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FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

ANNUAL REPORT 2018

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2018

Fraunhofer-Institut für Lasertechnik ILT

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Dear Readers,

»Times change and we change with them«. Ovid formulated this irrevocable truth long before our era. It is certainly no news that we have to change with the times – rapidly and sometimes extremely when we conduct research and aspire to be innovative – if we want to be successful. But how does this change actually work?

In accordance with our nature, we first react to change – this behavior counteracts situations where our equilibrium is disturbed while it also minimizes their force. According to Newton's law »actio equals reactio«, as generalized by Chatelier, larger changes in boundary conditions should lead to even larger changes in the way we think. But this does not correspond to our nature at all! The more experience we have gathered and the more intensive the recipes for success have become anchored in our behavior, the more resistant our system will be to major changes in external boundary conditions. This applies to individuals as well as to organizations.

Children learn quickly because they do not have to alter their complex space of experience; a scientist can maintain this drive through curiosity. An adult »learned« human being has stored his collected experiences in structures, the latter of which hinder a natural reaction that is proportional to the external impulse, in a first approximation. Indeed, change is difficult and we only too gladly ignore the causes for it. To make it possible to be ready for change – especially in the case of major changes – we must now specifically delete experiences in order to give space to new thoughts and appropriate reactions.

Fraunhofer ILT is very well positioned to take on the technological challenges that lie ahead. In addition to working on industrial tasks, we cooperate closely with the chairs of RWTH Aachen University, for example in the Digital Photonic Production DPP Research Campus, to develop new fundamental findings and generate innovative impulses in our laser community. Convince yourself of the quality of our R&D work by reading the numerous project examples in this annual report and do not hesitate to contact us if you are interested. We love short paths of communication and direct dialog.

The year 2019 will see the face of the main person in charge at Fraunhofer ILT change. Today, we don't know whether this will bring major or, initially, minor changes, but it is certain that these changes will provide an opportunity both to test and cultivate the tried and tested and to identify and shape new potential. I wish all employees at the institute, the chairs and the campus of RWTH Aachen University much success, and customers a greater benefit from what we are trying to achieve every day: the creation of new prerequisites for innovations that will help our country and Europe have an even better future.

Cordially,

Prof. Dr. rer. nat. Reinhart Poprawe

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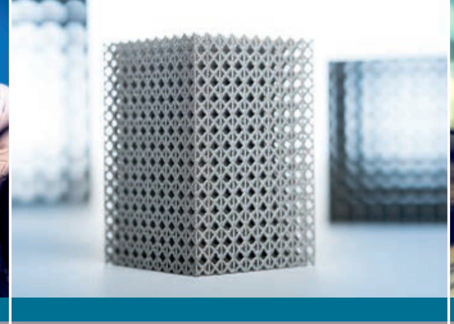

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2018

DECLARATION OF PRINCIPLES

MISSION

We have placed ourselves in a leading position to guide the transfer of laser technology to the industry, world-wide. We constantly expand our expertise and know-how, initiate trends of the future and, thus, decisively contribute to the continuing development of science and technology.

CUSTOMERS

We focus on what our customers need. We place great emphasis on discretion, fairness and partnership in our customer relations. According to the requirements and expectations of our customers, we develop solutions and implement them. We want our customers both to be pleased and pleased to return to us.

OPPORTUNITIES

By concentrating on our core competencies, we expand our knowledge in our networks strategically. We strengthen our network consisting of industrial and institutional partners with complementary services and establish strategic partnerships. We increasingly operate on international markets.

FASCINATION LASER

We are fascinated by the unique properties of laser light and the diversity of applications resulting from them. We are excited by the possibility of setting international standards through leading technological achievements and first-time industrial implementation.

STAFF

Our success is based on the interaction of the individual and the team. Each one of us works independently, creatively and oriented toward a specific goal. All the while, we proceed reliably, with attention to detail and are aware of the need to conserve resources. We place our individual strengths in the team and treat our colleagues with respect and fairness. We work together, across disciplines.

STRENGTHS

Our broad spectrum of resources enables us to offer one-stop solutions. We deliver innovative and cost-effective solutions and offer you R&D, consulting and integration. We solve our customers' tasks in multi-disciplinary teams using diverse and innovative facilities.

MANAGEMENT STYLE

Cooperative, demanding and supportive. Our management style is based on knowing the value of our employees as individuals, of their know-how and commitment. We have our employees formulate targets and make decisions. We place great value in effective communication, goal-oriented and efficient work as well as in making clear decisions.

POSITION

Our expertise extends from developing beam sources, processing and measuring technologies, via applying them all the way to integrating a plant within the customer's production line. We work in a dynamic equilibrium between applied basic research and development. We actively formulate and design research policy goals.

PROFILE OF THE INSTITUTE

SHORT PROFILE

ILT – this abbreviation stands 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 540 employees and more than 19,500 m² of net floor area, 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, labeling as well as surface treatment and micro manufacturing. Process development and systems engineering stand 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, bio-functionalization 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 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 nearby Research Campus »Digital Photonic Production DPP«, companies cooperating with Fraunhofer ILT 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 20 companies already use these advantages. 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.

DQS certified by
DIN EN ISO 9001
Reg.-No.: DE-69572-01

RANGE OF SERVICES

The services of the Fraunhofer Institute for Laser Technology ILT are continually being adapted to the practical requirements of industry and include the solution of manufacturing problems as well as the realization of test series. In detail this means:

- Development of laser beam sources
- Components and systems for beam guiding and forming
- Packaging of optical high power components
- Modeling and simulation of optical components as well as laser processes
- Process development for laser materials processing, laser measurement technology, medical technology and biophotonics
- Process monitoring and control
- Model and test series
- Development, set-up and testing of pilot plants
- Integration of laser technology into already existing production plants or measuring systems
- Development of X-ray, EUV and plasma systems

DIFFERENT WAYS OF COOPERATION

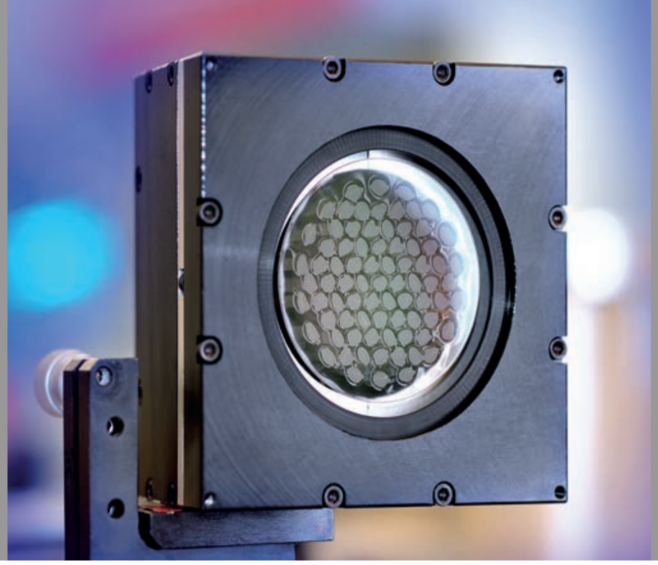
The Fraunhofer Institute for Laser Technology ILT is cooperating with R&D-partners in different ways:

- Realization of bilateral, company specific R&D-projects with and without public support (contract for work and services)
- Participation of companies in public-funded cooperative projects (cofinancing contract)
- Production of test, pilot and prototype series by Fraunhofer ILT to determine the reliability of the process and minimize the starting risk (contract for work and services)
- Companies with subsidiaries at the RWTH Aachen Campus and cooperations by the Research Campus »Digital Photonic Production DPP«

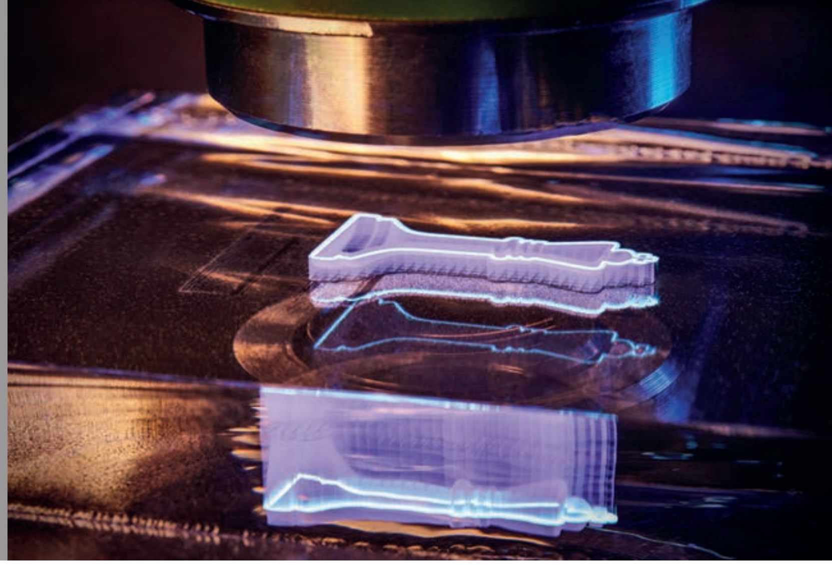
By means of cooperation with other research organizations and specialized companies Fraunhofer ILT offers solutions even in the case of interdisciplinary tasks. A special advantage hereby consists in the direct access to the large resources of the Fraunhofer Society.

HIGHLIGHTS

VCSEL preheating for laser powder bed fusion (LPBF).



EU project »ultraSURFACE«: piezoelectrically deformable mirror (PDM) for high-speed surface finishing.



High-precision and fast production of 3D glass components with tailor-made UKP laser radiation.

R&D HIGHLIGHTS 2018

Finishing surfaces at high speed

In the EU research project »Ultra Dynamic Optical Systems for High Throughput Laser Surface Processing - ultraSURFACE«, Fraunhofer ILT and nine international partners developed two new optics that will enable lasers to polish, coat or structure surfaces ten times faster than before, while at the same time significantly reducing costs.

On the one hand, a piezoelectrically continuously deformable mirror during laser polishing ensures that the laser beam adapts to the constantly changing processing situation with switching times of less than five milliseconds. On the other hand, a diffractive optical element splits the laser beam into a square beam bundle of four partial beams. Each individual beam is adjusted in its position every millisecond so that processing is possible without distortion.

Flexible high-speed cutting of sheet metal ribbons replaces stamping process

Particularly in the areas of hybrid lightweight construction and electromobility, the demands placed on sheet metal processing in terms of flexibility and productivity are constantly growing. Tool-free production with laser technology offers a solution for economically producing sheet metal parts with any variable cutting contours, maximum material and weight savings despite fluctuating and unpredictable batch sizes. Together with Fraunhofer ILT, Honda has replaced the previous punching of steel sheets (measuring up to 1.8 x 4.0 m with a thickness of 0.5 to 2.3 mm) with an extremely fast laser cutting process that operates at speeds of up to 115 m/min at its plant in Yorii, Japan. With the laser cutting system, Honda has achieved an output of 18,700 body parts per day since its introduction in 2015. In a joint project with its partner BILSTEIN GmbH & Co. KG in Hagen, the researchers at Fraunhofer ILT have gone one step further: Here they have made the laser cutting process for flexibly rolled strip material – in which the thickness of the material varies according to the local requirements of the subsequent component – both more flexible and more productive.

Aiming high with VCSEL heating

With laser powder bed fusion (LPBF), stresses can arise in the component generated due to temperature differences between the laser spot and the rest of the component. Depending on the geometry and material, this difference can lead to distortion and cracks in the material. Heating the component from below over the substrate plate is not sufficient to counteract this, especially with higher structures.

As part of the Digital Photonic Production DPP Research Campus, a BMBF funding initiative, experts from Fraunhofer ILT and the RWTH Chair for Technology of Optical Systems TOS are working together with their partner Philips Photonics to develop a setup in which the component is heated from above the powder bed using laser diodes (joint project »DPP Nano«). For this purpose, an array of six vertically emitting laser bars (VCSEL) with a power of 400 W each will be installed in the process chamber. With infrared radiation at 808 nm, this array can heat the component from above to several hundred degrees Celsius during the assembly process. The bars are controlled individually so that sequences of different patterns are also possible. The VCSEL heating reduces the thermal gradient, thus also the stresses, and higher parts can be produced than with conventional process technology.

Laser material deposition with optimized powder gas jet

The supply of the filler material plays a decisive role in systems for laser material deposition (LMD). Scientists at Fraunhofer ILT have developed an inline system for measuring, testing and qualifying the focused LMD powder gas jet. This system enables nozzles to be certified and caustics to be fully characterized. Thanks to the camera and integrated lighting, users can also visualize and monitor processes.

Together with TRUMPF, Fraunhofer ILT developed the machine-supported inline process. The system solution features a camera module on the laser processing head with movable optics and illumination, a laser module for measuring the nozzle, and control electronics. The particle density distribution and caustics of the powder gas jet are, thus, recorded very accurately. For inline measurement of the powder gas jet, the module can be integrated into any TRUMPF-LMD optic.

Additive manufacturing for the automotive industry

Under the coordination of Daimler AG, five companies and two research institutes examined the »Integration of additive manufacturing processes in automotive series production – AutoAdd« as part of the BMBF's »Photonic Process Chains« funding initiative. The focus was on integrating an LPBF process chain (laser powder bed fusion) into the series production environment in order to reduce unit costs.

The BMW Group and Daimler defined requirements for the additive process chain, which TRUMPF and Fraunhofer ILT used to develop various LPBF system and finishing concepts. This resulted in potentially series-capable optical concepts and a modular system architecture. In addition, the project partners analyzed novel, scalably produced materials and used simulation models to design various LPBF plant concepts. Thanks to the AutoAdd results, the entire process chain can be automated and non-productive time reduced. The project team has developed generally applicable key figures for the evaluation of LPBF production systems and identified them for the most common system manufacturers. It is now deemed possible to integrate an economical additive process chain into automotive mass production.

UKP laser radiation – shaped according to customer requirements

Lasers with ultrashort pulses are ideal for precise glass processing. Scientists at Fraunhofer ILT are developing a technology that uses diffractive and refractive optical elements (DOEs and ROEs) for tailor-made shaping of these laser beams. This allows special beam profiles or complex intensity patterns to be generated, whereby the energy of a beam can also be distributed over an entire array of up to 196 similar partial beams. In this way, glass can be processed or cut quickly and with high precision.

Fields of application can be found, for example, in the automotive industry: Together with the LLT chair at RWTH Aachen University and TRUMPF and 4JET Technologies, Fraunhofer ILT is working on head-up display glass for vehicles in the BMBF-funded Digital Photonic Production DPP Research Campus. In the »DPP Femto« project, the customized laser pulses are used to generate micrometer-sized impurities in the glass that reflect LED light at a defined angle, thus making them suitable for future display glasses. Alternatively, predetermined breaking points can be generated for subsequent laser cutting of glass with particularly clean contours, whereby no further post-processing is required.

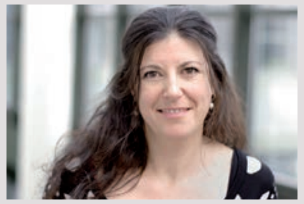
STRUCTURE OF THE INSTITUTE

The 32nd Board of Trustees meeting of Fraunhofer ILT in Aachen.

