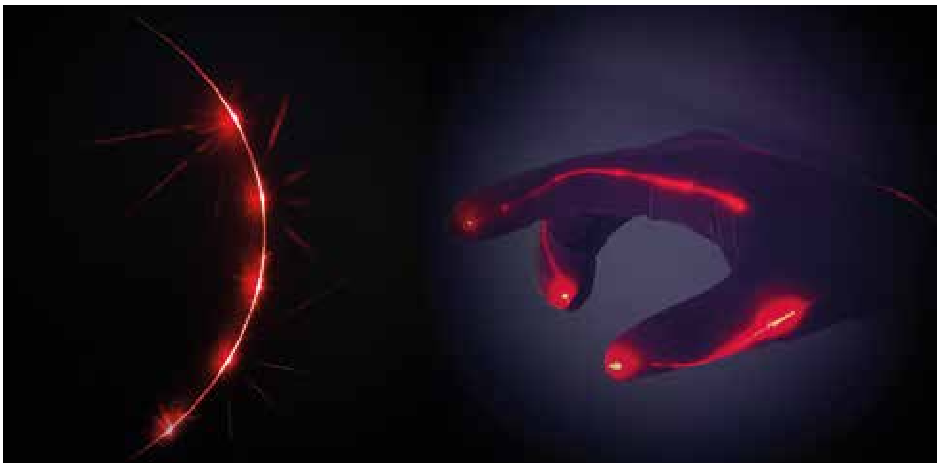
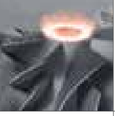


Figure 3: The Cyberglove for real time motion capturing of a human hand.

Figure 4: The Cyberglove in a virtual reality application.



EUV Multilayer Optics

Dr. Torsten Feigl
CEO optiX fab GmbH

Introduction

The demand to enhance the optical resolution, to structure and observe smaller and smaller details has pushed the optics development in recent years. Induced mainly by the production of more powerful electronic circuits with the aid of extreme ultraviolet (EUV) lithography at 13.5 nm wavelength, one can observe an increasing interest in optical components for shorter wavelengths. Due to absorption, the penetration depth of EUV radiation into matter is a few nanometers only. Hence, reflective optics have to be used for imaging and light collecting such as EUV and X-ray multilayer mirrors which consist of alternating nanometer films having different refractive indices. Those EUV and X-ray multilayers are the core business at optiX fab GmbH, a spin-off company of Fraunhofer-Institute of Applied Optics and Precision Engineering (IOF). The company was founded in 2012 to commercialize Fraunhofer IOF's EUV optics research and development activities. Located in Jena, Germany, optiX fab designs, develops and fabricates EUV imaging, illumination and collector optics. optiX fab is currently supplying chipmakers, EUV tool and source manufacturers as well as institutes, universities, synchrotron beamlines and EUV research consortia worldwide with customized multilayer and grazing incidence optics for EUV lithography applications at 13.5 nm and the entire XUV, soft and hard X-ray spectral range.

Collector mirrors for EUV Lithography

The usable power and the collector optics lifetime of high-power extreme ultraviolet light sources at 13.5 nm are considered as the major challenges in the transitioning of EUV lithography from the current pre-production phase to high volume manufacturing. At optiX fab GmbH different technologies for the precise deposition of high-reflective and laterally graded multilayers on curved collector substrates were developed in the past.

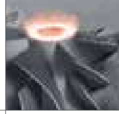
Figure 1 shows a coated 5.5 sr collector mirror for high-power LPP sources. The measured peak reflectivity of the collector mirror exceeds 68 % at 13.5 nm. The ellipsoidal substrate with an outer diameter of more than 660 mm is one of the largest EUV multilayer optics today. The laterally graded Mo/Si multilayer coating was deposited with the EUV sputtering system NESSY.

The angles of incidence vary from normal incidence at the mirror center to about 36 degrees at the mirror edge. In order to meet the Bragg condition at every position of the mirror surface a one-dimensional lateral film thickness gradient had to be realized. A deviation of 30 picometers from the design wavelength of 13.5 nm represent a maximum period thickness error within the multilayer stack of 15 picometers only.

EUV Schwarzschild Objectives

Schwarzschild Objectives are used as imaging optics in the EUV spectral region because of their large aperture, high mechanical stability, and they are free of chromatic aberrations. The use of such kind of objectives is manifold starting from applications for EUV lithography, fundamen-

Fig. 1: Mo/Si coated EUV collector mirror for high-power LPP sources.



tal research using Synchrotron radiation to imaging optics for X-ray lasers. A Schwarzschild objective consists of a convex and a concave multilayer coated mirror. Depending on the optical path of the objective it can be used for the magnification (e.g. microscopy) or demagnification (e.g. lithography) of objects and structures.

Extreme component requirements of a Schwarzschild objective have to be met in order to realize diffraction limited imaging at 13.5 nm wavelength. The tolerable maximum surface figure error is in the sub nanometer range. Hence, substrate surface deformation by gravitation, intrinsic mechanical stresses of the coating and the mechanical holder has to be taken into account and – if necessary – corrected properly. The optical components have to be positioned and centered within their low-stress mechanical holder with an accuracy of a few microns. A hydrocarbon-free mounting design is essential to minimize the contamination and degradation of the optical surfaces.

Beside the realization of EUV Schwarzschild objectives for diffraction limited imaging, optiX fab developed and realized various objectives for different applications in the EUV spectral range in the past. Figure 2 shows a modified 10x Schwarzschild objective for 13.5 nm to generate high focus intensities for fundamental investigations of photon-matter interactions.

Fig. 2: 10x Schwarzschild objective for 13.5 nm.

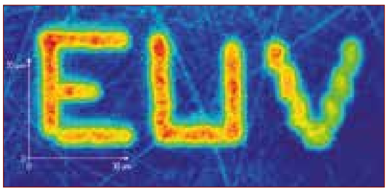


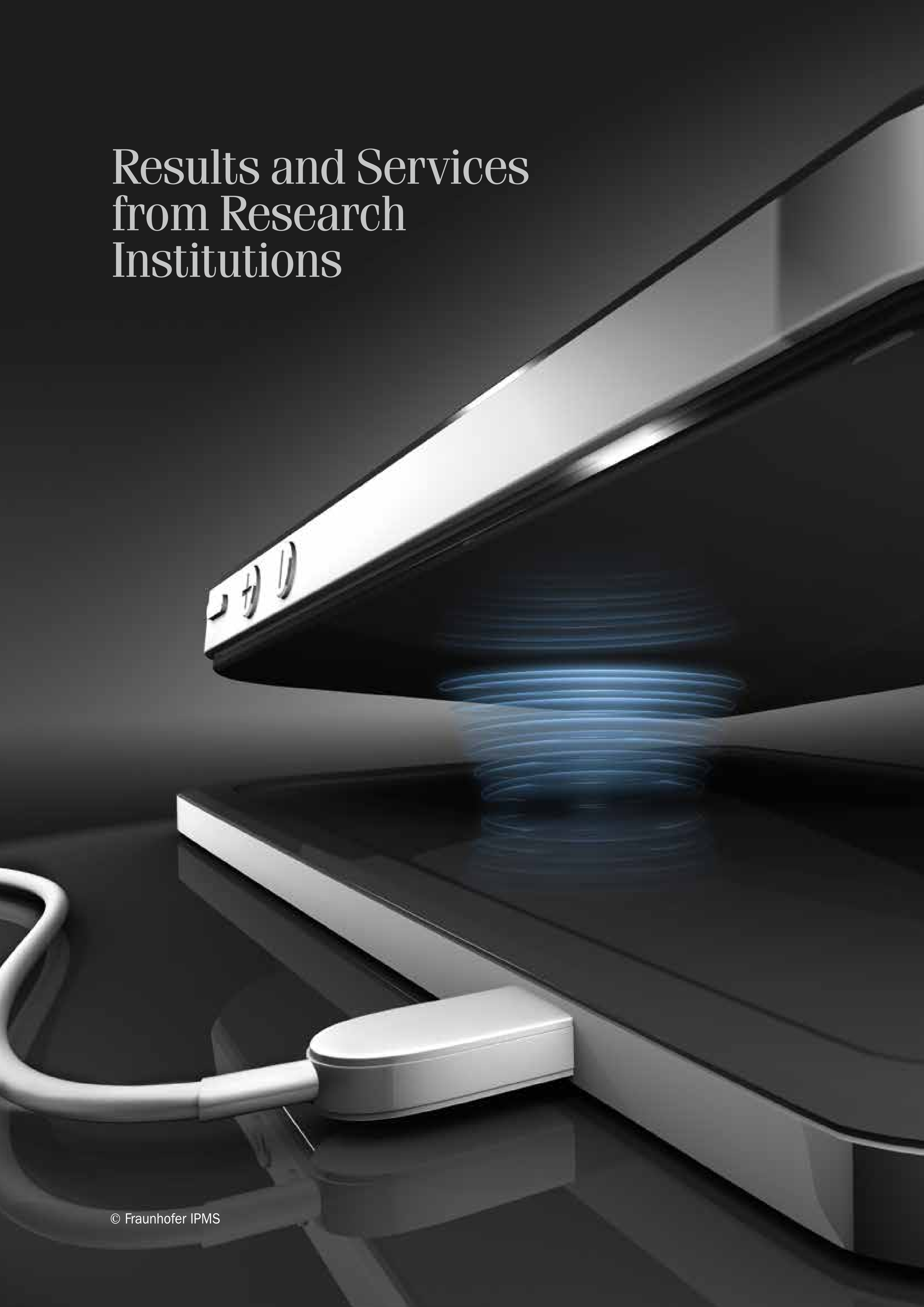
Fig. 3: Color centers in LiF crystals by structuring with 13.5 nm spot (Laser-Laboratorium Göttingen).

The numerical aperture of the Schwarzschild objective is 0.44. The spherical substrates are made of ULE and are coated with a high-reflective Mo/Si multilayer. The mechanical holder of the primary and secondary mirror was optimized for a horizontal optical path. Both mirrors are vertically mounted using a 120° three-point support.

The EUV Schwarzschild objective was adapted at the laser produced plasma source of the Laser-Laboratorium Göttingen. An EUV spot was generated by tenfold demagnification of a 50 µm pinhole that has been positioned close to the plasma source. Focus intensities of some mJ/cm^2 were demonstrated at a focus diameter of 5 µm. The EUV spot was used for direct structuring of selected materials. Figure 3 shows the creation of color centers in LiF crystals by direct writing with 13.5 nm.

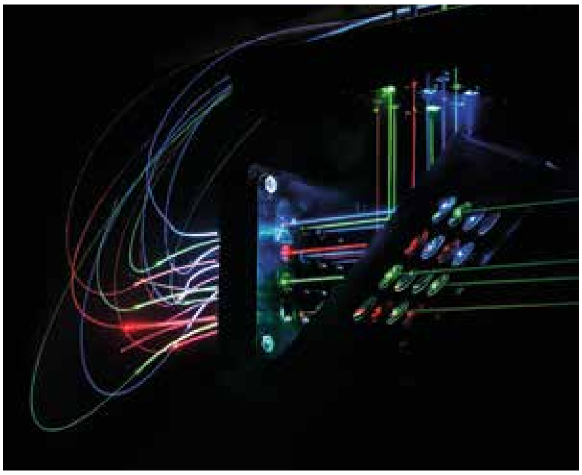
Dr. Torsten Feigl
optiX fab GmbH
Hans-Knöll-Str. 6
07745 Jena
Germany
Phone +49 3641-675-500
Fax +49 3641-675- 509
Mail torsten.feigl@optixfab.com
Web www.optixfab.com

Results and Services from Research Institutions



Ergebnisse und Dienste von Einrichtungen der Forschung

Fraunhofer Institute for Laser Technology ILT



Source: Fraunhofer ILT, Aachen / Volker Lannert.

ILT – this abbreviation has stood for combined know-how in the sector of laser technology for more than 30 years. 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 more than 415 employees and more than 19,500 m² net floor space, the Fraunhofer Institute for Laser Technology ILT is among the most significant contracting research and development institutes in its sector worldwide.

The four technology areas of the Fraunhofer ILT cover a wide spectrum of topics within laser technology. In the technology area »Lasers and Optics« we develop 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 addition to the development, manufacture and integration of components and systems, we also address optics design, modeling and packaging. In the technology area »Laser Material Processing« we solve tasks involving cutting, ablating, drilling, cleaning, welding, soldering, marking as well as surface treatment and micromanufacturing. Process development and systems engineering stands in the foreground, which includes machine and control engineering, process and beam monitoring as well as modeling and simulation. 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« we develop processes and systems for our 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 our contract research. With EUV technology, we are entering the submicron world of semiconductors and biology.

Under one roof, the Fraunhofer Institute for Laser Technology ILT offers research and development, system design and quality assurance, consultation and education. To process the research and development contracts, we have numerous industrial laser systems from various manufacturers as well as an extensive infrastructure. In the user center of the Fraunhofer ILT, guest companies work in their own separate laboratories and offices. This special form of technology transfer is based in a long-term cooperation contract with the institute in the sector of research and development. As an additional benefit, the companies can use the technical infrastructure and exchange information with experts of the Fraunhofer ILT. Around ten companies use the advantages of the user center. Alongside established laser manufacturers and innovative laser users, new founders from the sectors of custom plant construction, laser manufacturing engineering and laser metrology find appropriate surroundings to implement their ideas industrially. The Fraunhofer ILT is part of the Fraunhofer-Gesellschaft, with 67 institutes, nearly 24,000 employees and an annual research budget of more than 2.1 billion euros.

Fraunhofer
ILT

Fraunhofer Institute for Laser Technology ILT
Steinbachstr. 15
52074 Aachen
Germany
Phone +49 241-8906-0
Mail info@ilt.fraunhofer.de
Web www.ilt.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT

www.lasercongress.org

Supporting Organizations and Media Partner of 2018

optecnet Deutschland – Innovationsnetze Optische Technologien

SPECTARIS – German Hightech Industry Association

VDI Technologiezentrum

VDMA

VDA – Verband der Automobilindustrie

AKL – Arbeitskreis Lasertechnik e.V.

ELI – European Laser Institute

EPIC – European Photonics Industry Consortium

European Commission

LASER TECHNIK JOURNAL

Fraunhofer ILT

Fraunhofer Institute for Applied Optics and Precision Engineering – Photonics made in Jena

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena conducts applied research in the field of photonics and develops innovative optical systems to control light - from the generation and manipulation to its application. The services offered by the Institute covers the entire photonic process chain from opto-mechanical and opto-electronic system design to manufacturing of custom-specific solutions and prototypes. Current focuses of our research activities include freeform technologies, micro- and nanotechnologies, fiber laser systems and optical technologies for safe human-machine interaction.

Directly bonded fused silicia GRISM

In addition to industrial CO_2 emissions, agriculture also contributes significantly to climate change. With spectrometers brought into space via satellite, space agencies are now able to measure the amount of greenhouse gases in the air. These spectrometers analyze the light reflected from the earth by dissecting it into its component colors. To attain the highest possible resolution, grating and prism structures are combined: prisms deflect blue light the most intensively, while grating is best at bending red light. But so far it has hardly been possible to combine the two structures so that they would be suitable for space.

The technology of hydrophilic bonding, which is already known in the field of silicon wafers, makes it possible to combine the optical elements with each other at atomic scale. In this process, oxygen and hydrogen atoms are bonded to the wafer's surfaces. By pressing the surfaces together at elevated temperatures in a vacuum, rigid (covalent) oxygen bridges are formed between the two parts. This technology was now successfully transferred to transparent silica glass.

The advantages: The oxygen bridges firmly connect grating and prisms together, and the radiation in space cannot damage them. In addition, there is no intermediate layer, as in the case of adhesive, which would distort the measurements. The challenge was to accurately position the grating and prisms exactly to each other. Therefore a mechanical edge is produced on the grating which precisely corresponds to the direction of the grating. The resulting orientations deviate by only about one arc minute.

Fig. 1: Directly bonded fused silica GRISM (Prism + Grating) with grating at the inner surface.

Broadband Antireflection Coatings for Optical Lenses

Reducing the reflected light in optical systems is a basic aim of photonics. Reflected light causes losses in the intensity of transmitted light and can generate ghost images and stray light. To reduce these aberrations, antireflection (AR) interference multilayers are typically used. The application of sub-wavelength structures represents an alternative approach. Suitable nanostructures can be produced via plasma etching on surfaces consisting of organic materials. The combination of interference coatings with nanostructured layers has been further developed within the scope of the BMBF joint project FIONA.

The application of AR coatings on the surface of strongly curved lenses is a challenge. Vapor deposited layers are generally thinner on inclined areas. As a consequence, the reflectance spectrum in the inclined regions is shifted to shorter wavelengths which can increase the reflectance in the visible spectral range. To ensure sufficient performance in this range on inclined surfaces, the spectral range of an AR coating can be extended to include the near infrared region, thus enabling coverage of the visible range over the entire lens.

To achieve broadband AR performance, several coatings comprising inorganic layers and organic nanostructures have been developed. One of the newly developed broadband 65 designs consists of alternating high-index and low-index layers accomplished by a plasma-etched nanostructured organic layer. A residual average reflectance below 0.3 % was achieved in the spectral range from

Fraunhofer IOF

400 nm to 1500 nm, which is significantly lower than that achievable with classical interference systems.

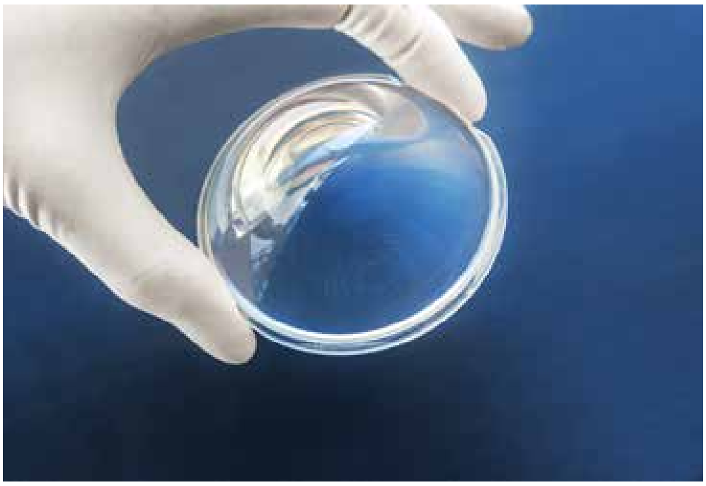


Fig. 2: A curved glass lens, half-side AR-coated.

High Power Fiber Lasers at 1 µm and 2 µm

Fiber lasers continuously increase their market share in the field of high power lasers for material processing. They can be easily integrated into complex machines, efficiently cooled and provide good beam quality. Depending on the processed material, lasers with different spectral emission properties are advantageous. The IOF has developed high power fiber laser systems around 1 µm and around 2 µm wavelength.

For the past years, Fraunhofer IOF has been developing ytterbium-doped fibers. Significant progress has been made concerning fiber design and preform fabrication, enabling the drawing of step index fibers with ultra-low numerical aperture. This allowed increasing the fiber core size while still maintaining single transverse mode operation, suppressing nonlinear effects and making higher laser powers possible. Simultaneously, the average heat load in the fiber was reduced by tailoring the doping concentration to avoid thermal destruction and the onset of (power limiting) modal instabilities.

By using an in-house fiber with a 23 µm core diameter and a numerical aperture of less than 0.04, the IOF was able to present an output power of 3.5 kW from a narrow-linewidth (180 pm) fiber system at 1067 nm central wavelength. Due to low ytterbium doping concentration, the heat load could be reduced and modal instabilities were avoided, maintaining near diffraction-limited beam quality. By increasing the spectral linewidth to 7 nm, power-limiting nonlinear effects could be further suppressed, increasing the achieved output power to a pump-limited level of 4.3 kW. This is the highest output power presented so far for a such a system.

The "eye-safe” spectral region around two microns is particularly interesting for medical applications, but also for processing of plastics. The IOF has developed a diode-pumped monolithic fiber laser at 1970 nm wavelength based on thulium-doped fibers. The high quantum defect (generating additional heat) and high purity requirements for glasses in all components of such a system are specific challenges in such a system. By applying excellent cooling and optimizing splice technology, an all-fiber oscillator with 567 W output power and good beam quality could be implemented. It was stable in operation and only power-limited by available pump power.

Fig. 3: Preform production for high power fiber lasers.

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

Leibniz Institute of Photonic Technology Jena

Photonics for Life – from Ideas to Instruments

The Leibniz-IPHT's work is marked by fundamental research, the intensive dialogue with users and the translation of the research results. With development and application of photonic technologies the Leibniz-IPHT intends to improve the health-related quality of life and to provide solutions for security as well as environmental protection.

The Leibniz Institute of Photonic Technology (Leibniz-IPHT) performs fundamental photonics and biophotonics research on application tailored photonic methods and systems to tackle important challenges faced by society today and future generations equally." Prof. Dr. Jürgen Popp, scientific director of Leibniz-IPHT.

From ideas to instruments

At Leibniz-IPHT innovative photonic and biophotonic processes and systems are explored from basic principles to their application. In addition to the continuous expansion of our technological capabilities, our research aims at photonic and biophotonic solutions by improving key parameters of analytical spectroscopy regarding resolution, sensitivity, specificity, speed, compactness, automation and their transfer to user-specific systems.

Their technical realization is based on intensive research in micro-/nanotechnology, fiber technology and systems technology. These existing core competencies of our co-workers are combined with an excellent infrastructure. Cleanroom facilities, an in-house fiber drawing tower, one of the most modern facilities of its kind in all of Europe as well as an outstanding technical equipment are a unique feature of the Leibniz-IPHT and an indispensable requirement to implement the whole process chain in the institute: from fundamental research on optical technologies to their translation into tailor-made system solutions for various areas of life. From Ideas to Instruments.

Photonics for Life

The research activities are positioned at the interface of three core research topics. Within the research focus *Biophotonics* innovative methods and instruments for molecular spectroscopy and hyperspectral imaging, high-resolution light microscopy as well as for fiber-, chip- and nanoparticle-based analyses are investigated. The comprehensive approach involves also the development of solutions for sample preparation as well as for image and data analysis.

The research focus *Fiber Optics* addresses the expansion properties as well as the efficient and flexible control of planar- and fiber-led light. Besides the development of specific optical fibers and their assembly to fiber-based sensors, *Fiber Optics* investigates new technologies to realize photonic crystal fibers and opens new spectral wavelength regions for linear and non-linear light sources. One example for the application of optical sensor technologies is the detection of environmental pollutants in soil, air and water samples. With micro-structured optical fibers integrated into a miniaturized analytical instrument it is

PhD-student Sophie Thamm uses plasmonic metal structures for bioanalytics

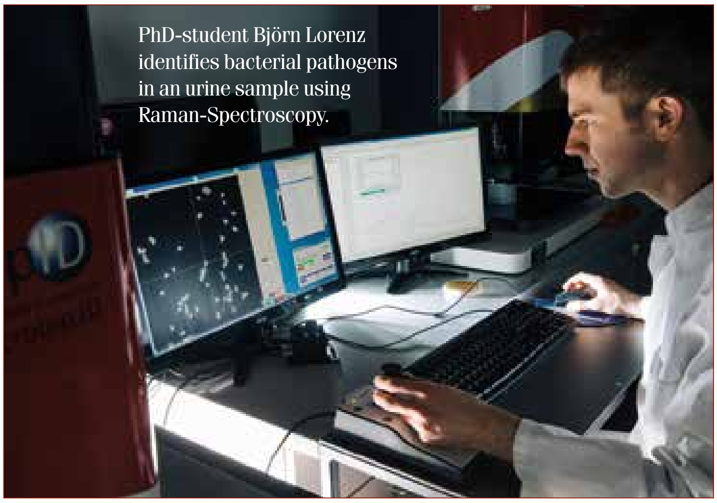
Photolithography facilities in the Leibniz-IPHT clean room possible to study such samples under adverse conditions directly on site and in real time.