BOARD OF DIRECTORS

Prof. Reinhart Poprawe
Director

Prof. Peter Loosen
Vice Director



Dr. Vasvija Alagic-Keller MBA
Head of Administration

ADMINISTRATION AND CENTRAL FUNCTIONS

Dr. Vasvija Alagic-Keller MBA
Administration and Infrastructure

Dipl.-Phys. Axel Bauer
Marketing and Communications

Dr. Alexander Drenker
QM Management

Dr. Bruno Weikl
IT Management

COMPETENCE AREAS

Dipl.-Ing. Hans-Dieter Hoffmann
Lasers and Laser Optics

Dr. Arnold Gillner
Ablation and Joining

Prof. Johannes Henrich Schleifenbaum
Additive Manufacturing and Functional Layers

Prof. Reinhard Noll
Measurement Technology and EUV Sources

BOARD AND COMMITTEES

BOARD

The Board of Trustees advises the Fraunhofer-Gesellschaft as well as the Institute's management and supports the links between interest groups and the research activities at the institute. The Board of Trustees during the year under review consisted of:

CHAIRMAN

C. Baasel, Carl Baasel Lasertechnik GmbH

MEMBERS

- Dr. Reinhold E. Achatz, Thyssenkrupp
- Dr. Norbert Arndt, Rolls-Royce plc.
- Dr. Hans Eggers
- Dr. Ulrich Hefter, Rofin-Sinar Laser GmbH
- Dipl.-Ing. Frank Herzog, Concept Laser GmbH
- Dipl.-Ing. Volker Krause, Laserline GmbH
- Dipl.-Ing. Michael Lebrecht, Daimler AG
- Prof. Gerd Marowsky, Laser Laboratorium Göttingen e. V.
- Manfred Nettekoven, Kanzler der RWTH Aachen
- Dr. Joseph Pankert, Philips Photonics GmbH
- Dr. Silke Pflueger
- Prof. René Salathé, ExpertInova AG
- Dr. Torsten Scheller, JENOPTIK Automatisierungstechnik GmbH
- Susanne Schneider-Salomon, Ministerium für Kultur und Wissenschaft
- Dr. Ulrich Steegmüller, OSRAM
- Dr. Klaus Wallmeroth, TRUMPF Laser GmbH + Co. KG

The 33rd Board of Trustees meeting was held on September 12, 2018 at Fraunhofer ILT in Aachen.

DIRECTORS' COMMITTEE ILA

The Directors' Committee advises the Institute's managers and is involved in deciding on research and business policy. The members of this committee are: Prof. R. Poprawe, Prof. P. Loosen, Dr. V. Alagic-Keller MBA, Dipl.-Phys. A. Bauer, Dipl.-Ing. T. Biermann, Dipl.-Phys. Dipl.-Volksw. D. Esser, Dr. A. Gillner, Dipl.-Ing. H.-D. Hoffmann, V. Nazery Goneghany, Prof. R. Noll, Dr. D. Petring, Prof. J. H. Schleifenbaum, Prof. W. Schulz, Dr. B. Weikl, Dr. J. Stollenwerk.

HEALTH AND SAFETY COMMITTEE ASA

The Health and Safety committee is responsable for all aspects of safety and laser safety at Fraunhofer ILT. Members of this committee are: Prof. R. Poprawe, Prof. P. Loosen, Dr. V. Alagic-Keller MBA, M. Brankers, R. Day M.Sc., R. Frömbgen, Dipl.-Ing. (FH) S. Jung, F. Käfer M.Eng., A. Hajdarovic, V. Nazery Goneghany, F. Voigt, Dipl.-Ing. N. Wolf, Dr. R. Keul (works doctor B.A.D), T. Yildirim M.Sc., S. Schoenen M.Eng. (B.A.D Gesundheitsvorsorge und Sicherheitstechnik GmbH).

SCIENCE AND TECHNOLOGY COUNCIL WTR

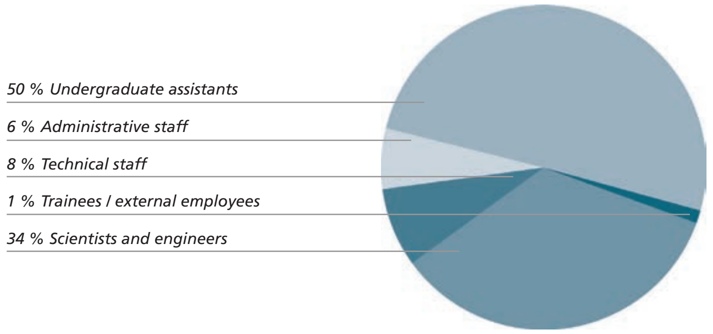
The Fraunhofer-Gesellschaft's Science & Technology Council supports and advises the various bodies of the Fraunhofer-Gesellschaft on scientific and technical issues. The members are the institutes' directors and one representative elected from the science/technology staff per institute.
Members of the Council from Fraunhofer ILT are:
Prof. R. Poprawe, Dipl.-Phys. Dipl.-Volksw. D. Esser.

WORKERS' COUNCIL

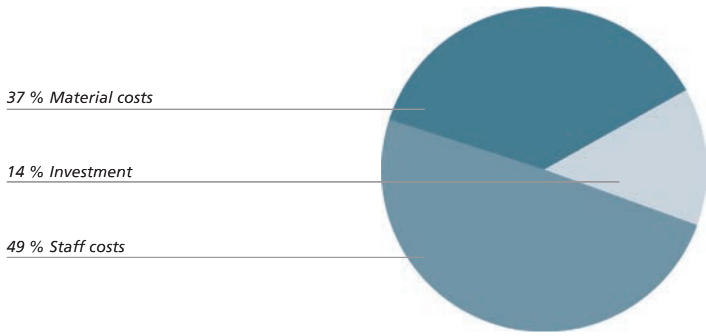
Since March 2003 there is a workers' council at Fraunhofer ILT.

THE INSTITUTE IN FIGURES

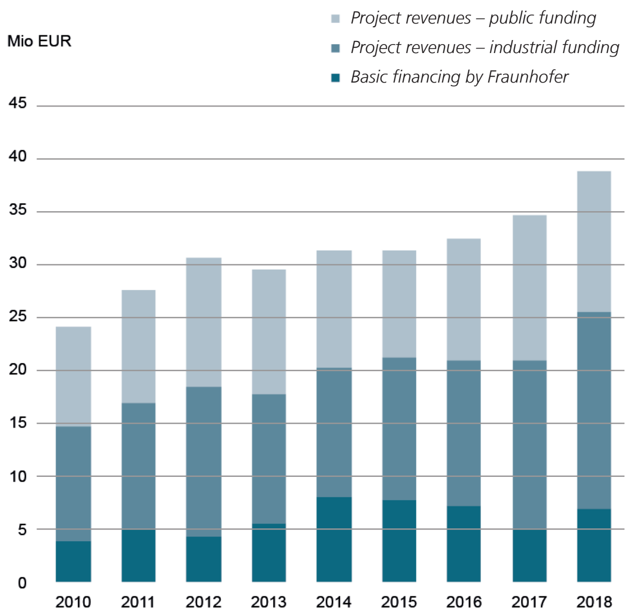
EMPLOYEES 2018	number
Personnel	**264**
- Scientists and engineers	188
- Technical staff	43
- Administrative staff	33
Other employees	**282**
- Undergraduate assistants	275
- External employees	3
- Trainees	4
Total number of employees at Fraunhofer ILT	**546**



EXPENSES 2018	Mill €
- Staff costs	22,0
- Material costs	16,4
Expenses operating budget	**38,4**
Investments	**6,1**



REVENUES 2018	Mill €
- Industrial revenues	18,5
- Additional financing from Federal Government, States and the EU	13,1
- Basic financing from the Fraunhofer-Gesellschaft	6,8
Revenues operating budget	**38,4**
Investment revenues from industry	**0,5**
Fraunhofer industry ρ_{Ind}	**49,3 %**



FACILITIES

The net floor area at the Fraunhofer Institute for Laser Technology ILT amounts to 19,500 m^2.

TECHNICAL INFRASTRUCTURE

The technical infrastructure of the institute includes a mechanical and electronic workshop, a metallurgic laboratory, a photographic laboratory, a laboratory for optical metrology as well as a department for design and construction.

SCIENTIFIC INFRASTRUCTURE

The scientific infrastructure includes a library with international literature, patent and literature data bases as well as programs for calculation of scientific problems and data bases for process documentation.

EQUIPMENT

The equipment of the Fraunhofer Institute for Laser Technology ILT is permanently being adapted to the state-of-the-art. At present, essential components are:

BEAM SOURCES

- CO_2 lasers up to 12 kW
- disc lasers up to 12 kW
- disc lasers with green wavelength
- mutimode fiber lasers up to 6 kW
- singlemode fiber lasers up to 5 kW
- diode laser systems up to 12 kW
- ultra short pulse lasers up to 1 kW with pulse widths in the range of nano-, pico- and femtoseconds
- frequency-multiplied laser in visible spectral range
- excimer lasers
- broadband tunable lasers
- MIR lasers (ps, ns) with average power > 10 W

PLANTS AND PROCESSING SYSTEMS

- three-axis processing stations
- five-axis gantry systems
- robot systems including six-axis articutated robot with tilt and turn table
- commercial engineering and laboratory systems for laser powder bed fusion (LPBF)
- direct-writing and laser-PVD stations
- beam guiding systems
- various powder and wire feed systems for additive manufacturing
- printer for sol-gel-hybrid polymers and nano- to microscale dispersions

SPECIAL LABORATORIES

- clean rooms for assembly of diode and solid state lasers as well as laser optics
- life science laboratory with S1 classification
- laboratory for battery technology

MEASUREMENT AND SENSOR TECHNOLOGY

- devices for process diagnostics and high speed video analysis
- laser spectroscopic systems for the chemical analysis of solid, liquid and gaseous materials
- confocal laser scanning microscopy
- scanning electron microscope
- Shack Hartmann sensor to characterize laser beams and optics
- measurement interferometer and autocollimator to analyze laser optics
- measurement equipment to characterize ultrashort pulse lasers
- equipment for vibration tests
- single photon detector (APD) for NIR lasers
- systems to characterize powder material

HONORS AND PRIZES

Thomas Schopphoven (left) and Gerhard Backes (right) at the Steel Innovation Prize ceremony.

The finalists of the Berthold Leibinger Innovationspreis at the jury meeting on July 13, 2018.

STEEL INNOVATION PRIZE 2018

Steel Innovation Prize to EHLA research team

Every three years, the German steel industry awards the Steel Innovation Prize to innovations that make this material far from a thing of the past. The prize does not only focus on products made of steel, but also on innovative processes such as Extreme High-Speed Laser Material Deposition (EHLA), which was already awarded the Joseph von Fraunhofer Prize in 2017. On June 13, 2018, Thomas Schopphoven and Dr. Andres Gasser from Fraunhofer ILT as well as Gerhard Maria Backes from the Chair for DAP at RWTH Aachen University received the second prize of the Steel Innovation Prize in the category »Steel in Research and Development« for the environmentally friendly laser alternative to chromium(VI) coating.

Best Tutorial Award at the ASME Turbo Expo

Robin Day from the Chair for Digital Additive Production DAP at RWTH Aachen University, Dr. Sascha Gierlings from the Fraunhofer Institute for Production Technology IPT, Dr. Benjamin Döbbeler from WZL at RWTH Aachen University and Dr. David Welling from Makino Milling Machine Co., Ltd. won the Best Tutorial Award in the session »Manufacturing Materials & Metallurgy« at the ASME Turbo Expo in Oslo on June 13, 2018. They presented trend-setting research results from the fields of milling, new manufacturing possibilities by means of eroding as well as additive and networked manufacturing in industry 4.0.

JEC Innovation Award for Fraunhofer ILT

The use of composite materials for »ground transportation« was the focus of the new JEC event »The Future of Composites in Transportation« in Chicago on June 27 and 28, 2018. A highlight of the event, the »Future of Composites in Transportation by JEC Innovation Award« in the »Passenger Car« category was bestowed to Fraunhofer ILT and other partners cooperating in the »HyBriLight« project. Dr. Alexander Olowinsky accepted the award on behalf of the project in Chicago. The prize was awarded for the development and manufacture of a hybrid roof bow based on the original part of a BMW 7 Series vehicle. Weber Fibertech GmbH, Werkzeugbau Siegfried Hofmann GmbH, Fraunhofer LBF, SCANLAB GmbH and the BMW Group were also involved in this development.

Best Presentation Award at LANE 2018

At LANE 2018, Dennis Arntz from the Chair for Laser Technology LLT at RWTH Aachen University took second place in the Best Presentation Award for his lecture on »Quantitative study of melt flow dynamics inside laser cutting kerfs by in-situ high-speed video-diagnostics«.

Springorum Medal and Borchers Badge

The Springorum medal and Borchers badge were bestowed on September 8, 2018 as part of the RWTH graduate festival. Florian Eibl and Johannes Weitenberg (Fraunhofer ILT) were honored with the Borchers badge and Georg Rödler (Fraunhofer ILT) received the Springorum medal.

BERTHOLD LEIBINGER INNOVATIONSPREIS 2018

Berthold Leibinger Innovationspreis 2018 to the EHLA research team

For the development of the »Extreme High-Speed Laser Material Deposition« (EHLA), Thomas Schopphoven and Dr. Andres Gasser from Fraunhofer ILT as well as Gerhard Maria Backes from the Chair of Digital Additive Production DAP at RWTH Aachen University received the first prize of the Berthold Leibinger Stiftung in Ditzingen on September 21, 2018, endowed with 50,000 euros. The Berthold Leibinger Innovationspreis has been awarded every two years since 2000 for outstanding research and development work on the application or generation of laser light and is one of the world's most prestigious awards in the laser industry.

Award at Expo Singapore – Industrial Transformation – Future of Manufacturing Summit

At the Expo Singapore - Industrial Transformation - Future of Manufacturing Summit on October 17, 2018, Dr. Bernd Jungbluth (Fraunhofer ILT), Dr. Claus Schnitzler (AMPHOS GmbH), Peng Penn Loo (Wavelengths Opto-Electronics) and Houkun Liang (A*STAR SIMTech) received an award for their project »Digitized high-power deep-UV, sub-ps laser for additive manufacturing« by the 1st Singapore-Germany Academic Industry (2+2) International Collaboration Grand Call in Advanced Manufacturing.

Student Paper Award at ICALEO 2018

During the closing session of ICALEO 2018 on October 17, 2018 in Orlando, Dennis Arntz and Dennis Haasler from the Chair for Laser Technology LLT at RWTH Aachen University received the Student Paper Award from Prof. Christoph Leyens (Chairman ICALEO). Dennis Arntz won first place for his paper »In-Situ High Speed Diagnosis - A Quantitative Analysis of Melt Flow Dynamics Inside Cutting Kerfs During Laser Fusion Cutting with 1 µm Wavelength« and Dennis Haasler second place for his paper »Investigation of Heat Accumulation Effects during Percussion Drilling by High Power Ultrashort Laser Radiation«.

Poster Award of the »DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.«

Thilo Barthels of Fraunhofer ILT was honored with the poster award for his presentation »Innovatively manufacturing surface filter inserts to mechanically filter bacteria out of water« at the event »Trace Substances and Pathogens in the Water Cycle - SUK 2018« of the »DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.«.

FRAUNHOFER COIN

Fraunhofer Coin for Prof. Poprawe

At the meeting of the institute directors in Braunschweig on October 25, 2018, Professor Reinhart Poprawe was honored with the Fraunhofer Coin for outstanding services to the Fraunhofer-Gesellschaft. After the death of Joseph von Fraunhofer and Georg Reichenbach, King Ludwig the First of Bavaria minted a coin in their memory, which the Fraunhofer-Gesellschaft has been minting as an honorary award in a limited edition since 1986.

TRAINING THE NEXT GENERATION

Light installation »The Cathedral Shines« at the Katschhof in Aachen.

Participants of the Girls' Day at Fraunhofer ILT.

Girls' Day – Girls' Future Day on April 26, 2018

On April 26, 2018, the three Aachen-based Fraunhofer Institutes ILT, IPT and IME opened their doors to interested girls (grades 5–7) and offered insight into the institute's daily work. In addition to a brief introduction to the institutes and guided tours of the laboratories and halls, the schoolgirls were also able to conduct experiments on the following topics themselves:

- Vaccine from tobacco: How plants produce medication,
- Experiment: Filtering DNA from a tobacco plant,
- Operation »Flying Egg« – Construction of an aerial vehicle and
- Experiment: Building an own hologram and a laser light barrier.

First Hackathon from May 22–25, 2018

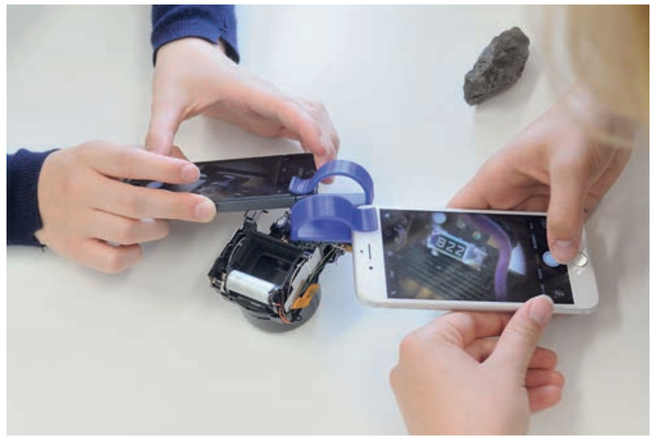
Fifteen students from different disciplines developed their own laser musical instruments in three diverse teams during the Hackathon »Laser Musical Instruments«, organized by the Chair for Technology of Optical Systems TOS at RWTH Aachen University. From the laser guitar to the laser synthesizer to the laser xylophone, the 15 participants programmed, soldered and dabbled on their instruments independently and gained a lot of new knowledge in the process. At the end of the event, they particularly praised this kind of learning.

First night of 3D printing on July 12, 2018

On July 12, 2018, the first night of 3D printing took place at the Photonics Cluster on the RWTH Aachen Campus. The DPP Research Campus, the Chair for Digital Additive Production DAP at RWTH Aachen University and Fraunhofer ILT gave over 80 Aachen citizens the opportunity to take a look behind the scenes of 3D printing. Expert talks by the Ford Motor Company and McKinsey & Company provided a technical add-on in a relaxed atmosphere to illustrate the future of 3D printing in industrial production. In the networking that followed, live DJs and a good atmosphere ensured a lively exchange between interested parties and scientists.

Student University of Mechanical Engineering from August 6–10, 2018

In 2018, the Student University of Mechanical Engineering took place again at the RWTH Aachen University with the participation of the »Integrative Production Technology Excellence Cluster for High-Wage Countries«. Twenty-four students from all over Germany, but also from Belgium and Turkey, spent a week in Aachen to get a first impression of the mechanical engineering course of studies and its great potential. By visiting various institutes and the demonstration factory of the Smart Logistics cluster, the students gained insights into the fields of production technology, process engineering, plastics technology, textile technology as well as optics and laser technology. In addition to hearing presentations and lectures, the participants were also able to experiment and, for example, program small robots. On August 10, 2018, they then discovered the world of photonics and examined structures on the 10 µm scale or got to the bottom of optical phenomena in everyday life, such as »catacaustics in the coffee cup«.



Experiments with macro lenses for the smartphone at the Student University of Mechanical Engineering 2018.

Summer School »Production Technology meets Industry 4.0«

As part of the Cluster of Excellence »Integrative Production Technology for High-Wage Countries«, an international Summer School on »Production Technology meets Industry 4.0« took place from August 6 to 24, 2018. On one day, the 35 international students at the Chair for Digital Additive Production DAP at RWTH Aachen University dealt with the topic »Digital Additive Production« and gained insight into various additive manufacturing processes as well as the digital development and design of AM components.

Fraunhofer Student Event »The Cathedral Shines« on September 28, 2018

According to the motto »Science and art in one evening is not possible. Yes, it is.«, 4000 students and employees of the Fraunhofer Institutes in Aachen celebrated 40 years of UNESCO World Cultural Heritage with a varied stage program and a spectacular 3D light installation at the Katschhof in Aachen.

»5 to 12« – The RWTH Science Night 2018

The RWTH Science Night »5 to 12« presents science in an unusual form at an unusual time. Science is made understandable and tangible for all generations in an entertaining way with a wide range of exciting lectures, film screenings and cabaret and musical contributions. On November 9, 2018, the Chair for Technology of Optical Systems TOS at RWTH Aachen University presented the laser harp that was created as part of a project work under the motto »Light to touch – making music with light«.

Graduate Congress Germany in Cologne

On November 22 and 23, 2018, Fraunhofer ILT introduced itself for the first time at the Graduate Congress Germany, the country's largest job fair for students, graduates and professionals. In addition to 250 other exhibitors, Fraunhofer ILT held personal discussions with students and graduates from the engineering, business and natural sciences to inform them about entry and career opportunities with the institute. In addition, interested parties were given the opportunity to familiarize themselves interactively with Fraunhofer key topics in the »Escape Game Cube«.

31st bonding company contact fair on December 5, 2018

For the third time in a row, Fraunhofer ILT presented itself in Aachen at the largest student-organized company contact fair – the bonding. In addition to 402 other exhibitors, Fraunhofer ILT informed students and graduates from the engineering, economics and natural sciences in particular about career opportunities.

3rd Women's Future Day of RWTH Aachen University on December 11, 2018

Fraunhofer ILT introduced itself for the first time at the Women's Future Day at RWTH Aachen University. During this event, which was specially organized for female graduates of RWTH Aachen University, Fraunhofer ILT provided information about career opportunities for female scientists in the form of a company pitch, a panel discussion and personal discussions.

ALUMNI NETWORK

The winners of the Science Slam with Fraunhofer Human Resources Director Prof. Alexander Kurz (1st from le.).

The builders of the laser harp at the Alumni Summit in Aachen.

LIVING ALUMNI NETWORK AT FRAUNHOFER ILT

Fraunhofer ILT and the associated chairs and subject areas of RWTH Aachen University significantly contribute to the qualified training and advanced training of young scientists in the field of laser technology. In 2018 alone, 123 students completed their bachelor's or master's theses at Fraunhofer ILT and 16 employees their doctorate degrees. Thanks to their practical experience and in-depth insight into innovative developments, these employees are equipped with the best prerequisites to take up work in science and industry. They are, therefore, junior staff in demand.

To promote contact between alumni and ILT employees as well as with each other, Fraunhofer ILT has been operating the alumni network »Aix-Laser-People«, which now counts more than 450 former alumni, since 2000. Over 80 percent of alumni work in the manufacturing industry, many of them in laser-related industries. 20 percent of alumni continue to work in science and around 10 percent have founded companies. By transferring »innovative minds« into industry and science, the institute makes a direct benefit to society.

In addition to the alumni network »Aix-Laser-People«, the association »Arbeitskreis Lasertechnik AKL e.V.« bundles the thematic interests of those who continue to work in the field of laser technology. About 150 alumni, i.e. a good third, are members of the AKL e.V.

Contact at Fraunhofer ILT

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Alumni Summit from September 27–28, 2018 in Aachen

The Fraunhofer Alumni Summit took place in Aachen from September 27 to 28, 2018 and was organized by the Fraunhofer Alumni e.V. and the Fraunhofer-Gesellschaft in close cooperation with Fraunhofer ILT in Aachen. About 150 participants took part in the extensive conference program and visited the three Fraunhofer Institutes ILT, IPT and IME in Aachen.

»Smart Production of Tomorrow: Opportunities and Perspectives in Additive Manufacturing« - exciting lectures and top-level discussions with leading figures from science, politics and industry were on the agenda of the Fraunhofer Alumni Summit in 2018. Another highlight was the Science Slam, in which young scientists presented research projects from the field of additive manufacturing in an original way.

The Fraunhofer-Gesellschaft intends for the Fraunhofer Alumni Summit to promote the connection of former employees to Fraunhofer as well as the alumni among each other. »The event offers an excellent forum for a top-class exchange of knowledge and information and supports the formation of important networks and cooperation.« said Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft.

Armin Laschet, Minister President of North Rhine-Westphalia, was also a guest. He praised the idea of the alumni network and the impetus that Fraunhofer provides for the economy through close cooperation with medium-sized companies, and not only in his federal state.

This time, the thematic focus was on the opportunities and perspectives of additive manufacturing, which is regarded as one of the most important key technologies for implementing the German government's high-tech strategy.

Additive Manufacturing at its best

The summit participants were able to catch up on the first results of the strategic Fraunhofer research cooperation »futureAM« in lectures by the four Fraunhofer Institute directors Prof. Emmelmann, Prof. Leyens, Prof. Schleifenbaum and Prof. Bergs and at an exhibition accompanying the conference. Experts for additive manufacturing from BMW, Siemens, Airbus and Trumpf discussed the opportunities and perspectives of this future-oriented technology, which is being developed within the framework of the Digital Photonic Production DPP Research Campus in Aachen. The project enables the Fraunhofer-Gesellschaft, RWTH Aachen University and the industry to cooperate systemically and for the long-term, all of whom conduct joint research in the Industry Building DPP under one roof. This innovative cooperation model was presented by Prof. Poprawe in his lecture.

Science slam for creative ideas

The young scientists were enthusiastic about the Science Slam in the afternoon. They gave the alumni an entertaining introduction to their research projects on »Additive Manufacturing«. Simon Vervoort of Fraunhofer ILT won the Science Slam.
The titles of the lectures were:

- »Sensor Integration - 3D Printing with Laser and Feeling«, Dipl.-Ing. Simon Vervoort (Fraunhofer ILT),
- »New Bones from the Printer«, Christoph Gayer M.Sc. (Fraunhofer ILT),
- »3D-printed Replacement Organs – Reality Tomorrow?« Jelena Ochs M.Sc. (Fraunhofer IPT) and
- »Additive Manufacturing + Machine Learning = Buzzword Bingo²«, Jonathan Krauss M.Sc. (Fraunhofer IPT).

After an evening reception by the mayor of the city of Aachen, Marcel Philipp, in the city hall, the 150 participants of the Fraunhofer Alumni Summit, including numerous alumni of Fraunhofer ILT and the associated chairs of RWTH Aachen University, were able to attend the light installation »The Cathedral Shines«. This art event took place as part of celebrating the Aachen cathedral chapter for the anniversary »A UNESCO World Cultural Heritage Site for 40 Years: the Aachen Cathedral«.
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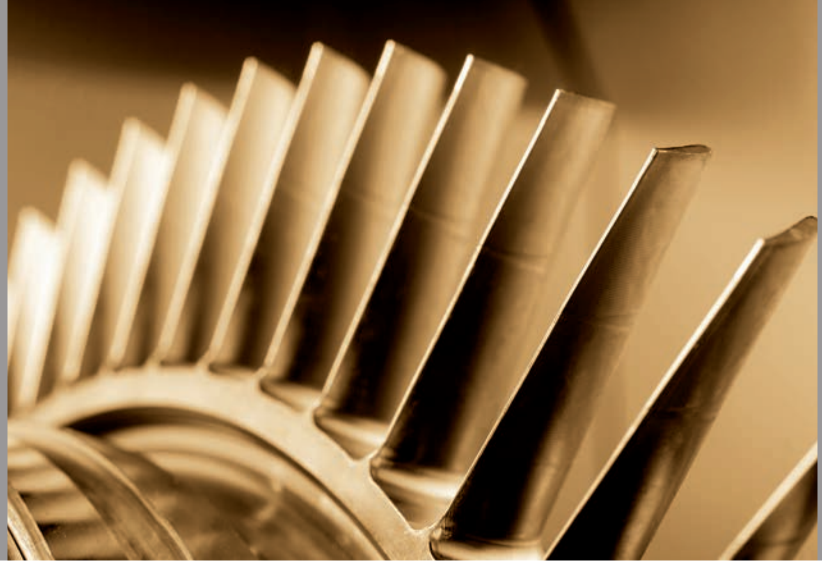
Source and further information on the Internet at:
www.fraunhofer.de/de/schnelleinstieg/alumni.html

MOBILITY
LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY



SMART PRODUCTION AND REPAIR IN TURBINE CONSTRUCTION

By 2036, the number of airplane passengers is expected to double to 8 billion per year, which has direct consequences for the maintenance and repair of aircraft turbines. Fraunhofer ILT is developing laser-based manufacturing and system solutions for the efficient repair of high-value engine components, thereby actively contributing to the growth of the aircraft industry and the expansion of mobility.

Repair challenges

Aircraft turbines are subject to high mechanical and thermal loads. The materials commonly used to make such components are iron, nickel and titanium and repairing them often means that worn areas have to be restored. This requires adapted process chains in which the components are prepared, digitized, machined, deposition welded, heat-treated and then finally machined. In addition to conventional welding processes, thermal spraying processes are also used to deposit material on the substrate. However, these processes often have disadvantages such as excessive energy input and distortion in the component or insufficient adhesion of the coating.

Laser material deposition in turbine construction

Since the energy input of a laser can be easily controlled both temporally and spatially, the laser is particularly suitable for applying material to highly sensitive turbomachinery components. The filler materials are fed in wire or powder form, melted by the laser beam and metallurgically bonded to the base material.

Fraunhofer ILT provides process control and system technology adapted to the geometry and material. These include process control for nickel-based alloys that have a high gamma coating content and are difficult to weld, influencing the microstructure using pendulum techniques, repairing components made of monocrystalline materials and material deposition of oxidation-sensitive titanium-based alloys.

In systems engineering, Fraunhofer ILT offers customized solutions for modular powder and shielding gas feed nozzles and other components for highly efficient powder feed as well as coaxial wire feed heads that enable material deposition independent of direction.

Process chains and Industry 4.0

Fraunhofer ILT offers solutions for individual steps in the process chain. These include digitization using line scanners and GOM, software for offline programming for laser material deposition, the above-mentioned process control for complex 3D geometries and adaptive post-processing by milling. Solutions are currently being developed in the industrial 4.0 environment, such as sensor integration in machines, data acquisition and evaluation, as well as the development of »digital twins« for the repair of turbine blades.

Smart components with integrated sensors

Acquiring the actual operating conditions of a turbine is a critical success factor for optimally configuring all operating parameters under different load conditions and maximally utilizing the service life of highly loaded components. The actual conditions in view of fatigue and wear are decisive to provide the best possible maintenance and repair; these conditions can deviate significantly from the theoretically possible service life due to different environmental conditions.

For the accelerated development of turbine components as well as for the acquisition of data for »digital twins« for comprehensive simulation, it is therefore essential to collect a large amount of measurement data close to the effective point. Both embedded and applied sensor elements can be used for the online data acquisition of strains or temperatures.

In the field of embedded sensor technology, encapsulated sensors are inserted into cavities within a component and connected to it in a form-fit and firmly bonded manner. During additive production using laser beam melting, the sensor technology is integrated directly into the turbine component close to the effective point. For the sensor technology used, the necessary sensor structures are applied to the surface of the turbine component using ceramic thick-film technology, free of adhesives and solder. The multilayer system – consisting of insulation, conductor and resistance layers, based on glass ceramic materials with individual layer thicknesses between 10 and 30 µm – is built up step by step using 3D-suitable printing processes and sintered using laser radiation. Robust strain and temperature sensor structures for application temperature ranges up to 500 °C can currently be manufactured.