The research focus *Photonic Detection* concentrates on the interaction between light and matter. Based on intensive technology research innovative sensor and detector concepts with highest sensitivity, near-sensor assembly and connectivity technology as well as multiplex and readout circuits are developed and integrated into spectroscopic and imaging photonic instruments. This leads for example to innovative safety technology like the passive THz security camera which is an alternative to established systems. By simply measuring the body's own THz radiation, it reliably detects weapons and explosives worn underneath the clothes. As it does not reveal anatomical details and does not use an active radiation source, it is ethically uncritical and harmless to health.

The research focus *Biophotonics* connects all technological research activities at Leibniz-IPHT for the application-specific design of system solutions. At the interface of the three research focuses, the institute generates innovative solutions and applications for urging challenges in medicine, health care, environment and nature protection, security and energy - according to the Leibniz-IPHT motto Photonics for Life.

Bridging Photonics and Life Sciences

The integration of the Leibniz-IPHT in efficient networks has generated strong scientific and industrial partnerships on regional, national and international level. These networks provide scientists at the institute with the necessary freedom to break new conceptual and practical ground. In dialogue with users and consumers tailor-made solutions for the knowledge and application-oriented research at the Leibniz-IPHT itself and its academic, industrial and clinical research partners are developed. The aim is to provide new analysis, diagnostic and examination methods for the medical as well as the life science and environmental research. Thus the Leibniz-IPHT adopts a bridging function between optics and photonics on the one hand and life science and medicine on the other hand. The institute's commitment ranges from cooperation projects with life science institutions to an Leibniz-IPHT-research group directly located in the clinic.



PhD-student Björn Lorenz identifies bacterial pathogens in an urine sample using Raman-Spectroscopy.

For example, the Leibniz-IPHT develops innovative methods to diagnose diseases as early as possible and to more precisely monitor the effect of therapy. To establish these future technological solutions and commercial methods that cover currently unmet medical needs, the Leibniz-IPHT uniquely makes use of the triad of technology, application and production.

Overcoming gaps in the innovation chain

The Leibniz-IPHT's philosophy is the translation of gained knowledge to users and consumers. The already mentioned triad of technology, application and production is also the base of the InfectoGnostics research campus in which the Leibniz-IPHT has a leading role. This public-private partnership is forging new paths in infection diagnostics. More than 30 partners from science, medicine and industry are developing marketable solutions for rapid and cost-effective on-site analysis (point-of-care testing) of infections – such as pneumonia (e.g. caused by antibiotic-resistant pathogens) and tuberculosis – in human medicine, animal diseases, and pathogen detection in food.

By being involved in interdisciplinary networks like InfectoGnostics research campus or at European level Raman4Clinics and by bringing actively together experts from industry, research and clinics the Leibniz-IPHT helps to overcome the so-called "valley of death" of innovation, especially in health technology. Right now the sector faces challenges to increase the effectivity of research and development, to shorten the development times and to secure a fast access of innovative medical products to the strictly regulated market. The Leibniz-IPHT faces these challenges by combining the fundamental scientific expertise with technological know-how. It is also a highly sought-after partner for economics and politics. With its interdisciplinary work and integrative role in the structural networks of industry and science the institute contributes to develop innovations more effectively from the idea to the successful application and to transfer research results faster to the benefit of users and patients.

Leibniz Institut of Photonic Technology
Prof. Dr. Jürgen Popp
Scientific Director
Albert-Einstein-Str. 9
07745 Jena
Germany
Phone +49 3641-206-301
Fax +49 3641-206-399
Mail juergen.popp@leibniz-ipht.de
Web www.leibniz-ipht.de
Twitter twitter.com/Leibniz:IPHT

Computational Optical Metrology

Optical metrology is one of the key enabling technologies in industrial production. Higher production rates, increasing complexity of the products, miniaturization and the need for in-line measurements call for new types of sensor systems that exhibit intuitively contradicting properties, such as speed, precision and insensitivity to mechanical distortions at the same time.

At BIAS we seek to meet future industrial demands by incorporating computational techniques into the measurement process. In contrast to standard methods in optical metrology, this approach relies on solving an inverse problem, where the recorded intensities can be interpreted as the effect that has been caused by the (unknown) shape, deformation, position or any other property of the underlying specimen. This creates new degrees of freedom for the metrology system, because the recorded signal does not need to be interpretable for a human observer. In contrast to standard image processing which aims at improving the analysis of measured data, here the computer processing is an inherent and integral part of the measurement process in the sense that we do not yield an interpretable result without it. We therefore may refer to these methods as computational optical metrology in analogy to similar activities in the field of computational imaging.

Due to the inherent inverse problem, methods of computational optical metrology are often both numerically and mathematically demanding, involving sophisticated algorithms and complex evaluation procedures. Having said this, there are great benefits gained from it. Using phase retrieval or computational shear interferometry (CoSI) for example, we can measure with interferometric precision using low brilliant eye safe light sources, such as light emitting diodes (LED) or even liquid crystal displays (LCD) and without the requirement of any mechanical stabilization (s. Fig.1 and Fig.2). Using digital holography, we can numerically refocus subsequent to the recording process in order to, e.g., acquire the position of objects spread across an entire volume within a fraction of a second. Using the scheme of compressive sampling we can reduce the amount of data that needs to be recorded, thereby increasing the measurement speed even for complex measurement tasks.

These examples show the great potential of computational optical metrology. Looking at the benefits, these techniques will become more and more important in the near future, where the ultimate goal is to acquire several million data points with high precision in an industrial production environment.

Fig. 1: The Golden Eye computational shear interferometer (without microscope objective): A liquid crystal spatial light modulator is used to encode incident light before it is imaged onto a CCD sensor. The recorded intensities are not interpretable for a human observer. However, after numerical processing, the system provides shape data with interferometric accuracy in the nanometer range and without any requirement for mechanical stabilization.

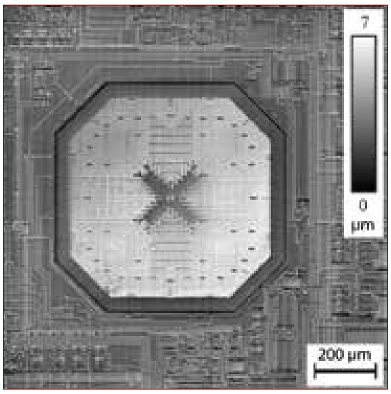


Fig. 2: Example of a measurement: The shape of a micro mechanical acceleration sensor under 5x magnification. The height of the conducting paths is approx. 1 μm.

bias
Bremer Institut für angewandte Strahltechnik

Dr. Claas Falldorf and Prof. Dr. Ralf B. Bergmann
BIAS – Bremer Institut für angewandte Strahltechnik GmbH
Klagenfurter Str.2
28359 Bremen
Germany
Phone +49 421-21 85 80 13
Mail falldorf@bias.de
Web www.bias.de

Innovations and Competencies in Industry

Innovationen und Kompetenzen aus Unternehmen

BERLINER GLAS GROUP – OEM optical solutions from concept to volume 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, laser and space technology, metrology and the display industry.

From concept to volume production

For our customers we are a reliable, competent long-term partner along the entire process chain – from concept to volume 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
- Electronics system design and development
- Coating design
- Customer-specific metrology

Key components

- Cylindrical lenses with lengths of up to 2,000 mm
- Aspherical lenses and freeform optics
- Spherical lenses and plano optics
- Array lenses
- Coatings
- Electrostatic and vacuum chucks
- High-precision structural parts

Assemblies & Systems

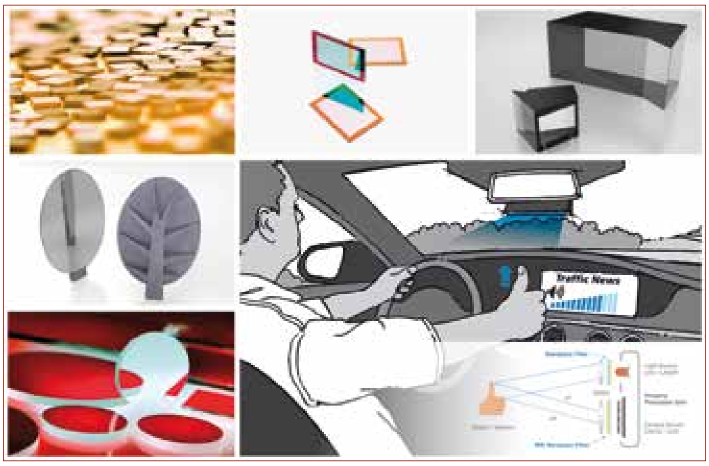
- Optical assemblies and systems
- Opto-mechanical assemblies and systems
- Electro-optical systems
- Lens systems
- Objectives, zoom systems
- Measuring systems
- Cameras

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

Solutions from Optics Balzers

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 70 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, Germany and Malaysia, 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
- Lightgate™
- Chrome coatings
- NIR filters
- Notch 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
www.opticsbalzers.com

Optics Balzers Jena GmbH
Otto-Eppenstein-Strasse 2
07745 Jena
Germany

Optics Balzers Malaysia Sdn. Bhd.
Plot 574, Lorong Perusahaan 4,
MY-13600 Penang
Malaysia

SCHÖLLY – EXCELLENCE INSIDE

High image quality, video algorithms and 3D inspection

Rising demands on non-destructive testing equipment

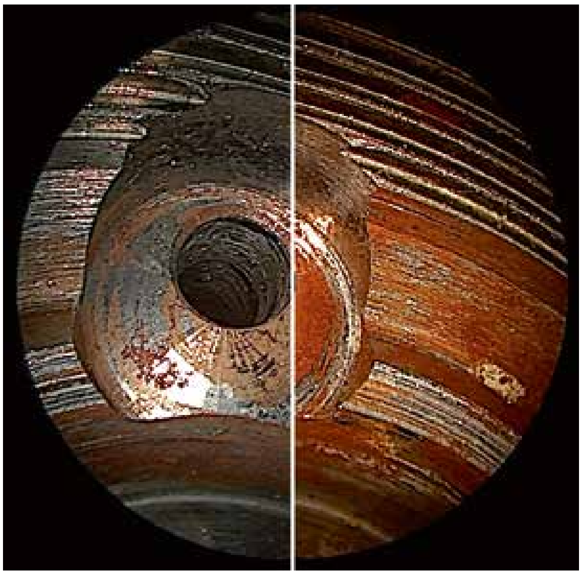
In the quality assurance in production facilities and in Maintenance Repair and Overhaul (MRO) the reliable detection of smallest deviations inside components or machines is of highest priority. Especially for security-related parts found in the automotive industry or in the aircraft maintenance visual testing is essential to avoid subsequent damages. The requirements on endoscopic equipment are stringent: besides high image quality and fast error detection, an efficient non-destructive testing process is important. In addition the increasing complexity of inspection tasks requires adaptable inspection systems. Moreover the trend of miniaturization leads to the demand of smaller probes.

With its latest camera platform SCHÖLLY is well prepared. The platform provides Full HD and includes video algorithms for fast detection of errors. The high usability is characterized by its fast adaption to different applications. An image capturing function can be used for the documentation of the inspection. The technologies can also be implemented in automated inspection solutions. 3D visualization systems are available as OEM versions.