Smart production with laser powder bed fusion

In the manufacture of turbine components, the laser powder bed fusion (LPBF) process theoretically allows unlimited geometrical freedom. However, different component geometries lead to different heat dissipation conditions, thus resulting in challenges with regard to constant component quality. For this reason, the industry requires an LPBF process control strategy adapted to the local characteristics of the components to be manufactured.

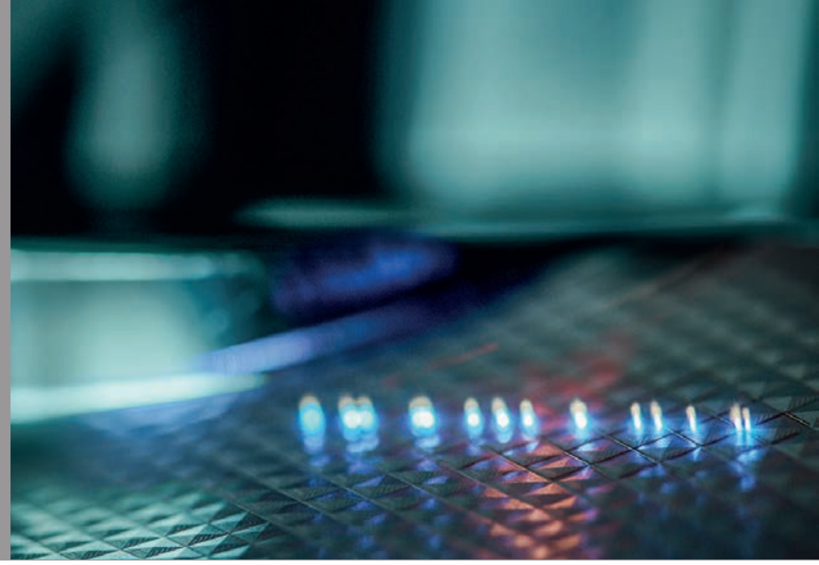
Together with data experts from Fraunhofer IGD, the Fraunhofer ILT scientists are developing software solutions and process control strategies as part of the »futureAM« lighthouse project, strategies that enable the energy input in the LPBF process to be controlled both temporally and locally. For this purpose, the component to be manufactured is divided into so-called voxels and each individual voxel is then assigned a combination of suitable process parameters. This means that different geometry classes can be produced with constant quality and reproducibility: a further building block for high-quality components in turbine construction.

Fraunhofer ILT continues to advance additive manufacturing technologies in the Fraunhofer Group, thereby making a contribution to the smart production of tomorrow.

Selected research results:
Mobility: pages 45, 50, 64–66, 70, 78–80 and 83–87.

Further information on the Internet at:
www.ilt.fraunhofer.de/en.html

PRODUCTION
LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY



FUNCTION-OPTIMIZED SURFACES USING LASER TECHNOLOGY

Functional surfaces are the key to innovative products that combine different properties in a minimum of space. In addition to developing purely technical functions, the institute aims to generate properties borrowed from nature. Current developments in the field of laser technology open up new perspectives for surface modification adapted to specific applications, a modification that often cannot be achieved with conventional manufacturing processes.

Tribological functionalization

Specific surface structures can be used to reduce wear in components moving against each other – such as sleeve bearings, sealing surfaces or roller bearings – to positively influence the hydrodynamic behavior of lubricating films. These structures make it possible to reduce friction forces and wear rates. Laser ablation can be used to generate hydrodynamically optimized structures with geometrical shapes from a few 100 nm down to the micrometer range on any surface. This means that bearing parts and hydrodynamic parts of bearing pairs can be adapted to each other specific to the application, lengthening operating times and lowering maintenance costs. High-power ultrafast lasers enable high ablation rates so that even large components can be processed economically.

As an alternative to conventional surface structuring, laser processes can be used to produce ultra-hard layers by applying hard material coatings selectively or by modifying nanoparticulate coatings that have been applied wet-chemically. These ceramic wear-resistant coatings have enormous potential and are used in the automotive industry, among others, to optimize the tribomechanical properties of highly stressed engine and transmission components. Nanoparticulate materials, e.g. in the form of sol-gel systems, can be applied to components as protective layers with little technological effort through processes that conserve energy and resources. Subsequently, the coatings are post-treated with selective laser treatment for layer thicknesses of 0.1 to 1 µm, thereby achieving microhardness values of more than 1000 HV. The central challenge of the coating process is the complete sintering of the ceramic material at temperatures above 1000 °C without influencing the function of the partly temperature-sensitive carrier materials.

Photonic functionalization

There are a wide range of applications for optically functionalized surfaces. Various optical effects can be achieved when planar periodic and aperiodic structures are generated with geometries in the range of 100 nm to several micrometers, depending on the size of the structures produced. With structures that are larger than the wavelength of the incident light, the light coupling into the material can be increased by multiple reflections and interference effects. Furthermore, the light can be scattered by smaller structures – in the size range of the light wavelength – which in turn increases the length of the optical path and leads to an increase in absorption in the medium. With very small structural periods, it is even possible to simulate the so-called moth eye effect, which almost completely eliminates surface reflections. This is used as anti-reflection effects for photovoltaic systems. In addition to such large-area processing methods, laser ablation is used to produce molding tools for the manufacture of microlenses and scattering structures for light extraction in LED lighting.

Fluidic functionalization

Laser processes can also generate hydrophilic or hydrophobic surfaces both directly on the component and, in the case of replicative manufacture of the component, by injection molding and casting processes, but also by laser structuring of the mold surface. Here, ultrafast lasers are particularly suitable for structuring both polymeric and metallic surfaces by selectively ablating a defined surface with deterministic structures in the micro and nano range.

Electrical functionalization

Electrical and magnetic functionalization offers great potential in the field of energy and semiconductor technology. With functionalized electrode surfaces, the power and energy density as well as the cycle stability of lithium-ion batteries can be improved, e.g. in energy storage technology. Another area of application is semiconductor technology, where transparent conductive oxides are created by the laser crystallization of thin layers. Conductivity can also be modified by laser remelting of semiconductors or by selective sintering of nanoparticles at low process temperatures. The processes for adjusting magnetic properties offer great potential in the field of transformer and electric motor technology.

Biological functionalization

Ultrafast laser radiation can be used to generate topographic structures and chemically active anchor structures in the < 100 nm range for biologically functional surfaces. These geometric and chemical functions influence adhesion, proliferation, cellular orientation, podium formation, migration, differentiation and gene expression of hematopoietic and mesenchymal stem cells (MSC). These technologies and knowledge make it possible to expand adult stem cells in vitro with improved results and to structure implants in tissue engineering and regenerative medicine.

Chemical functionalization

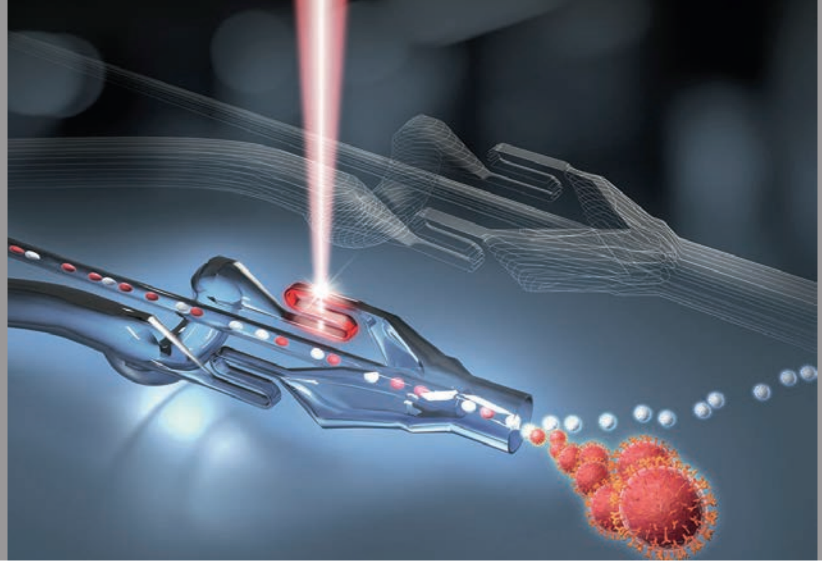
Catalytic reactions in chemistry are becoming increasingly important for new materials and new manufacturing processes. Thanks to laser structuring and laser modification, chemically active surfaces can be produced by coupling reactive molecules and atoms which exhibit synthetic functionalities, in the chemical sense as sensors and actuators. In this way, for example, photocatalytically active surfaces can be produced and allow a direct synthesis of functional molecules at high photon energies.

Selected research results
Production: pages 35, 41, 48, 51, 52, 54, 55, 57–61, 64–69, 71–73, 76, 77, 81, 82, 88 and 89.

Further information on the Internet at:
www.ilt.fraunhofer.de/en.html

HEALTH

LASER TECHNOLOGY SOLUTIONS
FOR INDUSTRY AND SOCIETY



LASER-BASED ANALYSES FOR PERSONALIZED MEDICINE

Lasers offer clinicians a wide range of options for diagnostic and therapeutic applications. As increasingly personalized medicine develops, new demands are being placed on clinical diagnostic procedures. The high sensitivity and selectivity of fluorescence-based laser measurement methods distinguish the laser as a tool for dealing with such diagnostic questions. Together with leading medical experts, Fraunhofer ILT is developing laser-assisted methods for laboratory diagnostics that will enable therapy options tailored to individual patients. A key topic is the development of microfluidic lab-on-a-chip systems, including multiplex diagnostics in routine operation.

Lab-on-a-chip systems for rapid analyses

Cells and biomolecules circulating in the blood are carriers of diagnostic information, the analysis of which is a key to highly effective, individual therapeutic concepts. To make this information accessible, scientists at Fraunhofer ILT are developing microchip-based sorter systems called µFACS (Microchip Based Fluorescence Activated Cell Sorter). With laser-induced fluorescence, clinically relevant cells of a blood sample are detected in microfluidic channels and gently isolated for further investigations. Different cell types can be detected with a single sorting chip and separated into separate sample vessels while maintaining the vitality and divisibility of the cells.

Sorting cells and biomolecules with light

Cells have characteristic proteins that are stored in the cell membrane. These proteins have a structure to which marker molecules can bind. The marker molecules are specifically stained with antibody-dye conjugates, which, in the µFACS system, are excited to emission with laser light and thus made visible. Laser beams of different wavelengths can differentiate differently labelled cells. The fluorescence light is directed via a fiber network to an optical detection system that analyzes the emitted light and assigns it to a specific species of cells.

With focused infrared laser light, the cells can be directed through a network of fluidic branches and then sorted. The measured fluorescence information determines where a cell is sorted. In this opto-fluidic switching process, the cell is always directed at a junction into the branch that has previously been irradiated with infrared light. Complex sorting structures consist of a combination of many such switchable junctions of microfluidic channels. The channels each lead into a collection vessel and allow the simultaneous sorting of different cell species.

Rapid infection diagnostics and resistance tests

This microfluidic sorting process is ideally suited for use in infection diagnostics, for example to detect and isolate pathogens in the blood. In the case of bacterial pathogens, the isolated pathogens can be further cultivated and used to test the efficacy of antibiotics: isolation of the pathogens, subsequent storage in a culture vessel, further propagation and testing of various antibiotics. The individual steps only take a short period of time, so that the overall diagnosis times are also short. Patient-specific, highly specific antibiotic profiles for treating bacterial infections can be established within a few hours. Compared to conventional resistance tests, diagnosis with µFACS saves valuable time of one to two days, which can be decisive for the choice of therapy.

Early detection of tumors with laser light

Tumor cells circulate in the blood at a very early stage of cancer. Their detection can be used to diagnose cancer at an early stage, even before the disease causes symptoms or can be detected with imaging processes. Circulating tumor cells in the blood can be detected with µFACS and isolated in the sorting chip for further clinical examination. After the sorting process, the isolated cells are available for personalized therapy selection with significantly increased therapeutic success.

A single analysis to detect a variety of diseases

The different detection channels of µFACS can be used to simultaneously identify different marker molecules in the blood. Multiplex diagnostics allows up to sixteen different disease markers to be detected in a single marking step and in just one measurement run. In such a multiplex analysis, the marker molecules can be specifically bound by a mixture of different diagnostic particle fractions in a blood sample and detected by particle fluorescence. In the annual routine check-ups with the family doctor, a large number of possible diseases could be diagnosed early from a single blood sample in order to prevent widespread diseases such as cardiovascular diseases.

Selected research results
Medical technology: pages 37, 92–96 and 103.

Further information on the Internet at:
www.ilt.fraunhofer.de/en.html

ENVIRONMENT

LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY

OPTIMIZED RECOVERY OF VALUABLE RAW MATERIALS USING LASER MEASUREMENT TECHNOLOGY

Fraunhofer ILT is developing measurement methods to optimize the use of raw materials in the raw material and recycling industry. Together with innovative companies, we are, thus, contributing to the sustainable use of natural resources.

Conserving resources is environmental protection

The exploitation of natural resources not only affects the local environment, but presently also leads to a foreseeable shortage as well as to restrictions for the economy and the population. The per capita consumption of raw materials in Germany in 2017 was statistically 16 tons per year and thus about 100 percent above the global average.

For a sustainable raw materials economy, society needs to rethink how it deals with such materials. Such a change must lead, on the one hand, to an economy that saves resources and, on the other hand, to one that recycles intensively. This process has already begun and is reflected, among other things, in the fact that the efficiency of raw material use has already increased by around a quarter since 2000.

Modern process control with laser technology

Since the quality of natural raw materials is subject to fluctuations and sustainable mining cannot be limited to the best grades, industrial processes must not only be flexibly managed, but also continuously and optimally adapted to the current material properties.

Modern process control is based on a combination of model calculations and close-meshed measurements. Laser technology enables the direct investigation of material flows without sampling and delivers results on both the physical state and the chemical composition continuously and without time delay. Thus, the energy supply or the dosing of aggregates can be continuously regulated according to demand and the intensity of pre-processing can be adjusted instead of working with large safety margins.

Recovering raw materials

Integrating measurement technology in the field of recycling to separate different materials goes one step further. Optical sensors detect, for example, packaging plastics or waste glass in order to separate them according to type.

Recycling has long been economically viable in metal production, as the material value is high and many metals can be remelted as often as required without loss of quality. In addition, compared to metal production from primary mineral raw materials, recycling saves a great deal of energy – in the case of aluminum even up to 90 percent. New challenges arise, however, as the diversity of materials increases. Indeed, the range of metals and metal alloys used in the industry is constantly growing, for example for lightweight construction in the automotive sector.

For loss-free recycling, metals must be separated down to the alloy level, which requires chemical analysis. Fraunhofer ILT has done pioneering work in this area and successfully demonstrated that laser analysis can be used to determine the alloy components of metal scrap quickly and without contact during transport on the conveyor belt and even to identify individual wrought aluminum alloys. Ongoing work is extending these possibilities to more complex materials such as tool scrap.

Closed-loop economy

New approaches to develop secondary raw materials bring the flows of raw materials closer to the ideal of closed-loop raw material economy. Concepts of urban mining or inverse production try to connect product and material flows to further locations. Technology metals, which are indispensable for a large number of technological products, are not extracted today as primary raw materials in Germany and Europe and their availability is classified as critical. These metals could be recovered from waste products, but are currently still largely lost in existing recycling processes or exported. Export often places them in landfills or they are recovered under working conditions and with environmental consequences that do not meet our minimum requirements.

This is where new processes come in, such as those carried out at Fraunhofer ILT with the ADIR network partners using the example of electrical recycling. Laser measurement methods identify valuable components and enable a targeted recycling strategy even with a large variety of products. Laser-assisted processes are then used to remove the components containing the recyclable materials and to process them in a specific way.

Monitoring in production and environment

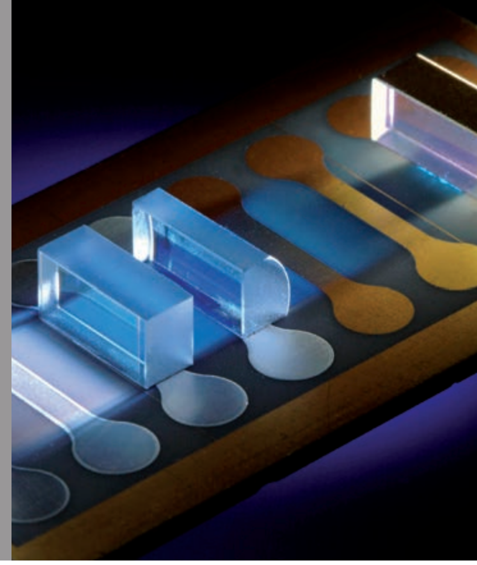
Fast, non-contact laser measurements are also valuable tools for monitoring. The continuous testing of semi-finished products, e.g. to avoid material mix-ups, reduces production waste and consequential damage, thus also increasing the efficiency of raw material use. The monitoring of by-products or secondary products can ensure their recyclability. Lasers can even be used to determine and continuously monitor the composition of hot, molten slags in order to check whether they are free of certain impurities and can be used safely as building materials, for example.

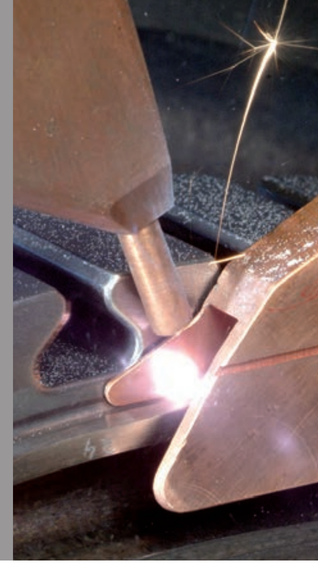
The monitoring of transport pipelines and process plants can be carried out over large areas using remote laser measurements in order to prevent undesirable emissions. Helicopters with laser sensors are used to detect methane leaks from natural gas pipelines and, thus, to quickly and efficiently eliminate not only the loss, but also the climate-damaging effects of methane.

Selected research results
Environment: pages 97, 101 and 102.

Further information on the Internet at:
www.ilt.fraunhofer.de/en.html

TECHNOLOGY FOCUS





LASERS AND OPTICS

The technology field Lasers and Optics focuses on developing innovative laser beam sources and high quality optical components and systems. Fraunhofer's team of experienced laser engineers builds beam sources which have tailor-made spatial, temporal and spectral characteristics and output powers ranging from µW to GW. These sources span a wide range of types: from diode lasers to solid-state lasers, from high power cw lasers to ultrashort pulse lasers and from single frequency systems to broadband tunable lasers.

In the field of solid-state lasers, oscillators as well as amplification systems with excellent power data hold the center of our attention. Whether our customers are laser manufacturers or users, they do not only receive tailor-made prototypes for their individual needs, but also expert consultation to optimize existing systems. In the realm of short pulsed lasers and broad band amplifiers in particular, numerous patents and record-setting values can be provided as references.

Furthermore, this technology field has a great deal of expertise in beam shaping and guiding, packaging of optical high power components and designing optical components. This field also specializes in dimensioning highly efficient free form optics. In general, the lasers and optics developed here can be applied in areas ranging from laser material processing and measurement engineering to illumination applications and medical technology all the way to use in aerospace applications and pure research.

LASER MATERIAL PROCESSING

Among the many manufacturing processes in the technology field Laser Material Processing, cutting and joining in micro and macro technology as well as surface processes count among its most important. Whether it be laser cutting or laser welding, drilling or soldering, laser metal deposition or cleaning, structuring or polishing, generating or layering, the range of services spans process development and feasibility studies, simulation and modeling, as well as the integration of processes in production lines.

The strength of the technology field lies in its extensive know-how, which is tailored to customer requirements. In such a way hybrid and combination processes also result. Moreover, complete system solutions are offered in cooperation with a specialized network of partners. Special plants, plant modifications and additional components are the constituent part of numerous R&D projects. For example, special processing heads for laser material processing are being developed and produced, based on a customer's specific needs. In addition, process optimization by changing the design of components as well as systems to monitor quality online count among the specializations of this technology field.

Customers receive laser-specific solutions that incorporate the working material, product design, construction, means of production and quality control. This technology field appeals to laser users from various branches: from machining and tool construction to photovoltaics and precision engineering all the way to aircraft and automobile construction.

MEDICAL TECHNOLOGY AND BIOPHOTONICS

Together with partners from the Life Sciences, the technology field Medical Technology and Biophotonics opens up new areas of applications for lasers in therapy and diagnostics as well as in microscopy and analytics. The process Selective Laser Melting, developed at the ILT, allows implants to be generated, tailored to the individual patent on the basis of data from computer tomography. The material variety ranges from titanium through polyactide all the way to resorbable man-made bone based on calcium phosphate.

In close cooperation with clinical partners, this field develops medical lasers with adapted wavelengths, microsurgical systems and new laser therapy processes for surgery, wound treatment and tissue therapy. Thus, for example, the coagulation of tissue or precise removal of soft and hard tissue is being investigated.

Nanoanalytics as well as point-of-care diagnostics demand inexpensive single-use microfluidic components. These can now be manufactured with high precision up into the nanometer range using laser-based processes such as joining, structuring and functionalizing. Clinical diagnostics, bioanalytics and laser microscopy rely on the institute's profound know-how in measurement technology. In the area of biofabrication, processes for in-vitro testing systems or tissue engineering are being advanced. Thanks to its competence in nanostructuring and photochemical surface modification, the technology field is making a contribution to generating biofunctional surfaces.

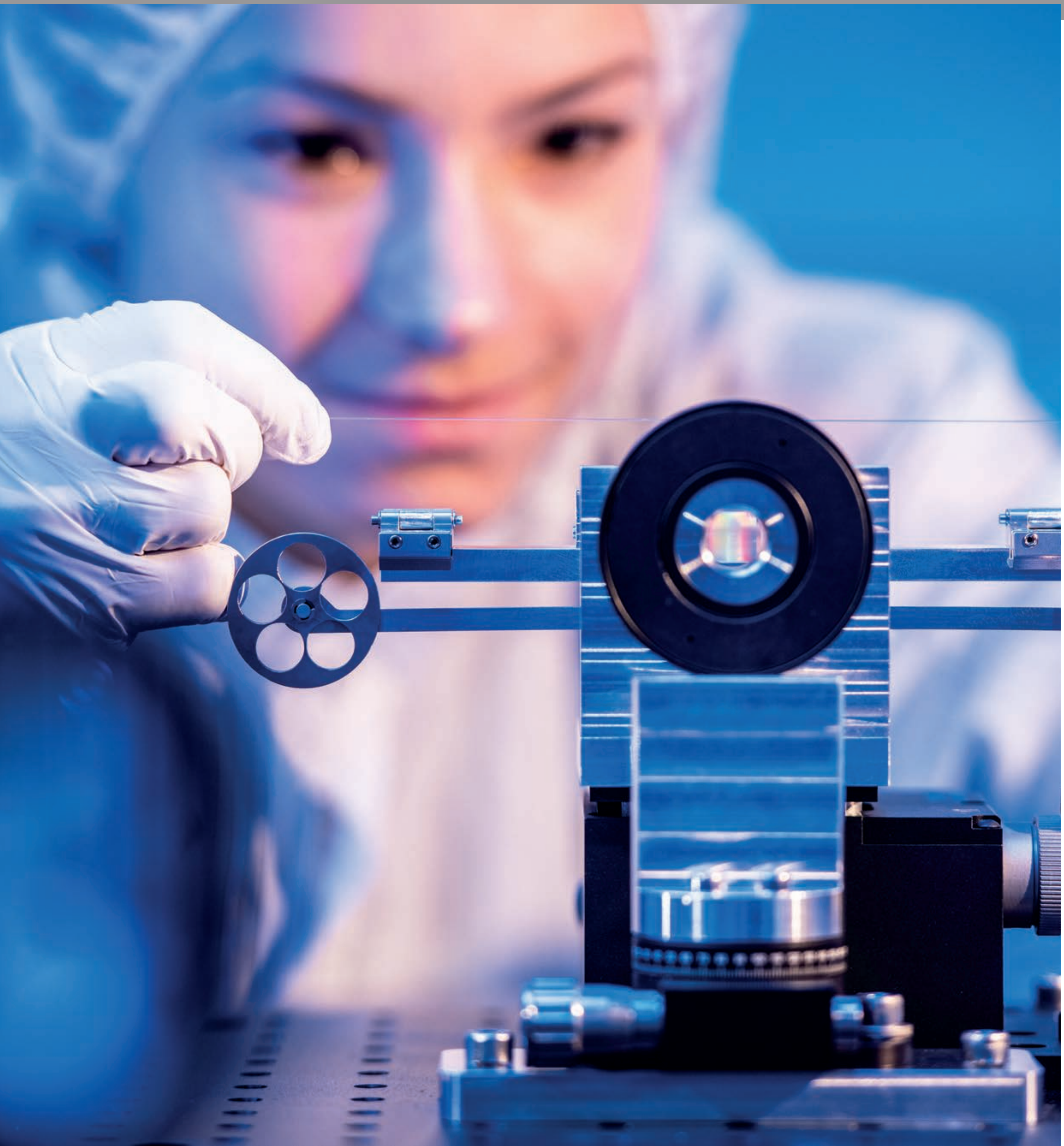
LASER MEASUREMENT AND EUV TECHNOLOGY

The focus of the technology field Laser Measurement Technology and EUV Technology lies in manufacturing measurement technology, materials analysis, identification and analysis technology in the areas of recycling and raw materials, measurement and test engineering for environment and security, as well as the use of EUV technology. In the area of manufacturing measurement technology, processes and systems are being developed for inline measurement of physical and chemical parameters in a process line. Quickly and precisely, distances, thicknesses, profiles or chemical composition of raw materials, semi-finished goods or products can be measured.

In the field of material analytics, the institute has acquired profound know-how in spectroscopic measurement processes. Applications are automatic quality control and positive material identification, monitoring of process parameters or online analysis of exhaust gases, dust and wastewater. The more precise the chemical characterization of recycling products, the higher their recycling value. Laser emission spectroscopy has proven itself as an especially reliable measurement tool. In addition to the development of processes, complete prototype plants and mobile systems for industrial use are produced.

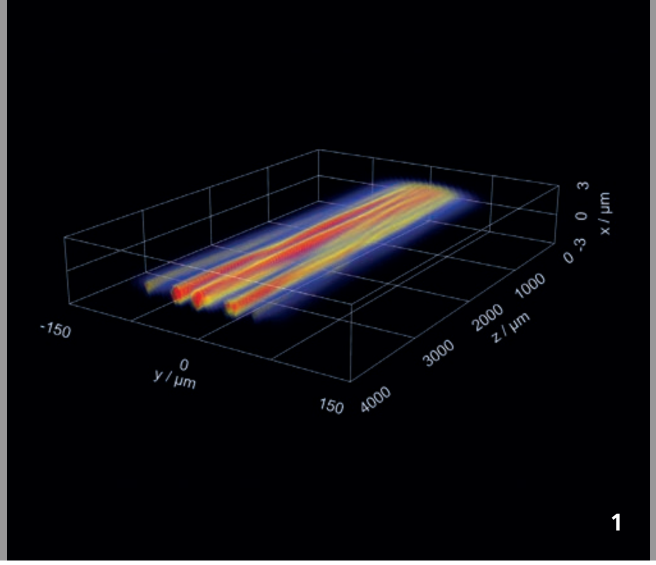
In EUV technology, Fraunhofer's experts develop beam sources for lithography, microscopy, nanostructuring or x-ray microscopy. Optical systems for applications in EUV engineering are calculated, constructed and manufactured as well.

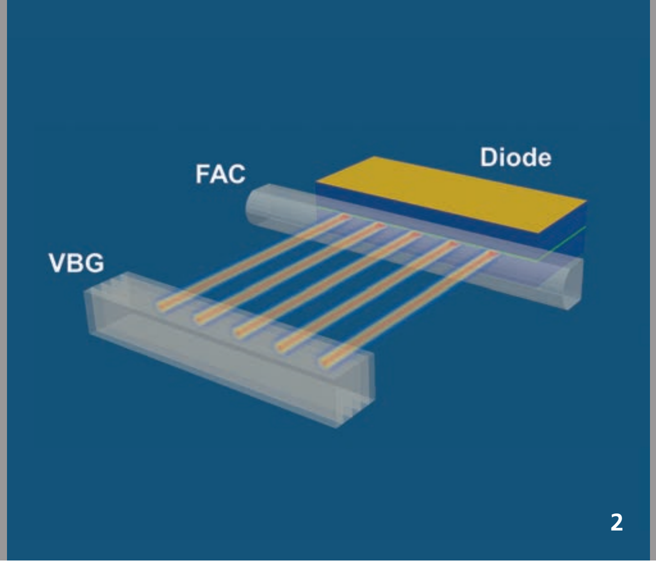
LASERS AND OPTICS



CONTENTS

Writing of Bragg gratings in optical fibers.





MULTIPHYSICAL MODELING OF HIGH-POWER LASER DIODES

Task

High-power laser diodes have the highest electro-optical efficiencies of all laser beam sources. Depending on the emission wavelength and operating point, they reach efficiencies of up to 70 percent. The degradation in beam quality at high output powers and the sensitivity to reflected radiation, however, currently hinder the use of direct diode laser systems in applications requiring high brilliance, such as laser remote welding. The sensitivity of the laser diodes to back reflection results in operating points below the maximum possible power.

Method

The »SEMSIS« software developed at the Fraunhofer ILT can be used to calculate the propagation of the optical field within the diode structure, the distribution of the electrical current density and the injected charge carriers, as well as the resulting optical amplification. The thermal model also takes into account the heating of the diode due to electrical losses and optical absorption. External resonators with elements for spectral stabilization are described by a wave-optical model. Finally, a defect model serves to describe the aging processes within the diode.

Results

By considering the complex interaction processes within the diode emitter, Fraunhofer ILT can model the reduction of the beam quality at high powers. Figure 1 shows this on the basis of the filamented optical field within an emitter. In addition, the institute can investigate the effects of external optical feedback on beam quality and damage mechanisms.

Applications

The software makes it possible to predictively design novel semiconductor structures and external optical resonators optimized for beam quality and lifetime. This allows users to selectively optimize the diode design so that costly and time-consuming parameter studies on real diodes can be reduced significantly.

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1 Optical field within a laser diode.

2 Optical feedback in external resonators.

ROBUST, COMPACT HIGH-POWER ULTRAFAST AMPLIFIER BASED ON YB-INNOSLAB

Task

Based on the Yb:YAG INNOSLAB concept developed at Fraunhofer ILT, ultrafast amplifiers have been customized for the laser manufacturer Amplitude Systèmes. In addition, know-how transfer to Amplitude will ensure that these 400 W power amplifiers for sub-ps pulses will continue to be developed and adapted.

Method

In view of the special demands on compactness, simplicity of adjustment and robustness against environmental conditions, Fraunhofer ILT fundamentally revised the existing Yb-INNOSLAB amplifier platform. Based on this, two prototypes for Amplitude Systèmes were built and characterized in-depth experimentally. In addition, Amplitude staff was trained at Fraunhofer ILT on the design and adjustment of the INNOSLAB amplifiers – an important part of the know-how transfer.