Full HD, image optimization by video algorithms and 3D inspection

High resolution is one of the preconditions that contribute to a high level of details shown on a screen. SCHÖLLY's latest camera platform provides Full HD resolution (1920 x 1080 p) and thus provides more than 2 million pixels. Comparable industrial inspection cameras offer considerably less resolution. High resolution solely is not the key factor. Besides resolution further aspects like color reproduction, dynamic range, signal to noise, dynamic pixel defect correction, automated brightness control and the possibility of adaption to different applications are important elements. Only if a manufacturer is able to perfectly align all technical preconditions the inspection system provides outstanding image results and the worker is able to detect smallest deviations.

The market requirement for smaller probes influences the practical implementation at the manufacturer's site. There is a balancing act to be made: In order to realize small probe diameters the use of image bundles instead of rod lens systems is necessary. Compared to rod lens systems, the image of image bundle endoscopes shows a honeycomb structure. It results from the impermeable sheath which surrounds each fiber and from the cavities between the fibers. In order to compensate these impacts SCHÖLLY includes video algorithms in its camera platform. These are programs that help to enhance image quality, to correct system errors (e.g. pixel errors) or to highlight specific areas on the screen. "Grid removal" is one of these video algorithms that enhance the image quality. The algorithm turns off the honeycomb structure of the image bundle endoscope. There are several image optimizing algorithms: "Smoke reduction" clears the view by reducing interfering particles like dust, smoke or fog on the screen. Even tempering colors can be visualized more easily and



Defects can be seen quickly by using video algorithms: Corrosion turns out clearly (right picture)

3D visualization leads to natural vision and faster inspections

reliably. “Color enhancement” emphasizes relevant criteria by enriching its color. Thus defects turn out immediately. Video algorithms help to balance technical preconditions and support the worker in order to detect even smallest errors faster and more reliably.

Flexible and modular systems that cover a big range of applications

Global standardization activities, supplier reduction and economic reasons require flexible systems that can be adapted to different inspection tasks. With its latest inspection system FlexiVision 100, based on a new camera platform, SCHÖLLY meets these requirements. The FlexiVision 100 is highly compatible e.g. with the existing endoscope program of the customer. By using the HD camera head, endoscopes and fiberscopes with DIN ocular can be connected. For miniaturized components with small access points SCHÖLLY's FlexiScope probes are particularly suited. The probes, starting at diameter 0.5 mm, can be connected via the FlexiScope 3 camera hand piece. The platform is ready for future developments like chip-in-tip endoscopes. For challenging applications it can be equipped with special video algorithms. OEM versions of the platform offer 3D visualization.

Excellence Inside

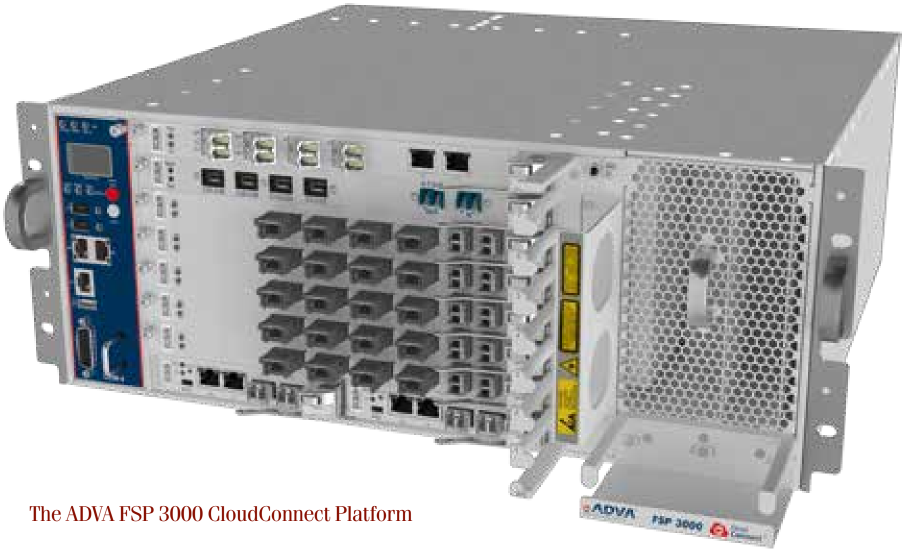
SCHÖLLY is a global engineering and manufacturing company focusing on high-end visualization systems in medical and technical fields. Looking ahead, one of our main objectives will remain to develop sustainable solutions and innovative products using state-of-the-art technology, in order to create real value for our customers and users. A total of around 600 employees ensure that these products come into operation globally and 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 given in a high-temperature environment. Our integrated systems for visualization are created within a network of optical, mechanical and electronic components, light modules and 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.

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

Open Terascale Transport for Cloud Applications

About ADVA Optical Networking

At ADVA Optical Networking we're creating new opportunities for tomorrow's networks, a new vision for a connected world. Our innovative telecommunications hardware, software and services have been deployed by several hundred service providers and thousands of enterprises around the globe. Over the past twenty years, our open connectivity solutions have helped to drive our customers' networks forward, helped to drive their businesses to new levels of success. We forge close working relationships with all our customers. As a trusted partner we ensure that we're always ready to exceed your networking expectations.



The ADVA FSP 3000 CloudConnect Platform

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

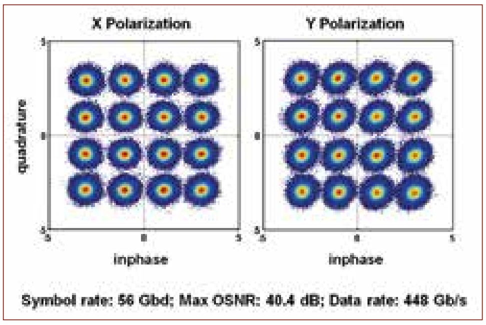
We are living in the age of the data center. Data centers have become the cornerstones of our digital societies and interconnecting these data centers is one of the biggest growth areas for optical networking technology. At ADVA Optical Networking, we have become one of the industry's most trusted partners in that space 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. For more information please visit our website www.advaoptical.com.

ADVA Optical Networking SE
Fraunhoferstrasse 9A
82152 Martinsried
Germany
Phone +49 89-890665-0
Web www.advaoptical.com

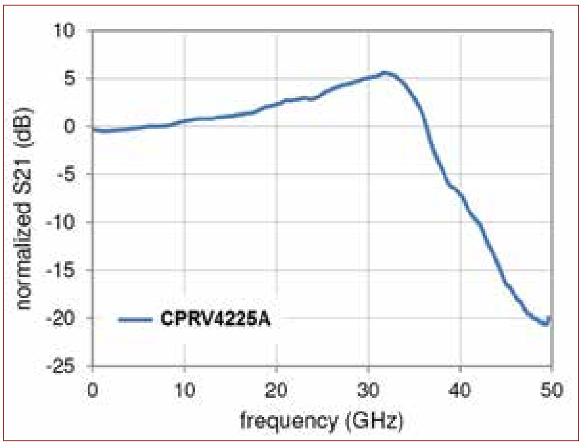
Next Generation Optical Communications

Finisar is the global technology leader and the world's largest supplier of optical components and subsystems. Our 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 vastly growing demand for network bandwidth driven by social media and the "Internet of Things". With nearly 14,000 employees around the globe, and its vertically integrated business model Finisar offers a broad portfolio of pluggable transceivers, transponders, active optical cables, networking subsystems, optical instruments, amplifiers and optical components. Coherent and Advanced Photodetectors and Receivers by Finisar offer exceptional performance for a wide variety of applications, including Communication, Test & Measurement, and Research & Development. The entire receiver and detector portfolio meets requirements for high-speed, extreme linearity and high RF power performance.

Finisar's site in Berlin, Germany is dedicated to continuously advancing the performance of high speed photonic devices in order to increase the capacity of the optical core telecommunications network. Berlin develops high-speed IQ modulators and integrated coherent receivers which encode and transmit, and then receive and decode the transmitted signal data.



Dual Polarization QAM16 Constellation Diagram



Normalized S21 as a Function of Frequency

High quadrature phase and amplitude modulation formats such as 64-QAM and polarization multiplexing provide a high number of bits per symbol in modern long-haul telecommunications systems. By increasing the symbol rate from 28 to 64 Gbaud, data transmission speeds of up to 600 Gb/s in a single wavelength channel can be reached.

Technology-agnostic Finisar continues to invest in its Coherent Communications portfolio and leverages the advantages of both Indium-Phosphide (InP) and Silicon Photonics (SiP) device technologies to enhance the capabilities of integrated coherent TOSA and ROSA components.

Finisar Berlin engages in various advanced development projects in close co-operation with the leading European technical institutes to increase the transmission capacity and integration depth while reducing the overall cost for a next generation telecommunication infrastructure.

The Research and Development team in Finisar Berlin (formerly u²t Photonics AG) has been first to market with its newest and fastest integrated coherent receiver CPRV422xA enabling 64 Gbaud coherent transmission systems. When being introduced this product allows systems customers to thoroughly test new platform developments using the latest DSP components. Finisar's new photoreceiver is compliant to the OIF-standardized micro-ICR footprint and provides 40 GHz of electrical bandwidth.

Finisar
Reuchlinstr. 10-11
10553 Berlin
Germany
Phone **+49 30-726 113-500**
Fax **+49 30-726 113-800**
Mail **berlin-contact@finisar.com**
Web **www.finisar.com**

INNOLITE
TAILORED MOLDS AND OPTICS

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

We offer leading edge solutions for center turning of mounted 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 configuration and manufacture of tailored ultraprecise molds for your plastic injection molding or hot embossing process. Upon request, we are also happy to produce small series for you.

Our broad spectrum of technologies in the field of optics production allows us to offer an efficiently manufacturable and cost-effective solution for your product from a single source.

Integrated in a network of cooperation partners in optics production, we are able to bring a wealth of experience to bear on your project while leaving room for innovative solutions. Flexibility for us means tailoring our procedures to your requirements, so that time and costs can be optimized while achieving the highest level of quality.

With our company's headquarter at the Innovation Center Digital Photonic Production, a part of the Photonics Cluster at the RWTH Aachen, we have access to the latest technology in the fields of machine and process development for optics production.

Our ongoing efforts to optimize the interplay between design, material, process and final function means that you receive the best possible solution for your technical production needs.

Fig. 1: ILCentric- Center turning of mounted lenses.

Fig. 2: IL600 Ultra-precision machining center.

Based on years of practical experience in the field of diamond machining, Innolite develops and distributes ultraprecision 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. Our specialty is the ILCentric an unique high performance center turning machine for high efficiency production of mounted lenses.

Innolite`s 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.

The use of state-of-the-art clamping systems means that ultraprecision and productivity no longer have to be mutually exclusive. The ability to assemble during machine running time, workpiece 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 ultraprecision machines, regardless of make.

Innolite GmbH
Campus-Boulevard 79
52074 Aachen
Germany
Phone +49 241-475708-0
Fax +49 241-475708-99
Mail info@innolite.de
Web www.innolite.de

Metal Optics – Ultra-precision Machining Centers – Machine Components

Tailor-made ultra-precision machine building and manufacturing of metallic optical components are the strong core business of LT Ultra. With more than 20 years of experience in ultra precision machining today the company is a competence center for multi-axis diamond machining.

The scope of metal optics ranges from injection molds for small lenses to automotive lights, from bar-code readers for logistic facilities to components for spectral analysis applications or components for particle accelerators – all over the world LT Ultra products and solutions secure the commercial success of our clients.

Our machine portfolio provides entire UP machines as well as key components like ultra-precision rotation stages and linear stages or interferometers. LT Ultra is a pioneer in integration of future-proof periphery and automation into our machines. Such as automatic tool-changers and tool-setting or in-situ measurement devices that allow producing and measuring of the work piece in one setting. Your benefits are unique precision, time saving and security of investment. Get your machine solution tailored specifically to your requirements. The unparalleled manufacturing depth guarantees highest reliability and contemporary pricing.

As a privately owned company, LT Ultra cooperates with its customers on a long-term relationship. Our experienced experts provide intensive consulting and a close cooperation from the beginning.

ULTRA-PRECISION MACHINES

LT Ultra has a continuous portfolio from UP-turning and milling machines, to large embossing roller turning machines

- UP-turning, -milling, -planing, -grinding, -micro structuring, -engraving
- Extreme contour accuracy and surface quality
- Bearing systems free of stick-slip for increments <<10nm
- Range of standard machines
- Customized machines or even built from scratch according to your needs

UP milling machine MMC 900H with full automatic tool changer, online process surveillance and temperature control system

- Accessories that range from different spindles to fast tool axes or from automatic tool changers to in-situ measurement devices

METAL OPTICS

LT Ultra produces metal optics on self-developed machines

- Full range from flat mirrors to free-form surfaces, molds or structured surfaces
- Highest precision of parts regarding contours, roughness, surface quality
- Outstanding price-performance-ratio
- From single part to mass production
- Fast delivery

Metal optic of a particle accelerator made of copper

LT ULTRA
OUR PROFESSION IS PRECISION

LT Ultra-Precision Technology GmbH
Aftholderberg, Wiesenstr. 9
88634 Herdwangen-Schönach
Germany
Phone +49 7552-40599-0
Fax +49 7552-40599-50
Mail info@lt-ultra.com
Web www.lt-ultra.com

Nanoscribe: High-Precision 3D Printing

Nanoscribe is market- and technology leader for 3D printers on the nano-, micro-, and mesoscale. The state-of-the art Photonic Professional GT systems allow additive manufacturing and maskless lithography in one device. Based on the technique of two-photon polymerization, they offer the highest resolution known in 3D fabrication, as well as submicron feature sizes.

When common additive manufacturing technologies like stereolithography reach their limitations, these 3D printers reveal their full potential, providing a 100x higher resolution and smaller features sizes.

Greatest Flexibility

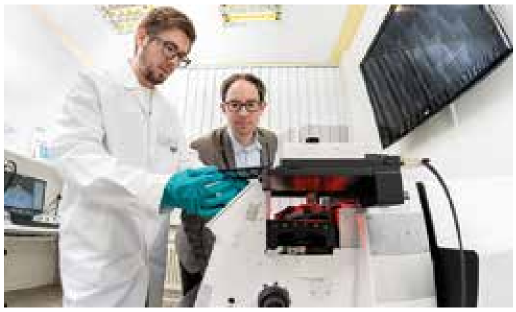
Previously unavailable design freedom and structural heights far beyond grey scale lithography guarantee the best solutions and make them an unknown tool for scientific as well as industrial customers. In combination with a user-friendly software package, the system is best embedded along the 3D printing workflow and offers a high degree of automation. It allows both additive and subtractive manufacturing of photosensitive polymers on a broad range of substrates. Subsequent processes, such as electroplating and single or double inversion using ALD and CVD, allow the transfer of polymer templates into different materials (e.g., gold, titanium dioxide, and silicon). Nanoscribe's portfolio is complemented by tailor-made photoresists and process solutions.

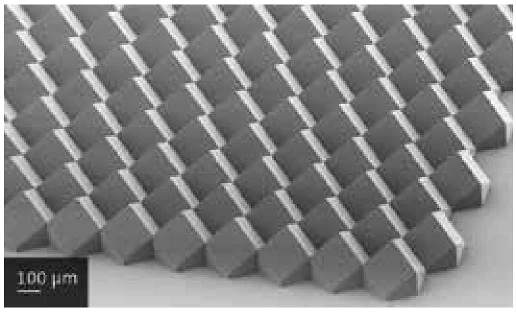
Applications in Photonics and Micro-Optics

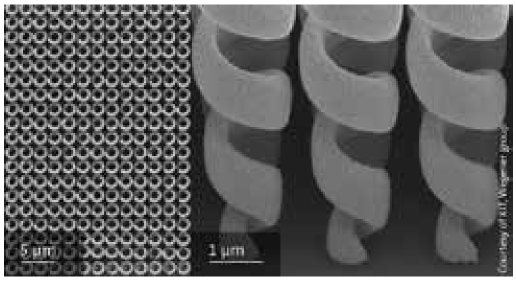
Photonic Professional GT systems are drivers of innovation for numerous key technologies. They are used for a broad range of applications, such as:

- Micro-optics
- Wafer level optics
- Plasmonics
- Photonic crystals
- Photonic metamaterials
- Optical interconnects
- Optical sensors

As of today, Nanoscribe´s disruptive 3D printers are successfully used in more than 30 countries worldwide as the novel standard for microfabrication. A broad array of honors and awards, such as the 2014 Prism Award or 2015 WTN Award as well as Nanoscribe's finalist position for the Deutscher Gründerpreis 2015 underscore the extraordinary performance and significance of this expanding medium-sized company. In 2007 Nanoscribe was founded as a spin-off from the Karlsruhe Institute of Technology (KIT).







Nanoscribe GmbH
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
Germany
Phone +49 721-981-980-0
Fax +49 721-981-980-130
Mail info@nanoscribe.com
Web www.nanoscribe.com

OWIS GmbH – 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® belong 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 or own employees. In Germany, Austria, Denmark and in the Benelux Countries distribution is made by the own sales force. Individual solutions are also worked upon with the customers on-site. Customers from universities, laboratories and industry enterprises appreciate OWIS® because of their high level of competence and reliability as well as the exemplary quality and 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
79219 Staufen i. Br.
Germany
Phone +49 7633 95 04 - 0
Fax +49 7633 95 04 - 440
Mail info@owis.eu
Web www.owis.eu/mobile.owis.eu

High-Speed Microscopy for Quality Control

Piezo Drives in the Real-Time Autofocus System:

A great number of large-surface objects must be examined during quality control for tiny details. Because of the high degree of miniaturization, the need for microscopic test processes in the semiconductor and electronics production is significant. Other areas such as biotechnology or pharmacy, have similar requirements. However, particularly when high resolution is necessary, conventional microscopy processes cannot keep pace with the speed of the automation technology, that is usual today. Thanks to new high-throughput microscopy systems with piezo actuators, that has now changed.

For large samples such as wafers, printed circuit boards and microwell plates, high magnification microscopic image recording often takes too long. Then again, because high throughput is necessary for industrial quality assurance, many do without 100%-testing and are satisfied with random inspection of just a few selected places (Fig. 1). The Fraunhofer Institute for Production Technology IPT has developed a new image-recording process that allows large-surface objects to be completely microscoped within seconds.

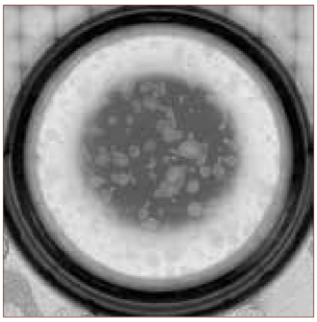


Fig. 1: The process of high-magnification microscopic image recording of wafers (a) or microwell plates (b) often took too long. That has now changed thanks to new high-speed microscopy. Image: Fraunhofer IPT

On-the-Fly Measuring For High Frame Rates

During image recording, the stage moves the object continuously at a constant velocity. This allows the sample to be digitized at high frame rates. Because the object is illuminated by a flash, the image is also free of motion blur. The time-optimized scanning process is combined with real-time data handling and image-processing steps.

Piezo Actuators and their Properties

Piezo-based drive systems take care of these tasks (Fig. 2). With a travel range of approximately 500 µm, they are well-suited to autofocus applications.

The PIFOC-Z drives from PI (Physik Instrumente) used by the Fraunhofer IPT offer the best solution for such applications.

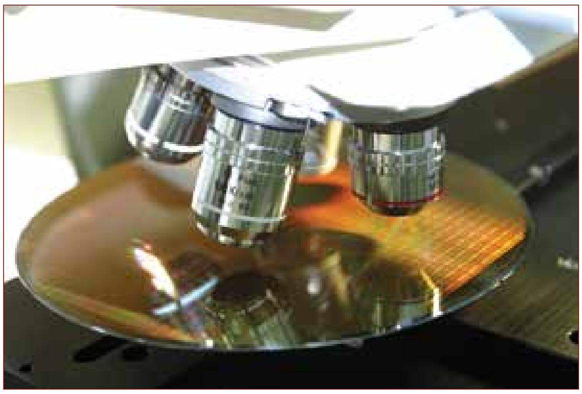


Fig. 2: It is possible to make the PIFOC-Z drives very small and stiff. Response times are short and, thanks to excellent guiding, precision positioning is possible even over comparatively large travel ranges to 100 or even 400 µm. (Image: PI)

It is possible to make them very small and stiff. Therefore, their response times are short and, thanks to the stable guiding, precision positioning is possible even over comparatively large travel ranges up to 500 µm. The zero-play and high-precision flexure guide ensures high focus stability. Fine positioning is therefore possible in a range of less than a nanometer.

On-the-Fly Measuring For High Frame Rates

For control, the IPT uses an E-709 digital controller with linearization algorithms, which can simply be connected to the overall system via an analog interface. The QuickLock adapter for the drives also allows easy integration. This opens up a wide range of completely new possibilities for microscopy under industrial conditions; Piezo drives have contributed to this.

PI

Physik Instrumente (PI)
GmbH & Co. KG
Auf der Roemerstrasse 1
76228 Karlsruhe
Germany
Phone +49 721-4846-0
Fax +49 721-4846-1019
Mail info@pi.ws
Web www.pi.ws

Your Experts for Light Measurement Solutions

Instrument Systems
KONICA MINOLTA Group

Light is measured more often than you would think. Our measuring instruments are indispensable for LED and lamp manufacturers, producers of entertainment electronics, in the automotive and aviation industries as well as in research and development.

For many years we have been actively involved in standardization organizations such as DIN and CIE, and we cooperate with the leading metrology institutes. As a subsidiary of Konica Minolta we have a strong global network at our disposal, and at the same time benefit from the flexibility of a successful medium-sized enterprise.

The spectrometer – crucial element of a good measurement system

All our measurement solutions are based on our widely recognized CAS 140 series of spectroradiometers which have already established themselves as reference systems.
The CAS 140CT combines high accuracy with a robust design and simple operation. The centerpiece is a Crossed-Czerny-Turner spectrograph incorporating a high-end, back-illuminated CCD detector. The spectrometer design thus effectively reduces stray light, resulting in a significantly improved dynamic range and measurement accuracy.

Spectroradiometry and photometry

Whether for measurement of the solar spectrum or an energy-saving lamp, our spectroradiometers determine illuminance and radiant power over a wide spectral range from UV to IR.

Measurement technology for automotive lighting

Our Optronik product line includes turnkey solutions and photometric laboratory equipment for automotive, traffic and aerospace applications.

LED measurement

LEDs and OLEDs are very test-intensive products. Our solutions for the determination of luminous flux, luminous intensity, color coordinates and spatial radiation properties are ideal for measurements in the laboratory and fast tests in production.

Solid-state lighting measurement systems

New standards require comprehensive optical characterization of solid-state lighting products. Instrument Systems provides powerful and compact goniophotometers for development and production, as well as large and small integrating spheres with diameters of up to 2 m.

Display measurement

For testing displays we offer high-precision imaging photometers and colorimeters, as well as goniometric measurement systems. All parameters, e.g. luminance, homogeneity, contrast and color, are determined with a high degree of precision.

We bring quality to light

Instrument Systems provides its customers with innovation, quality and reliability. Our hallmarks are customer focus and professional consulting.