Results

The prototypes demonstrated that 5 W of seed power could be amplified to over 500 W of output power at pulse durations < 500 fs. Without chirped pulse amplification, the system was operated at repetition rates of 20 MHz, i.e., pulse energies > 25 µJ. Climatic and 24-hour tests demonstrated that the temperature behavior and the long-term stability of the laser power are suitable for industrial use.

Applications

Amplitude Systèmes has integrated the laser system into commercial laser systems for, among other things, use in materials processing, metrology and science.

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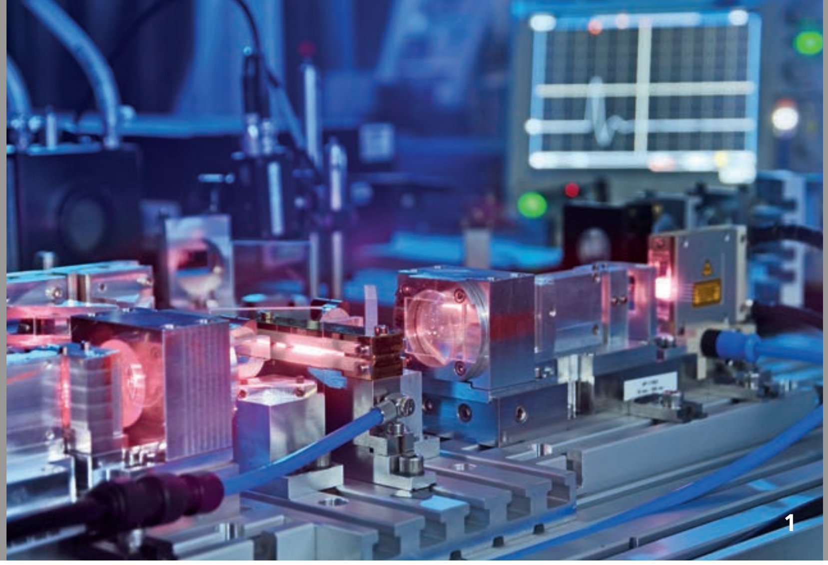
3 High-power INNOSLAB amplifier (middle) integrated in a commercial laser system.



ND:INNOSLAB HIGH-GAIN LASER AMPLIFIER WITH 400 W OUTPUT POWER

Task

Today, short-pulse lasers with pulse durations in the sub-ns range are used in numerous applications in laser material processing, such as in the automotive industry, in electronics or in the structuring of thin films. Here, challenges are scaling the laser power, reducing the manufacturing costs and simplifying the beam source while making the system highly robust. Currently, high-power short-pulse beam sources usually consist of a mode-locked oscillator and a subsequent multi-stage amplifier. Among others, the BMBF-funded joint project »IMPULS« aims to develop a laser amplifier for sub-ns pulses; such an amplifier should make it possible to generate the highest possible amplification and to scale the output power in a range above 300 W at pulse repetition rates of a few 100 kHz. Moreover, it is planned to use only one amplifier stage.

Method

The objective is to be achieved by optimizing the established Nd:YVO_4 crystal-based INNOSLAB design. For this purpose, Fraunhofer ILT is investigating technologies such as in-band pumping, the adaptation of the crystal geometry and heat sink and a favorable doping profile in the laser crystal. The beam propagation of the beam to be amplified in the laser amplifier represents another degree of freedom that is optimized for achieving maximum gain.

Results

A mean laser power in excess of 400 W has been achieved with a single stage INNOSLAB amplifier at pulse repetition rates in excess of 400 kHz and pulse lengths of 10 ps and 300 ps. Here, a pulse energy of 950 µJ was also shown for pulse lengths of 10 ps at 392 W average power. The beam quality without further filtering is $M^2 < 1.5$ with an o/o efficiency of more than 40 percent. The institute has demonstrated an efficient single-stage gain of more than 470 for an input power from 0.5 to 235 W output power.

Applications

With the parameters shown, the developed laser beam source is suitable, in particular, as a fundamental beam source for frequency conversion. For this reason, the »IMPULS« project also includes work on frequency conversion to UV and MIR and comparative experiments on laser material processing, in addition to providing the fundamental wavelength of 1064 nm. The experiments will be carried out on different components from the automotive industry and especially address components made of polymer materials and fiber composites.

The R&D project underlying this report was commissioned by the Federal Ministry of Education and Research (BMBF) under grant number 13N13966.

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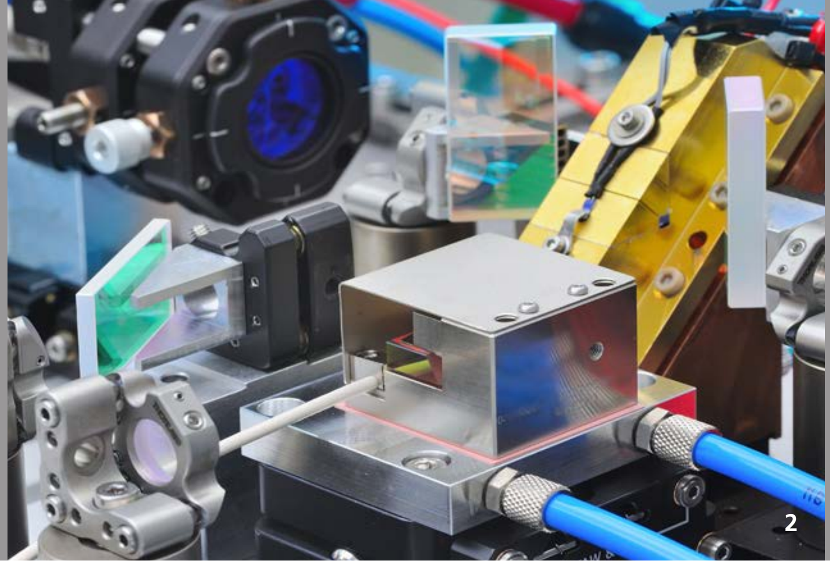
1 Single-stage 400 W Nd:YVO_4 laser amplifier.



PULSED TM:YLF LASER BEAM SOURCE AT 1.9 µM

Task

As part of the project »DIVESPOT« with the Max Planck Institute for the Structure and Dynamics of Matter, Fraunhofer ILT has developed a pulsed laser-beam source that has an output wavelength of 1.9 µm. The beam source will serve to optically pump the amplification medium Cr:ZnSe. Since the luminescence lifetime of Cr:ZnSe in the upper state is only about 5 µs at room temperature, the power must be made available for efficient pumping in high-energy short pulses. The project aims to achieve repetition rates of up to 10 kHz and pump pulse energies in the mJ range.

Method

To generate laser light with a wavelength of 1.9 µm, Fraunhofer ILT has constructed a solid-state laser with Tm:YLF as a gain medium. An acoustic-optical modulator is used for the Q switch. The requested output parameters require a high average power in the oscillator. In order to achieve sufficient heat dissipation, the institute has installed the laser crystal, therefore, in an optimized heat sink. In addition, soldering technology is used to connect the crystal optimally to the heat sink. To provide the required optical pumping power, highly brilliant laser diodes pump the Tm:YLF rod from both ends.

Results

The institute has developed and built a pulsed laser beam source emitting at a wavelength of 1.9 µm. The repetition rate can be freely selected between 1 and 9 kHz. In this case, regardless of the repetition rate, a pulse energy of at least 2 mJ can be generated in single mode operation. The pulse lengths of the system are in the range between 300 and 650 ns.

Applications

The developed laser beam source can be used to optically pump the laser medium Cr:ZnSe. The 1.9 µm laser beam sources are suitable for use in the medical field, e.g., as a laser scalpel in surgery. Another possible application is in plastic welding.

The project »DIVESPOT« is being funded within the framework of the Fraunhofer Max Planck Cooperation Program.

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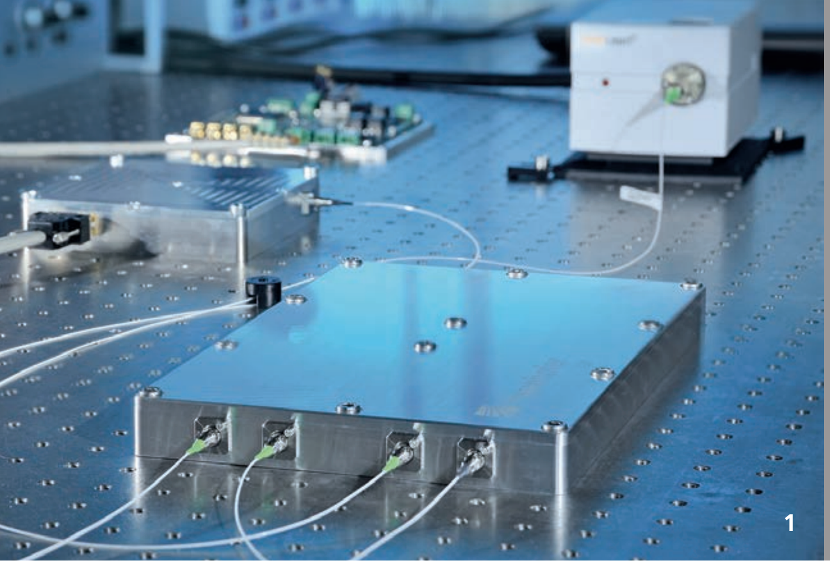
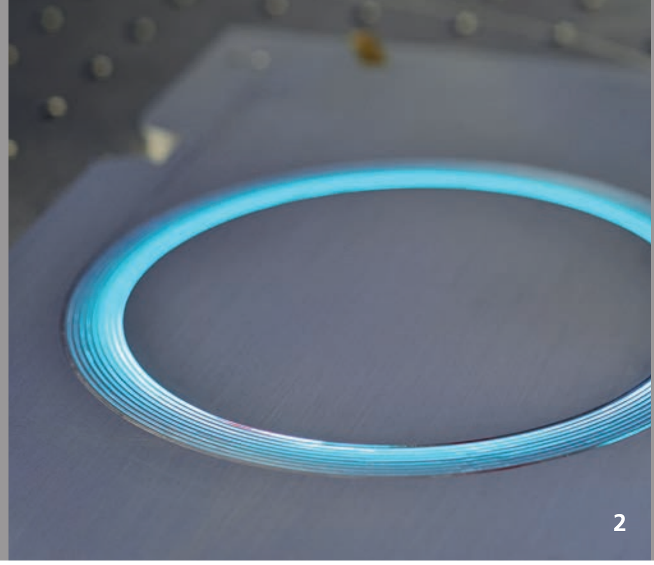
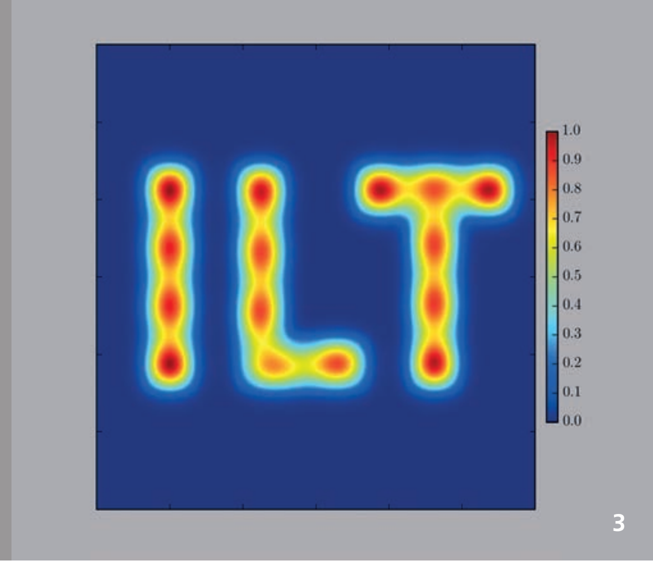
2 Pulsed Tm:YLF laser.







HIGHLY STABLE FIBER AMPLIFIERS FOR GRAVITATION MEASUREMENTS

Task

In studies conducted for the European Space Agency ESA, Fraunhofer ILT is developing linearly polarized, narrowband and power-stabilized single-mode fiber amplifiers for use in satellite-based gravitational-wave and gravitational-field measurements. Further development projects will be carried out in terms of power scaling and increasing the technological maturity level (TRL) based on a high-stability fiber amplifier from the preliminary study for the Next Generation Gravity Field Mission (NGGM), which has successfully met the specifications.

Method

Currently, the institute is revising the design to adapt the fiber amplifier to the high requirements of gravitational wave measurement: an output power > 2 W and sidebands at a distance of +/- 2.5 GHz around the central wavelength of 1064 nm. The seed used is a commercial nonplanar ring oscillator (NPRO), whose signal is amplified from 10 to 100 mW by a semiconductor optical amplifier (SOA). The institute has achieved a high stability of the SOA by controlling the pumping current via an external photodiode.

The mechanical design was updated and the fiber optic components of various international manufacturers were tested environmentally, both of which enhanced the fiber amplifier's TRL. Then, based on the results, an advanced amplifier was built. The complete amplifier system was then tested for its space suitability in an environmental test campaign.

Results

The necessary specifications could be demonstrated with the prototype for the gravitational wave measurement. In addition, the cw power could be scaled to within the range of 10 W. Thanks to the advanced module for gravitational field measurement, a comprehensive environmental test campaign consisting of vibration, shock and thermal vacuum tests was successfully completed.

Applications

The innovative fiber amplifiers are used to measure gravitational waves and the static gravitational field as well as for inter-satellite communication.

The work has been funded by the European Space Agency under the grant number 4000119715/17/NL/BW and RFQ/3-14347/15/NL/RA/zk.

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1 Fiber amplifier and pump diode box of the laser for the measurement of the earth's gravitational field.
2 Active fiber in base plate.

INVESTIGATION OF TRANSVERSAL MODEM COUPLING IN OPTICAL FIBERS

Task

Non-linear effects largely limit the maximum achievable power density in active and passive optical fibers in the single mode regime. Multimode fibers, however, can be used to overcome these limitations. Since mode coupling effects play a major role in the propagation of radiation, they significantly influence its homogeneity and beam quality. For this purpose, a mode-based simulation was developed, which analyzes how different fiber parameters, such as the core geometry or the numerical aperture, influence the achievable beam densities.

Method

A simulation based on the finite element method (FEM) was developed to calculate the eigenmodes of step index fibers with arbitrary fiber geometries and refractive index profiles. For the modes thus determined, the extent to which intrinsic and extrinsic factors – such as inhomogeneities or bending losses – influences modal propagation and mode locking in dielectric waveguides can be identified.

Results

Thanks to the simulation, Fraunhofer ILT is able to examine arbitrary fiber geometries in terms of their mode characteristics and bending sensitivity. Furthermore, it has used the simulation to determine the mode locking of transverse modes due to periodic structures and stochastically distributed perturbations in the fiber. With this understanding, the institute can selectively use the mode coupling, e.g., for the homogenization of the radiation, to influence the properties of the radiation. Current projects are working on implementing and testing the fibers designed in this way.

Applications

The new simulation tool allows users to selectively create new fiber designs optimized, for example, in terms of their achievable performance or beam homogeneity. Fields of application lie in industrial or medical areas where high power or application-specific beam profiles are required. With special fibers, new applications can be made possible and existing ones made more efficient.

The R&D project underlying this report was commissioned by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number ZF4328102AB6.