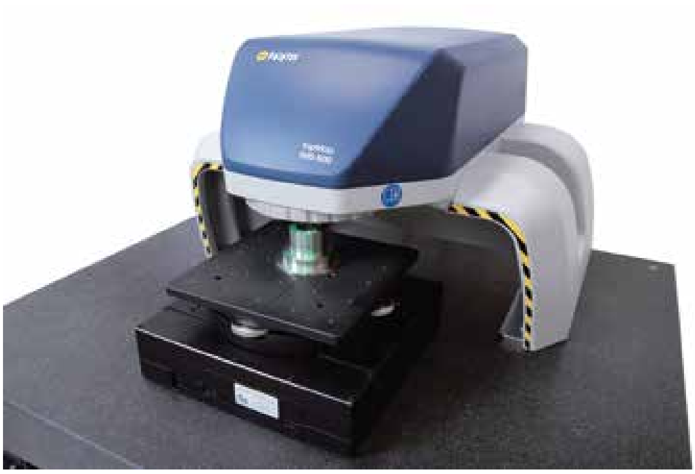
Instrument Systems GmbH
Neumarkter Str. 83
81673 München
Germany
Phone +49 89-45 49 43-0
Fax +49 89-45 49 43-11
Mail info@instrumentsystems.com
Web www.instrumentsystems.com

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 50 years.The commitment to supplying the most precise and reliable optical instruments and sensors available for non-contact measurement, sets Polytec apart from the competition as the gold standard in vibrometer and velocimeter systems.

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 state of the art for non-contact vibration measurement. No matter what your measurement need is, 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. Latest advancements allow the multi-point capturing of non-repeatable, transient phenomena.

3D Surface Profiling

Polytec is addressing the surface metrology market with innovative, high-precision 3D profilometer technologys that work 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, their large field of view together with nanometer resolution, they are ideal tools for determining roughness, 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 red-hot steel. Polytec's LSV systems are designed to perform continuously in harsh environments. The LSV is easily interfaced with your process through its digital or analog interfaces.

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

Customer-specific Tool Configuration for Thin Film Measurements

The new SENTECH spectroscopic ellipsometer SENresearch 4.0

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 offers tools for plasma etching, plasma enhanced chemical vapor deposition, and atomic layer deposition. Clusters of these tools are provided for complex R&D and industrial applications. SENTECH provides innovative solutions for non-contact, non-invasive optical characterization using ellipsometry and reflectometry.

SENTECH focusses on developing and selling high quality optical instruments, especially spectroscopic ellipsometers. Thickness and optical constantans of thin films and layer stacks can be measured. Further, the crystallinity, the anisotropy, the composition, the non-uniformity, and the surface roughness of materials and films as well as interfaces can be analyzed by this method. The tools are perfectly suited for research and development and for industrial use.

Customer-specific options and accessories

Every individual **SENresearch 4.0** spectroscopic ellipsometer is a customer-specific configuration of spectral range, options and field upgradable accessories. The ellipsometers can be configured for standard and advanced applications. Examples are the measurement of semiconducting and dielectric films, nanocomposites and nanolaminates, the analysis of anisotropic materials, 2D & 3D periodic structures. Fast kinetic measurements are featured as well. Optical models and measurement recipes are provided for a large variety of applications.

Spectroscopic ellipsometer SENresearch 4.0 with microspot option

Widest spectral range and highest spectral resolution

The **SENresearch 4.0** spectroscopic ellipsometer covers the widest spectral range from 190 nm (deep UV) to 3,500 nm (NIR). High spectral resolution is offered to analyze even thick films using FTIR ellipsometry.

No moving parts with SSA principle

There are no moving optical parts during data acquisition for best measurement results. The **Step Scan Analyzer (SSA)** principle is a unique feature of the **SENresearch 4.0** spectroscopic ellipsometer.

Full Mueller matrix by innovative 2C design

The extension of the SSA principle by the innovative 2C design allows measuring the full Mueller matrix. The 2C design is a field upgradable and cost-effective accessory.

SpectraRay/4 comprehensive ellipsometry software

The **SpectraRay/4** is the full-featured software package for advanced material analysis. **SpectraRay/4** comprises the **Interactive Mode** for research with guided graphical user interface and the **Recipe Mode** for routine applications.

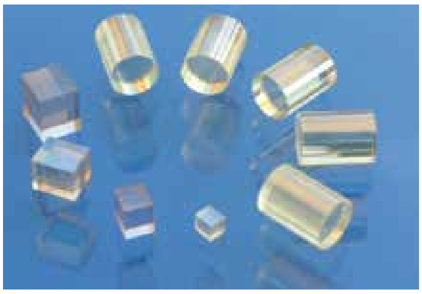
SENTECH Gesellschaft für Sensortechnik mbH
Konrad-Zuse-Bogen 13
82152 Krailing
Germany
Phone +49 89-8979607-0
Fax +49 89-8979607-22
Mail sales@sentech.de
Web www.sentech-sales.de

SENTECH Instruments GmbH
Schwarzschildstrasse 2
12489 Berlin
Germany
Phone +49 30-6392-5520
Fax +49 30-6392-5522
Mail info@sentech.de
Web www.sentech.com

CRYSTAL GmbH – Your Partner for Optics and Crystals

We know about crystals..

...and we have been doing so for over 25 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
- **Subcontracting of electro-optical assemblies**
  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
12459 Berlin
Germany
Phone +49 30-53 04 25 00
Fax +49 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.

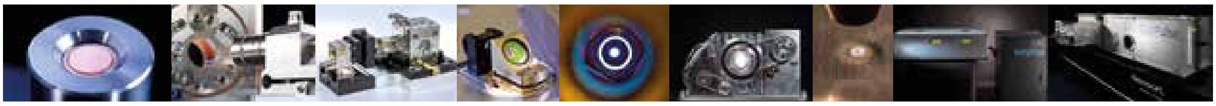
Located in Berlin, Germany, CryLaS serves customers in more than 35 countries worldwide. In addition to the experienced and technically capable direct sales and support team, CryLaS maintains a sales office in the US, and works with distributors in Asia and Europe.

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

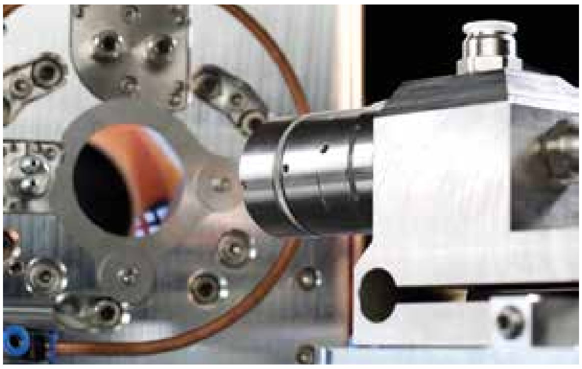
Thin Disk Laser Technology in Downtown Stuttgart

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, TDM 10 and TDM 30 (see figure) allow for maximum pump powers of 50 W, 1 kW, 2 kW, 10 kW and 30 kW, respectively, for one single disk.

An example is our modular 50 W – 120 W laser system VaryDisk FEMTO 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. The VaryDisk system 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 to kW level. Achieved values are 1.4 kW with 2 ps pulse durations at 1 MHz repetition rate, as well as 670 W at 2 kHz, compressible to 3 ps.

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.

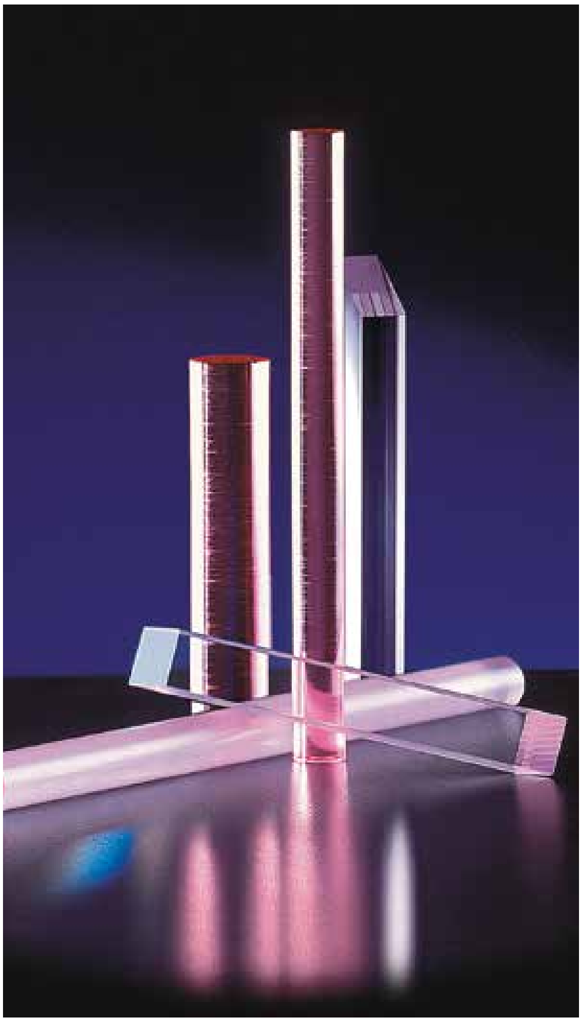
Furthermore, for material processing D+G offers a Helical Drilling Optics (HDO), which allows to drill precise holes with diameters in the range of 10 µm – 400 µm and an adjustable taper in the range of ±5°.

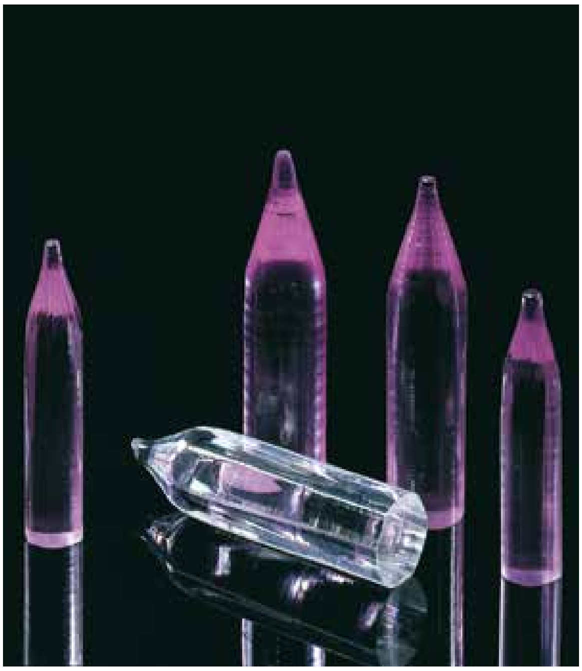
Dausinger + Giesen GmbH
Rotebühlstraße 87
70178 Stuttgart
Germany
Phone **+49 711-907060-550**
Fax **+49 711-907060-99**
Mail **info@dausinger-giesen.de**
Web **www.dausinger-giesen.de**

HAM PRÄZISION

For 30 years, Kristall-Technik Andreas Maier GmbH, headquartered in Schwendi-Hörenhausen, Germany, has been manufacturing components for solid-state laser systems. We are always the right contact when it comes to prototypes, zero series and large series products. We realize individual customer wishes through innovation and creativity. We have a wide range of company-specific possibilities, which enable us to offer an international service around the precision and laser optics to the different branches of industry. Our product range includes:

- Production of new crystals and crystal repair
- Pumping chambers
- Flowplates and flowtubes
- Sapphire tips for medical technology
- Mirror, lenses and protective glasses
- Infrared screens
- Processing of optical glasses
  and various hard materials





KRISTALL-TECHNOLOGIE
ANDREAS MAIER GMBH
Dr. Norbert Michel
88477 Schwendi - Hörenhausen
Germany
Phone +49 7347-61 260
Fax +49 7347-61 207
Mobile +49 152 226 244 22
Mail norbert.michel@ham-tools.com
Web www.laser-crystals.info

Laserline – The Benchmark in the World of Diode Lasers

Laserline is one of the pioneers in diode laser technology, and played a significant role in achieving a breakthrough with this laser type. Founded in 1997, the company grew within only a few years to becoming an international leading developer and manufacturer of diode lasers for industrial applications. As of today, about 4,000 Laserline diode lasers have been delivered worldwide. Laserline currently employs 260 people and has international subsidiaries on the American continent (USA, Brazil) and in Asia (Japan, China, South Korea) as well as sales partners in Europe (France, Italy, Great Britain) and in the Asia-Pacific region (India, Taiwan, Australia). The German company is focused on sustained growth, and by setting up its headquarters on company premises in Mülheim-Kärlich close to Koblenz, it sets the spatial conditions for future expansion in terms of development and production.

Laserline diode lasers can be found in a wide variety of different sectors and application areas. Typical application areas are classical forms of metal processing, as in welding, brazing, hardening or softening, as well as realization or repair of coatings. Furthermore, Laserline diode lasers have been established for plastic welding and in newer production processes like additive manufacturing (metal 3D print) or welding of fiber composites. Users can be found mainly in the automotive industry, engineering, as well as tool and mold-making. In aerospace and heavy industry, Laserline diode lasers are also in use.

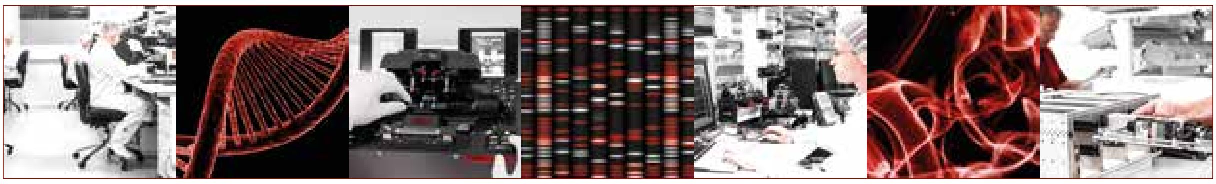
The power range of Laserline diode lasers reaches well into the multi-kilowatt area. As today's standard, lasers with up to 25 kW power are available; in test runs, 50 kW has already been realized. The exceptionally high wall-plug efficiency of almost 50 percent is groundbreaking. For applications with high demands for focusability, diode lasers with

a beam converter have been developed that offer beam qualities from 8 to 4 mm · mrad. Laserline diode lasers are both durable and low-maintenance, and are characterized by a compact and mobile design. This is possible because of the innovative Laserline diode cooling technique which makes flexible application scenarios possible. Furthermore, Laserline offers diode lasers as 19-inch rack-mount and customized laser designs. At its own application lab, industry specific solutions are developed, possibly realized as prototypes, and tested comprehensively. Additional components like processing optics, scanners, beam switches and monitoring systems round out the company's portfolio. Training, service and maintenance contracts are offered to operators. In the case of malfunction, a 24/7 service hotline and teleservice with remote diagnosis are available.

Laserline GmbH
Fraunhofer Straße
56218 Mülheim-Kärlich
Germany
Phone +49 2630-964-0
Fax +49 2630-964-1018
Mail info@laserline.de
Web www.laserline.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
07745 Jena
Germany
Phone +49 3641-2944-0
Mail sales@lasos.com
Web www.lasos.com

Omicron-Laserage Laserprodukte GmbH

Flexible Lasers and LED Light Sources for Industry and Science

Omicron develops and produces innovative laser systems and LED light sources and is one of the leading manufacturers for demanding applications in biotechnology, microscopy, microlithography, medicine and many more.

Innovative Products

LuxX+® / PhoxX+® : Ultra Compact and High Speed

The lasers of the LuxX+ and PhoxX+ series are compact single mode diode lasers. With fast, direct digital modulation capability of >250MHz and analogue power modulation >3 MHz as well as fast electronic shutter function with full modulation depth >500 kHz, the LuxX+ lasers have got unique modulation speeds. The PhoxX+ lasers offer full ON/OFF (infinite modulation depths) >180MHz digital modulation bandwidth. The lasers can be modulated with >25MHz analogue intensity modulation.The LuxX+ and PhoxX+ lasers are available in more than 30 different wavelengths in the range of 375nm to 1550nm with an output power of up to 500mW. Various input signals like differential modulation signals allow easy integration into existing or future customer's designs.

Multi Wavelengths Solutions

Single mode diode lasers

BrixX ps® Ultrafast Picosecond Pulsed Diode Lasers

With the innovative laser series "BrixX ps" Omicron for the first time presents universal diode lasers, which can be pulsed in the picosecond range, as well as being operated in "continuous wave" (CW) and modulated mode. The compact laser modules can emit ultrashort pulses down to 50 picoseconds. CW operation is possible with up to 1MHz analogue modulation and an electronic shutter function which can switch the emission on and off at a bandwidth of more than 150kHz. The light output can be free-space or fibre-coupled. In pulsed mode the repetition rate can either be triggered by an external synchronization signal, or by the internal, programmable frequency generator with up to 100MHz. Diodes with up to 500mW optical output power and wavelengths between 375 and 2300nm can be used in the "BrixX ps" systems.

SOLE, LightHUB, LedHUB – Flexible Multi Wavelength Solutions

The SOLE® laser light engines and LightHUB® compact laser beam combiners meet today´s needs in biotech and microscopic applications, they combine up to six wavelengths of diode and DPSS lasers. 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. Where the SOLE® laser light engines mainly address end-users, the LightHUB® compact beam combiners are very attractive for OEM integration. The customer can choose from over 30 different wavelengths in the range of 355 to 2090nm. Various power levels of up to 1.000mW per laser line are available.

The Omicron LedHUB® is a high power LED light source for biotech, industrial and analytical applications. With up to 6 different wavelengths between 340 and 940nm it can be used in applications like widefield microscopy, optogenetics, chemical analysis, forensics and many more. The modular principle of the LedHUB® provides the possibility to start with only one or two wavelengths initially and user-upgradeability by further wavelengths at a later stage. The capability of fast switching between the wavelengths and high speed analogue modulation of the intensity is a key feature for demanding applications.

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

PHOTON ENERGY

PHOTON ENERGY GmbH is active in the field of photonics for more than 25 years as supplier for laser sources and laser marking systems. It's business activities comprise two segments:

- development and production of laser sources
- development and production of complete laser marking machines

Laser Sources

PHOTON ENERGY manufactures:

- q-switched Nd:YAG and Nd:Vanadate lasers
- ultra short pulsed, mode-locked Nd:Vanadate lasers.

The main application for the lasers is precision micro-machining and materials processing: Cutting, drilling, marking, structuring of almost all materials including transparent materials. The laser stand out due to:

- compactness
- optical performance
- robustness and stability
- ease of integration

Laser Marking Machines

PHOTON ENERGY offers complete laser marking solutions from small table top systems to larger workstations for integration into production lines or as stand-alone machines. The machines rely on PHOTON ENERGY's proprietary laser marking software as well as its own laser technology. Both enables the company to provide highly customized solutions for various applications. Customization does not only refer to the hardware configuration and the laser marking process, but also to the software which can be integrated with the customer's ERP-system to enable complete production control.

- Intuitive use
- reliability
- customization

guarantee the company's ongoing success.

PHOTON ENERGY originated from NWL Lasertechnologie has more than 25 years of experience in the field of lasers and laser marking. The company is ISO 9001:2008 and ISO 13485:2001 certified and has a world wide sales and service network.

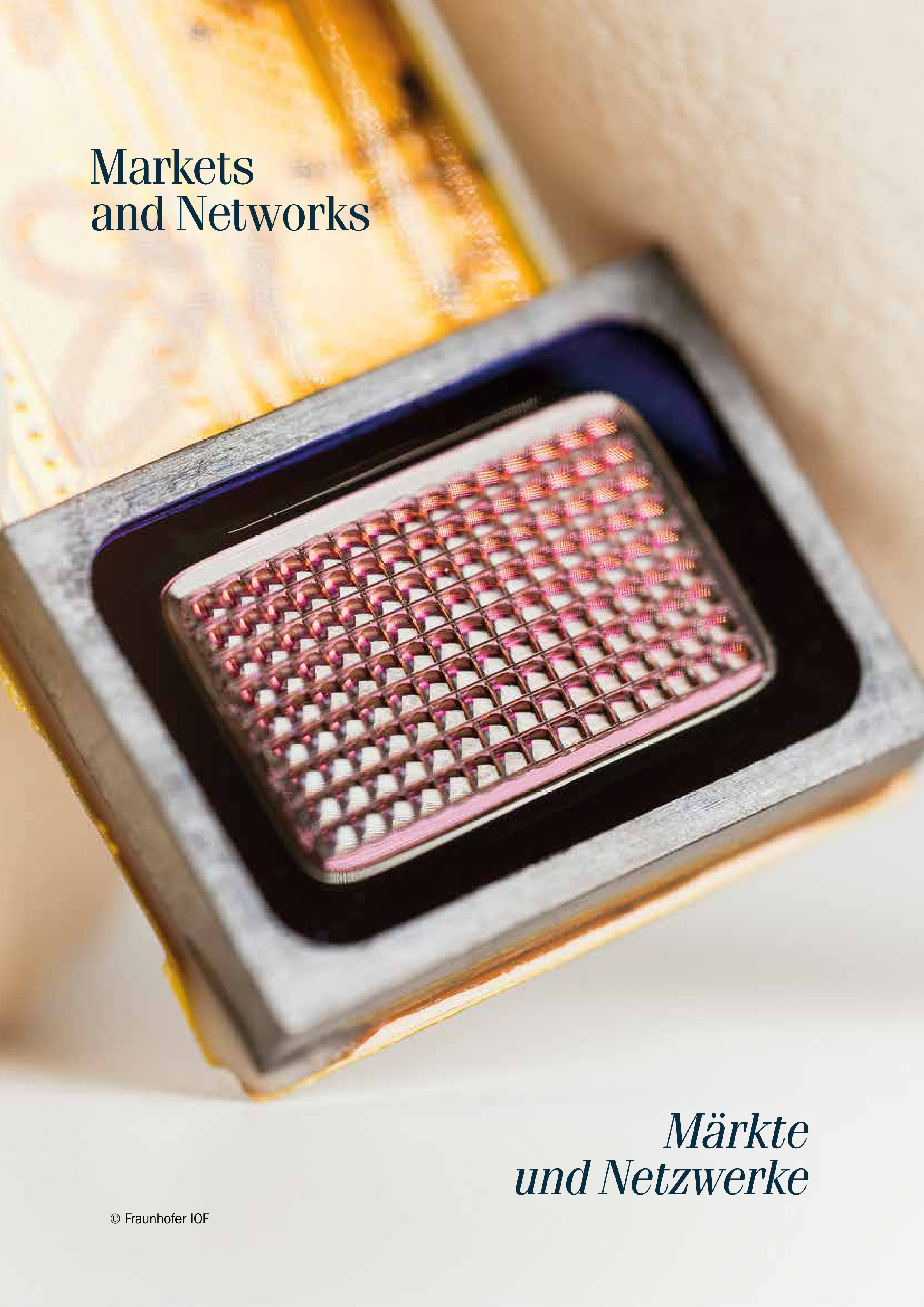
PHOTON ENERGY is a privately owned SME business located in metropolitan region of Nuremberg, in the southern part of Germany, profiting from technology knowledge available in this region through universities and leading

companies like Siemens or Alcatel-Lucent.

The company's latest success story became complete workstations for black-marking of surgical instruments. PHOTON ENERGY's technology differs substantially from conventional laser marking technologies. It's markings are based on special nano-structures providing excellent contrast and perfect protection against corrosion and fading during passivation - and sterilization - processes.

PHOTON ENERGY GmbH
Bräunleinsberg 10
91242 Ottensoos
Germany
Phone +49 9123-99034-0
Fax +49 9123-99034-22
Mail info@photon-energy.de
Web www.photon-energy.de

Markets and Networks



Märkte und Netzwerke

INAM – a New Network for Functional Materials – Providing a Platform of Exchange, Shared Infrastructure and Substantive Cooperation

The Innovation Network for Advanced Materials (INAM) has been launched in 2016 and already comprises 14 members like Osram, Humboldt-University Berlin, IRIS Adlershof, Fab Lab Berlin, Humboldt Innovation, Certi, Ledvance and start-ups like Inuru.