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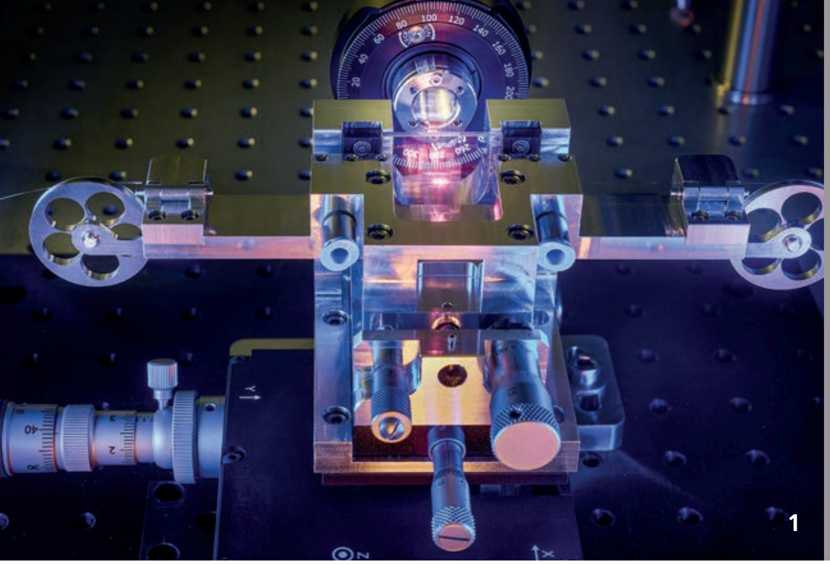
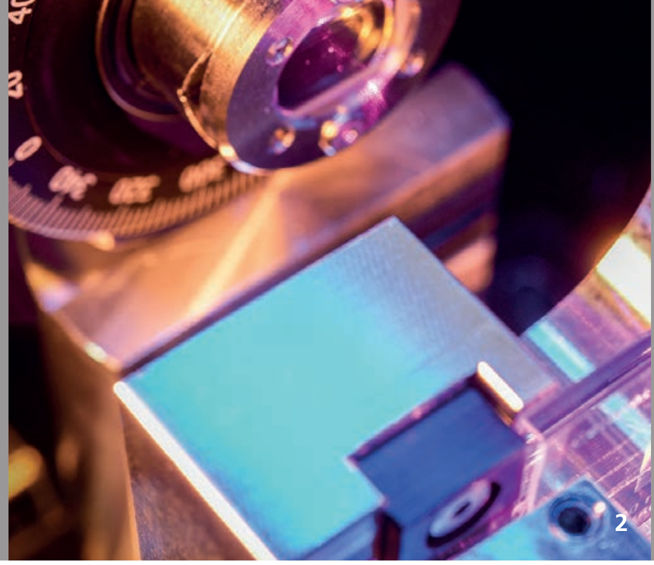
3 Example of a near field characteristic for fiber with ILT-shaped refractive index profile.





FIBER BRAGG GRATINGS FOR THE FREQUENCY STABILIZATION OF MULTI-MODE HIGH PERFORMANCE LASERS

Task

Fiber lasers and fiber-coupled diode lasers are among the cheapest, most efficient and most flexible beam sources for cw laser applications and are, therefore, used for many industrial applications. However, applications such as the efficient pumping of some laser-active media require a comparatively narrow emission bandwidth and a stable central wavelength. Fiber Bragg gratings (FBG) function as fiber-integrated external, wavelength-selective resonator output mirrors and are, thus, used for frequency stabilization both for fiber-coupled diode lasers and for fiber lasers. While various FBGs are commercially available for transverse fundamental mode radiation, there are currently no solutions for multimode radiation.

Method

FBGs consist of a periodic modulation of the refractive index along the propagation direction of the light in the fiber core. While the distance of the modulations is directly proportional to the reflected wavelength, the contrast and number of modulations influence the spectral width of the reflection and the reflectance. Using an ultrafast laser in the infrared emission region and two-beam interference, Fraunhofer ILT has selectively written these periodic modulations into the fiber core. The basis for the writing process is the non-linear absorption in the glass, which eliminates the need to pretreat the fiber. Therefore, the method can be used for a variety of commercially available fibers.

Results

The modular setup for writing FBGs, developed in the BMBF project »Ekolas«, makes it possible to use adapted processing optics for different fiber geometries. The FBGs thus produced were used as external resonator output mirrors for frequency stabilization of high-power fiber and diode lasers.

Applications

The technology offers fiber-coupled multimode high-power diode and fiber lasers the ability to build fiber-integrated frequency stabilization, eliminating the need for additional optical elements.

The R&D project »Ekolas« underlying this report was carried out on behalf of the Federal Ministry of Education and Research BMBF under grant number 13N13914.

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1 FBG workstation.
2 Long exposure of the FBG writing process using ultrafast laser radiation.

LASER PROCESSING OF GLASS FOR HIGH ASPECT RATIO STRUCTURES

Task

Classical precision-mechanical processing or ultrasonic drilling are not well suited for machining very fine structures or high aspect ratio bore holes into glass or other dielectric materials. For example, while preforms for fibers with hollow structures are manufactured with the laborious stack-and-draw process, a massive glass rod with bored out hollow structures would, in principle, be simpler. However, in this case, drillings of about 1 mm diameter and several 10 cm length are required.

Lossless geometric separation of ray bundles or spatial filtering, however, demands small openings in the order of magnitude of 100 µm in mirror substrates. The mirror surface needs to remain undamaged around the hole and the edges as sharp as possible. These geometrical forms can hardly be machined with present-day classical manufacturing processes.

Method

As an alternative to classical processes, Inverse Laser Drilling focuses the laser beam on the underside of the glass bulk. The workpiece is moved along the beam propagation axis and, by means of a scanner, the desired geometry is ablated layer by layer. To avoid chipping and to protect the surface, a glass substrate can be contact bonded to the work piece prior to machining and removed afterwards.

Results and Applications

This process has been used to structure the geometric shape of a photonic crystal fiber preform (60 bore holes, 750 µm diameter, 20 cm length) into a BK7 bulk. For spatial filters and geometric separators, undercut holes and slits with the order of magnitude of 100 µm have been structured into fused silica mirror substrates without chipping. Other materials like sapphire, ULETM or YAG can be machined with this method as well. Furthermore, laser processing has the advantage to be contactless and thus to cause no contamination.

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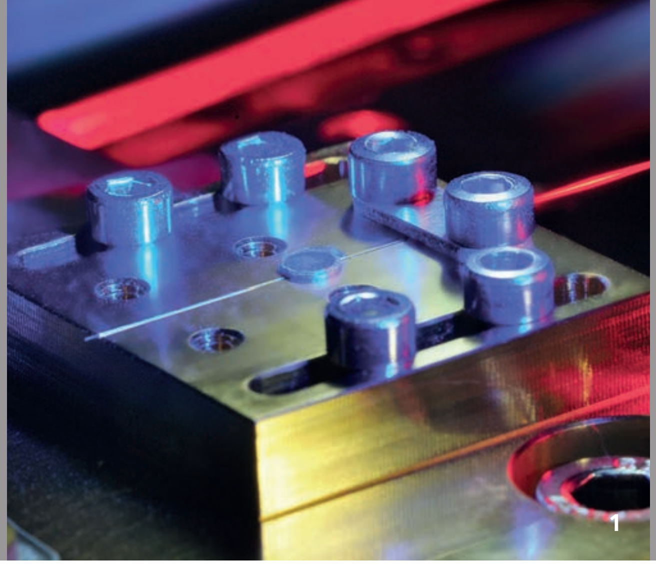
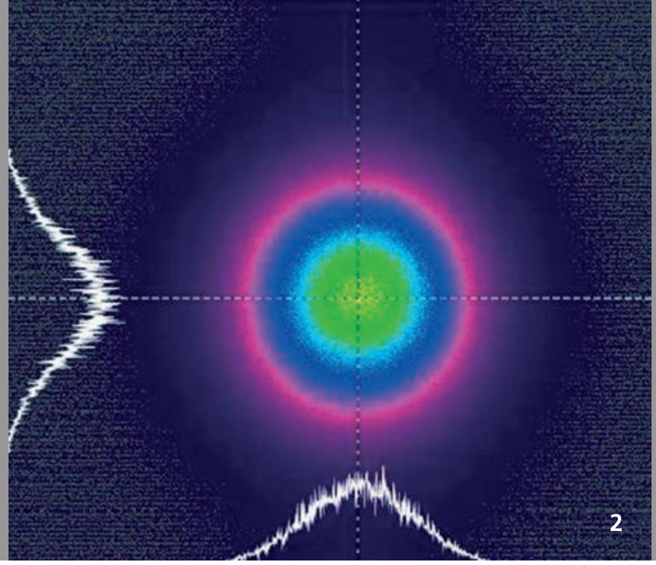
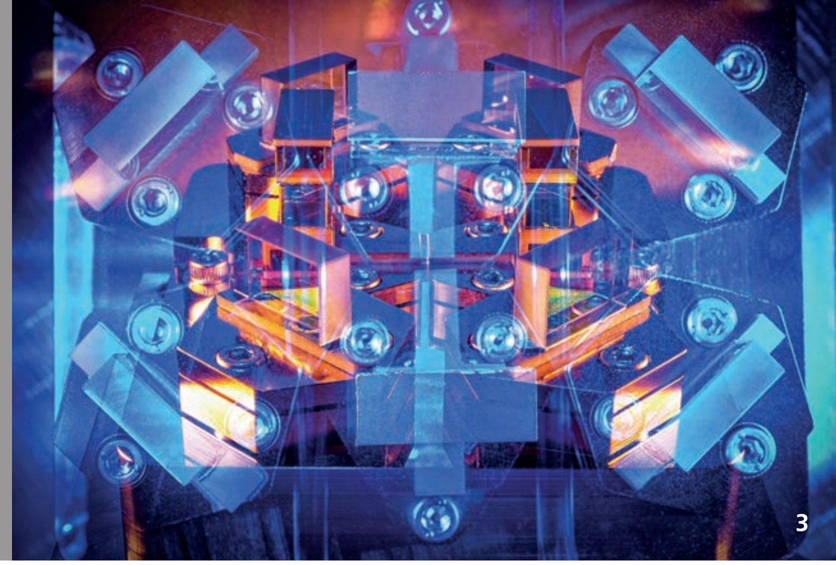
3 Geometric shape of a photonic crystal fiber preform.
4 Undercut and chip-free slit in a ULE mirror substrate with a diameter of 25 mm and thickness of 6.35 mm.







USE OF SOLDERING TECHNOLOGIES IN FIBER ASSEMBLY

Task

In addition to being used in space applications, soldering technologies for optical components are becoming increasingly important in many industrial applications. The active soldering technology developed by Fraunhofer ILT will be used to assemble fibers without the need of fluxing agents; moreover, the assembly takes place without an intermediary layer. In addition to developing the assembly process, the institute will investigate relevant beam properties in order to determine the effects of the soldering process on the properties of the fiber.

Method

With suitable active solders, fibers can be mounted on metallic and non-metallic substrates under ambient conditions. First, a process is used to wet the fiber and the surface of the substrate quickly and completely; this wetting process does not require a metallic intermediary layer. Soft solders are used advantageously to reduce thermally induced stresses.

Results

Fraunhofer ILT has been able to demonstrate the use of this innovative soldering technology in fiber assembly. Optical measurements show that in polarization-maintaining fibers, the thermally induced stresses have little effect on the beam properties of the fiber. Another advantage is the high thermal conductivity of the interface. Compared to conventional types of mounting, such as gluing or clamping, soldering technology is better able to transmit higher optical powers. The mechanical strength of the solder joints was proven by tensile tests.

Applications

Thanks to the new assembly design with active soldering, the process of fiber assembly can be made more economical and efficient. In addition to robust, temperature-resistant connections, which are free of organic materials, the innovative soldering technology makes it possible to construct long-term stable, complex laser systems for use in industry and research.

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1 Metal-fiber solder joint.

2 NA measurement of a soldered fiber.

DETAIL SIMULATION OF A PARAMETRIC FREQUENCY CONVERTER FOR THE »MERLIN« MISSION

Task

Within the Franco-German climate mission »MERLIN«, the methane distribution in the earth's atmosphere shall be measured by satellite. For this purpose, the backscatter signal of laser pulses is measured with two different wavelengths on and close to a methane absorption line. For the laser transmitter, an optical parametric oscillator (OPO) is used, which alternately converts the laser pulses at 1064 nm input wavelength to 1645.5518 nm (online) or 1645.846 nm (offline). The OPO must provide the required pulse energy (9 mJ), efficiency (30 percent) and beam quality ($M^2 < 3$) with precisely tuned beam characteristics at both wavelengths.

Method

Fraunhofer ILT will build a robust flight hardware with a mounting technology specially developed for space applications. The software tools used for the optical design of the OPO are also proprietary developments that enable a realistic and precise prediction of relevant beam properties.

Results

The detailed OPO simulation shows that the spatial beam characteristics of the OPO at the on- and offline wavelengths can differ significantly and to an extent that affects the measurement performance of the LIDAR method, if solely the pulse energy, efficiency and surface loading of the design are optimized. For example, the direction of both beam lines of sight can easily differ by more than 200 µrad while at most 40 µrad are tolerated. Only the targeted analysis and adaptation of all design degrees of freedom in the computer model make it possible to identify working points that actually fulfill all the requirements of the mission at the same time. An experimental search for this parameter set would be uneconomical and not useful when time concerns are taken into account.

Applications

The simulation tools developed by Fraunhofer ILT serve not only to optimize the MERLIN OPO but also to redesign or optimize the performance of other laser beam sources with output wavelengths from UV to MIR.

As part of the satellite project »MERLIN«, a cooperation between DLR Space Administration and CNES, Fraunhofer ILT is developing the beam source – the »Laser Optical Assembly« – of the laser transmitter on behalf of Airbus DS GmbH.

The work is being carried out on behalf of the Federal Ministry for Economic Affairs and Energy BMWi under the grant number 50EP160.