INAM supports the development of innovative and marketable products, which are based on functional materials applied in sensors, wearables, lighting technology, optoelectronic components or photovoltaics etc.

The Advanced Materials Competition (AdMaCom)

INAM's first big international activity was a 6-week accelerator program from 28th August to 10th October with developing concepts for innovative products and solutions. The teams – mostly scientists, engineers and startup entrepreneurs – visited over 75 local institutes and companies and received a weekly mentoring by big players such as Trumpf, LG, Specs, Henkel, Imperial College (UK) or Ledvance. This ensured an extensive exchange of ideas on potential collaborations and feedback. 15 Start-ups from over 4 different countries, whereas five travelled the long way from Brazil, proposed their business idea towards potential investors and cooperation partners.

AdMaCom finalists. Source: © Berlin Partner / INAM

The first strategic partnership that has evolved from INAM is between the Berlin based start-up volatiles lighting and Ledvance, a global player in the lighting industry. The start-up volatiles, specialised in innovative surface lighting modules, concentrates on the development of the software. Whereas Ledvance, pushes the processing of the hardware and resumes production.

„We just signed the cooperation with the Start-up Volatiles. Thus, we give an attractive product a chance in the market, ensure a young innovative company its future, open up a chance of development for Ledvance in Smart-Home-Business and secure employment in the Berlin factory." Peter Wetzel, plant manager at Ledvance.

AdMaCom Final:Jonas Pauly (INAM); Florian Nübling (volatiles), Lars Stühlen (Ledvance), state secretary SenWTF Dr. Hans Reckers (left to right). Source: © Berlin Partner / INAM

The Photonics Cluster in the Start-up Hub Berlin-Brandenburg

The capital region Berlin-Brandenburg became one of the globally leading sites for photonics through their diverse range of competencies, the various companies and research institutions. The innovative core of the cluster consists of over 400 technology companies and 36 research institutions with already more than 16,000 high qualified personnel.

With numerous incubators, accelerators and co-working spaces, the city provides optimal conditions for entrepreneurs from around the world. Berlin is Germany's hotspot for founders and venture capital. Entrepreneurs – and also potential entrepreneurs – find exactly the right environment here to implement their business ideas.

You want to shape the future and meet people who already do? Please check out www.inam.berlin.

INAM innovation network for advanced materials

THE GERMAN CAPITAL REGION
excellence in photonics

Gerrit Rössler
Clustermanager Photonics
Berlin Partner for Business and Technology
Phone +49 30-46302-456
E-Mail gerrit.roessler@berlin-partner.de
Web www.photonics-bb.com/en/


LAND
BRANDENBURG
be Berlin
The place to be for photonics
and microsystems technology
You are innovative.
You are growing rapidly.
You are well connected.
Then you are located in the capital region.
Not yet? See what we have to offer!
www.photonics-bb.com

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

Optical technologies are the key enabler for the tremendous technological revolution which is currently shattering our societies. “Big data” which might be translated to German by “Digitalisierung” would not be possible without the numerous ongoing technological breakthroughs and innovations in various fields of optics. Optoelectronic recording and processing technology on the other hand have an enormous impact on optical systems design and performance.

Light serves as an ideal tool for recording, processing, transmission and storage of huge amounts of data. Optical systems are thus the backbone of almost any development in this area. The scientific range of topics which influence optical technologies is similarly broad, ranging from material science, precision mechanical engineering, electronics, lighting and optical engineering to electrodynamics, physical and quantum optics. This highly interdisciplinary nature makes it even more important to organize an application oriented dialog.

Interface between science and industry

Since its foundation in 1923 the German Society of Applied Optics (DGaO) is committed to serve as an interdisciplinary platform for the exchange of applied research and industry in optics and photonics. More than 130 000 employees and an annual turnover of about 30 billion Euros make the optical technologies one of the most important technological areas for 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 research laboratories and universities on the other side. Various working groups and meetings on a national level focus on the most prominent topics like e.g. Biophotonics or optical sensor technologies. Furthermore DGaO promotes concept to provide an interface between science and industry more and more on an international level in cooperation with the OSA and the EOS.

Key role to establish applied and close-to-industry research 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 strong optics and photonics industry in Germany, DGaO plays a key role in establishing applied and close-to-industry research in optics in a European context.

Maintain high level of optics education and further training

Education and further training in the field of the optical engineering and optical technologies are other elements, which become more and more important especially in a European context. DGaO considers itself partner and intermediary between educational institutions and institutions for further training on one side and the needs of the optical industry on the other side. The preservation of the currently high level of optics education and further training opportunities is a great concern of DGaO.

Clean room environment for the assembly of optical metrology systems (courtesy of Qioptiq Photonics GmbH & Co KG)

Transfer of new topics from science to industry

Optics and Photonics in Germany clearly exhibit numerous best practice examples for the successful transfer of new technologies into innovative products in relatively short time. DGaO is devoted to further improve this by connecting people from science and industry. Some examples on innovative technologies and approaches may demonstrate this close link between science and 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

Variety of optical elements featuring spherical and aspherical lenses, mirrors, windows, prisms and more for specialized optical systems (courtesy of Edmund Optics, Germany)

3D printed optical sensor for metrology (courtesy of A. Heinrich, Hochschule Aalen)

Photograph of a highly integrated system for optical tweezing (courtesy of R. Kampmann, Karlsruher Institute of Technology/ TU Ilmenau)

more common in optical instruments covering different fields from consumer illumination optics and highly integrated microsystems up to EUV lithography lenses.

3D printers reach high fabrication precision and allow innovative illumination concepts for precision optical metrology. Ultra short pulse lasers have made two photon microscopy and lithography possible and are gaining growing importance. Frequency combs enable new types of optical measurements in spectroscopy and length measurements with extreme precision.

Micromechanical elements (MEMS), microdisplays and light sources such as LEDs and OLEDs become part of classical optical instruments like microscopes. Tunable optical elements enable innovative new solutions for sensing and imaging.

Promotion of young professionals and DGaO Young Scientist Award

The DGaO is furthermore devoted to the promotion of students, young scientists and professionals by supporting career planning, continuing technical professional training and networking.

The DGaO cordially invites nominations for the DGaO Young Scientis Award which is awarded annually at the Annual Meeting of the DGaO. (Details can be found at www.dgao.de).

Annual Meetings

The Annual Meeting of the DGaO 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 Pentecost. The meeting is accompanied by a trade-show, where companies and organizations are invited to present their products or services.

118th Annual Meeting of the DGaO in Dresden

In 2017 the Annual Meeting of the DGaO will take place in Dresden from June 6th -10th, emphasizing topics such as

- Computational Imaging
- Computer Vision
- Optics for extreme requirements
- New solutions for precision optics
- 3D-Metrology
- Biophotonics
- Optogenetics

Numerous short oral presentations (12 minutes) and poster presentations will be given to stimulate fruitful scientific discussions.

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

Prof. Dr. Stefan Sinzinger
President of the German Society of Applied Optics (DGaO)
Im Wolfsgarten 28
91056 Erlangen
Germany
Phone +49 9131-94 08 920
Mail dgao-sekretariat@dgao.de
Stefan.sinzinger@tu-ilmenau.de
Web www.dgao.de

Publisher / Herausgeber
trias Consult
Johannes Lüders
Crellestraße 31
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

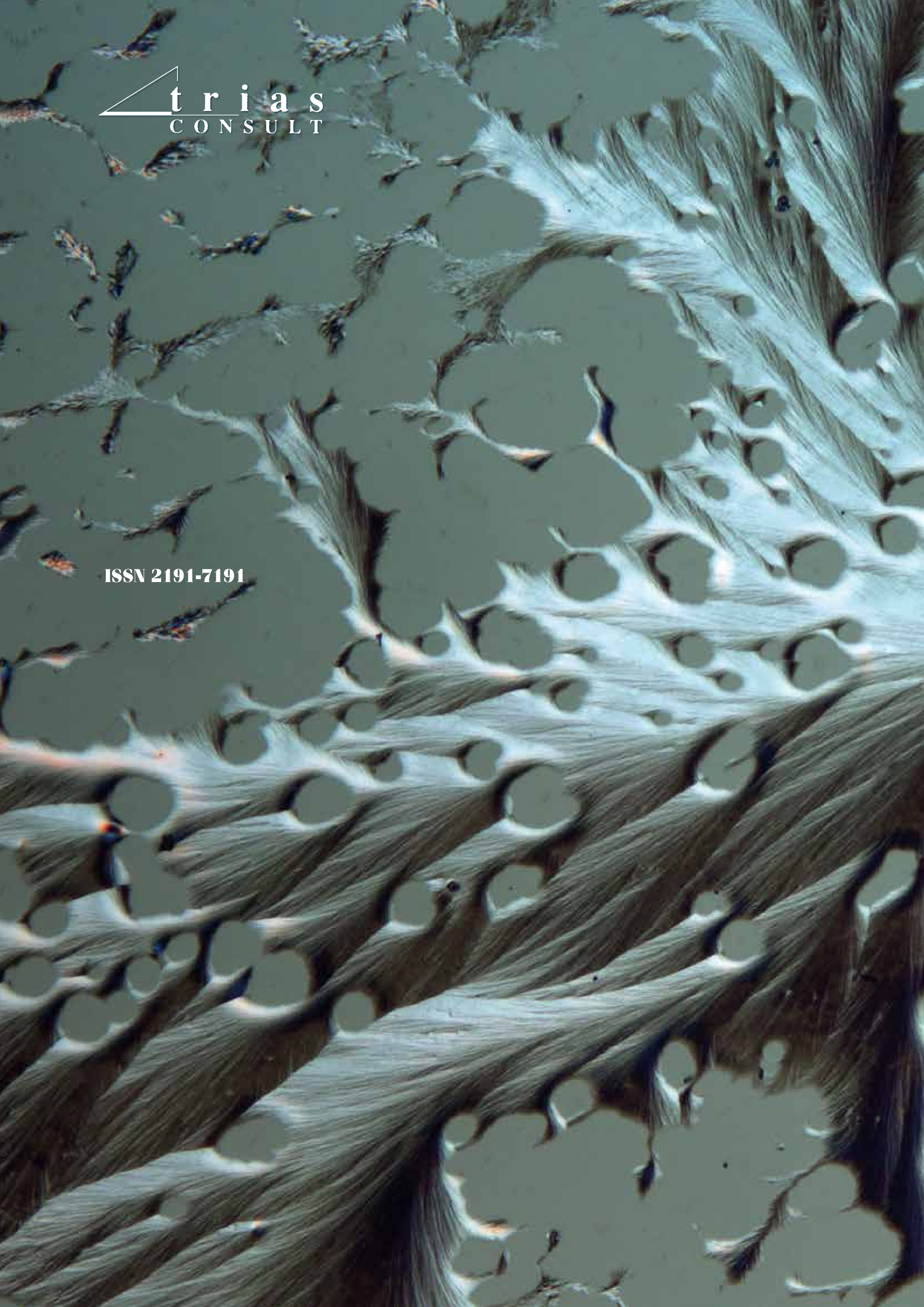
Printing / Druck
GCC Grafisches Centrum Cuno, Calbe
2017, Printed in Germany

ISSN 2191-7191

Photo Credits / *Bildnachweis*

Title Photo / *Titelfoto*
Frank Brückner, Berlin

Page / *Seite*
S 1 Fraunhofer HHI
S 6 Leibniz-IPHT / S. Döring
S 16 TRUMPF
S 56 Fraunhofer IPMS
S 65 SCHOTT
S 87 Fraunhofer IOF



trias
CONSULT

ISSN 2191-7191