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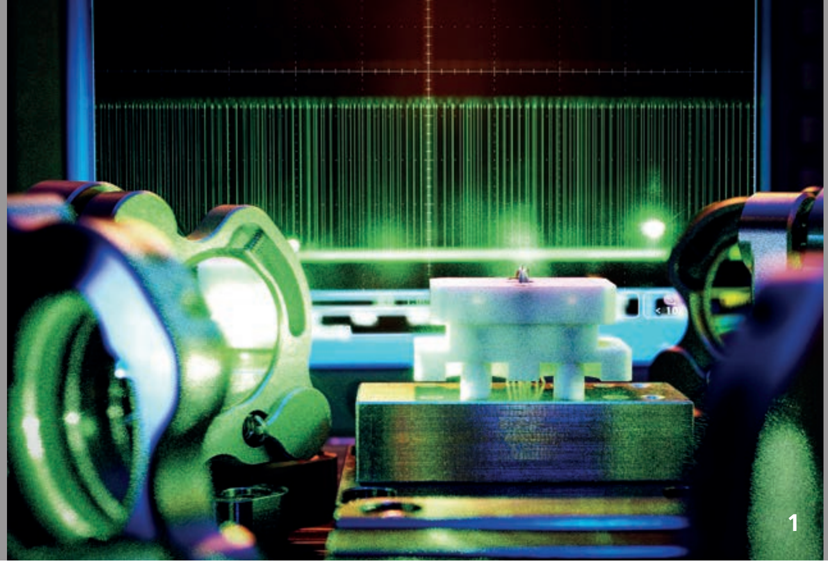
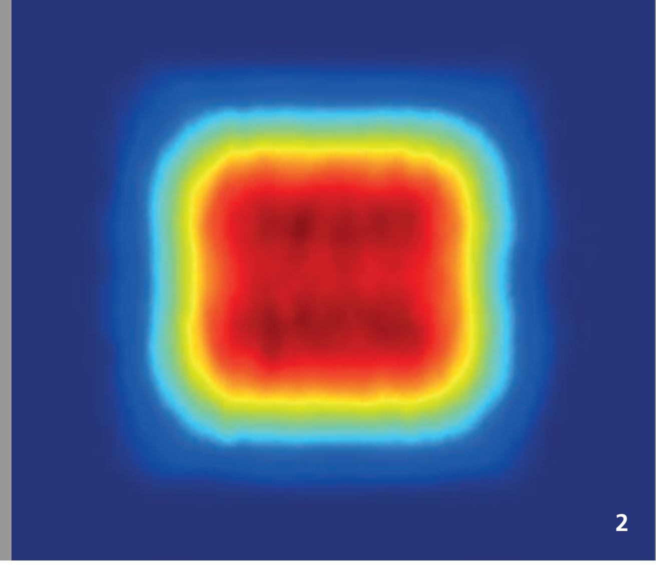
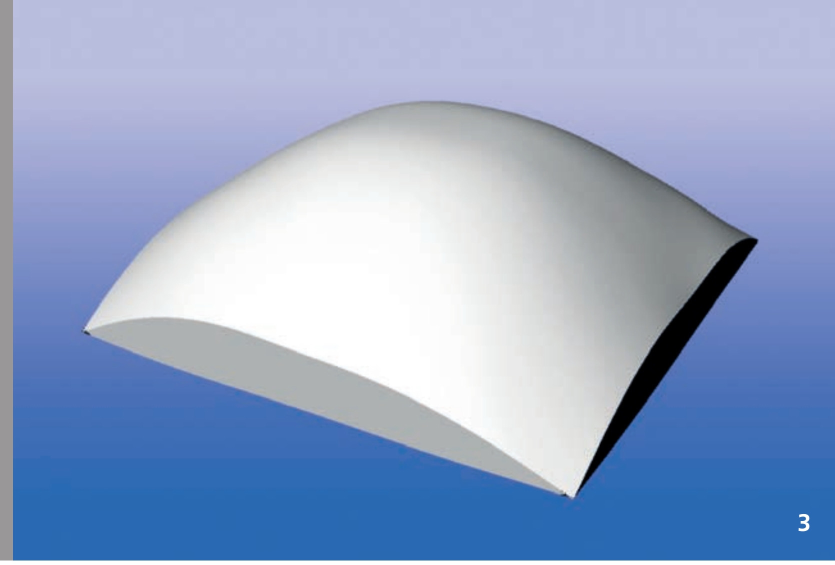
3 Technology demonstrator of the OPO.







PARAMETRIC PHOTON SOURCES FOR QUANTUM IMAGING APPLICATIONS

Task

One focus of the so-called second quantum revolution is the generation, manipulation and detection of isolated or coupled exotic quantum states. Thanks to this revolution, basic research has been able to demonstrate a number of spectacular effects that now promise a wide range of application potential. Photonic quantum states, for example, play an important role in the field of quantum sensors and communication as well as in quantum computing. In the lighthouse project »QUILT«, sponsored by the Fraunhofer-Gesellschaft, Fraunhofer ILT is developing, among others, parametric photon sources for mid-infrared (MIR) imaging applications.

Method

Quantum imaging aims to use non-classical photon states to overcome the limitations of classical optics. For example, entangled photon pairs can be used to separate interaction and detection wavelengths in imaging processes. In this case, a photon of the entangled pair interacts with the sample, while the other one is detected and provides information about the interaction of its partner via the entanglement. Such pairs of entangled photons can be generated by parametric fluorescence in nonlinear crystals and their wavelengths chosen freely; yet they can be far apart from each other. This makes it possible to use highly sensitive silicon detection for quantum imaging in the MIR.

1 Source of entangled photon pairs based on parametric fluorescence.

Results

Fraunhofer ILT has designed and built a demonstrator for generating entangled photons based on parametric fluorescence. In it, a periodically poled crystal is pumped at 532 nm with an optically pumped semiconductor laser, and photon pairs are generated at about 810 and 1550 nm. For photon pairs, rates of more than 10^6 per second could be demonstrated. In the next step, the institute will investigate the imaging process in an interferometer and test it for future application potential. In parallel, sources with even greater wavelength spacing will be used to enable imaging in the MIR.

Applications

In addition to quantum imaging applications in biology and medicine, applications in quantum computing or quantum communication and sensor technology can also be addressed with the photon sources that have been demonstrated.

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DESIGN OF FREE-FORM OPTICS FOR EXTENDED LIGHT SOURCES

Task

Thanks to free-form optics, adapted illuminance distributions can be generated for various applications. For this purpose, the optical surfaces are described by a multitude of degrees of freedom and their parameters adapted specifically and correspondingly. While methods for designing free-form optics for idealized light sources such as point sources or collimated radiation are state of the art, transmission to real light sources still presents a current challenge.

Method

To design free-form optics for real light sources, Fraunhofer ILT has implemented a design algorithm based on a description of the free-form optics by polynomials defined piece by piece (splines). This algorithm is combined with a quick calculation of the resulting illuminance distribution and a mathematical optimization. The program developed by Fraunhofer can be run on a conventional PC.

Results

For various applications, optical surfaces have been calculated in the form of lenses or mirrors, whereby different light sources such as LEDs or diode lasers can be assumed. In particular, configurations have been generated in which the idealization of a point source or of collimated radiation is no longer sufficient to describe the input radiation. The illuminance distributions thus obtained are significantly closer to the specifications than in the case of a calculation with previous design algorithms.

Applications

The implemented method can be used in various applications of lighting technology, e.g., in automotive lighting or architecture. In addition, one focus of current work is using freeform optics for application-adapted beam shaping in laser material processing.

The R&D project underlying this report was commissioned by the German Federal Ministry of Education and Research (BMBF) under grant number 13N13476 as part of the Research Campus DPP.

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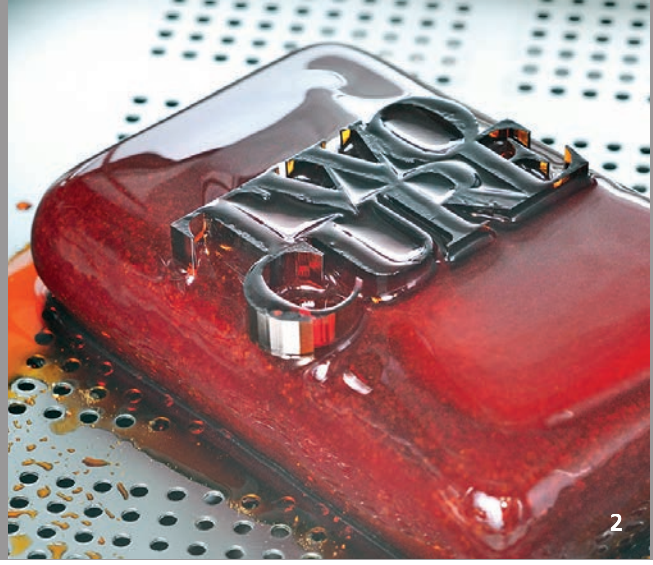
2 Top-hat intensity distribution simulated with a freeform optic for a divergent diode laser beam.

3 Freeform optic design for general lighting with LEDs.

LASER MATERIAL PROCESSING

CONTENTS

Ultrashort pulse laser for surface structuring: high-power tools for precision manufacturing.



PRINTING SUPPORT FREE WITH »TwoCure«

Task

Resin-based 3D printing typically requires support structures on the printed object, structures that support overhangs and enable complex components to be built. On the one hand, these structures require preparation in CAD, and on the other, they have to be laboriously removed after printing. For these reasons, they cause additional manual work, avoidable waste and a poorer surface. Previously, support structures were essential because the often filigree plastic structures must be supported and connected to a build platform.

Method

The »TwoCure« process developed at Fraunhofer ILT works in a similar way to stereolithography with photolithographic exposure, which triggers the layer-by-layer curing of liquid resins. In addition, the materials are solidified by cooling them below their glass transition or melting point. This is achieved using materials specially developed for this new technology and an adjustment of the process.

Results

The light engine (UV) projects the layer geometry of the component onto the (still) liquid resin layer, which irreversibly cures at the exposed areas. Due to the cooled environment (installation walls, process space and platform), the surrounding resin areas are solidified by »freezing«.

In this manner, the hardened structures can »float« support-free in the entire 3D build volume. The curing of the material is done chemically by light and the solidification of the surrounding material thermally by cold. The name »TwoCure« reflects these two types of hardening. Because completely frozen blocks are created, they can be ejected from machine and then a new print job can be started, all of which greatly simplifies the automation of the process. The components are »freed« in the last step by melting the frozen block.

Applications

The TwoCure technology is interesting for all companies that produce individual small plastic parts in large quantities or small batches. In the future, a TwoCure system can be used, for example, to automatically manufacture more than 100 individual earmolds for hearing aids, molds for jewelry production or small series for plastic components.

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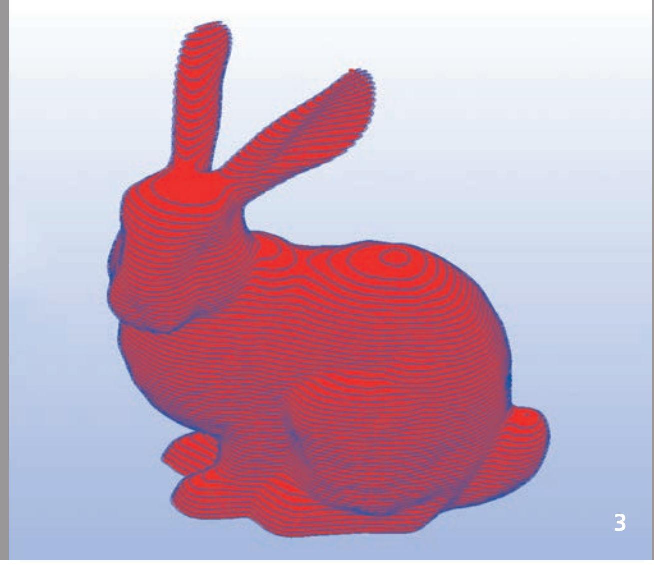
1 »TwoCure« system: cooled process chamber with dosing unit and high-resolution UV projection (50 µm, 2580 x 1650 pixels).

2 »Freeing« the components by melting the frozen block in the TwoCure process.



FAST TOOL-PATH PLANNING ALGORITHMS FOR ADDITIVE MANUFACTURING

Task

Thanks to its many years of experience in the field of CAM-NC tool path planning for laser material deposition and ablation as well as 3D printing, Fraunhofer ILT is developing software that can be used to generate tool paths from triangular networks. Its goal is to achieve the highest possible speed when processing finely triangulated geometries. The algorithms are to be provided as a library so that application developers can easily integrate them into their own software.

Method

The tool-path planning algorithms are prepared as a library with connections to the programming languages C++ and C#. Additional programming languages can be added. Internal algorithms are optimized for modern multi-core CPUs.

Results

Essential operations of the algorithms are the slicing of triangular meshes in layers and the generation of contour and hatch paths for these layers. This process is accelerated by parallelization on multi-core CPUs. For a test geometry with 350,000 triangles, the tool-path planning with commercial software takes between 6 and 40 seconds for a uniform layer thickness. With the newly developed algorithms, the tool paths are generated on a processor core in 6 seconds and on 16 processor cores with activated multi-core calculation in just 0.6 seconds.

Applications

For example, the program library can be used as a fast and flexible solution for tool-path planning for laser powder bed fusion (LPBF). A simple interface facilitates access for integration into user software. In close cooperation with the process developers, Fraunhofer ILT will add algorithms for the generation of supports tailored to LPBF in the future.

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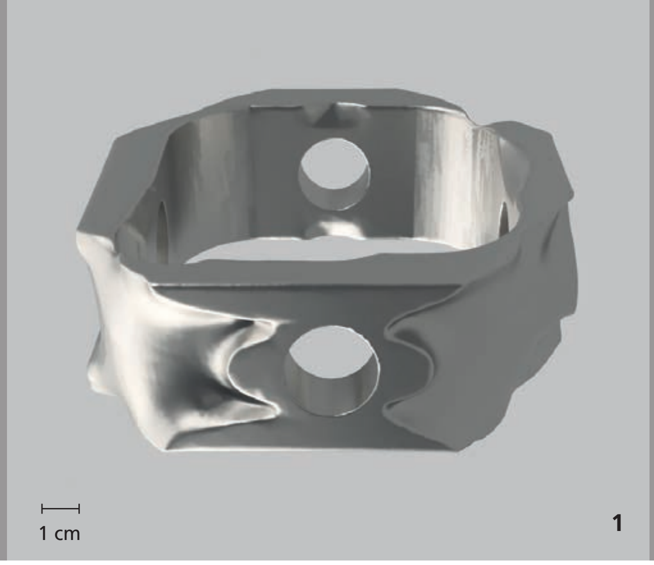
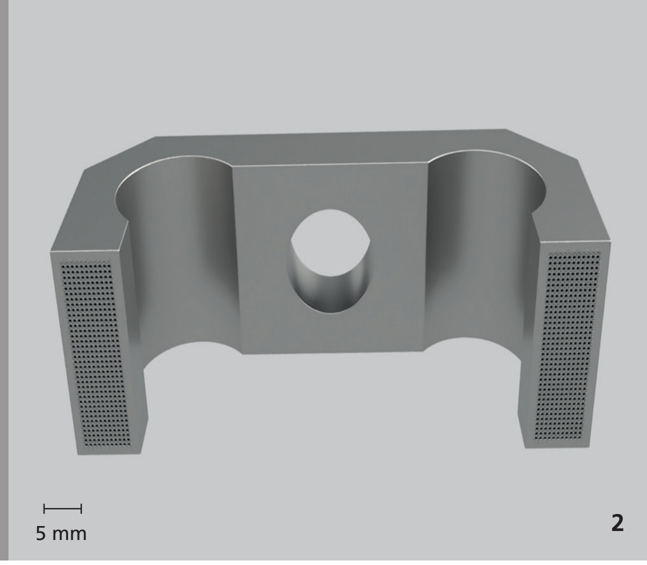
3 Generated tool paths for example geometry, contour tracks (blue) and hatching tracks (red).





WEIGHT REDUCTION OF AIRCRAFT COMPONENTS BY TOPOLOGY OPTIMIZATION OR LATTICE STRUCTURES

Task

For the aerospace industry in particular, reducing the weight of components is of great importance to achieve significant economic and environmental improvements. At the same time, the strict quality requirements, for example with regard to the mechanical properties, must be maintained.

As part of the »EMUSIC« project, Fraunhofer ILT will investigate the topic of weight reduction of aerospace components by using topology optimization or integration of lattice structures. The components are manufactured using the additive laser production process laser powder bed fusion (LPBF), which allows great design freedom.

Method

The load acting on the component is fundamental to topology optimization since it determines the distribution of forces (strain) in the component. In places with low force effects, less material is needed. Through iterative simulation (ABAQUS) steps, material is gradually removed until only the structures relevant for the function remain. The design guidelines for the LPBF process (minimum resolvable structures or maximum overhang angles) are taken into account.

The second approach is based on leaving the outer geometry of the component as is, but replacing the volume in which the effective force is low with lattice structures. With the institute's own Grasshopper plug-in, the CAD model is furnished with an internal lattice structure in order to achieve an optimal result. This method also leads to a significant reduction in the weight of the component.

Results

Two demonstrators were produced with a weight reduction of at least 30 percent each. Currently, these are being examined for their mechanical strength and compared with conventionally manufactured components.

Applications

Apart from use in the aerospace industry, the methods presented here are also suitable for weight reduction of components from other industries.

This project was funded by the European Union's »Horizon 2020« research and innovation program (grant agreement no. 690725 EMUSIC).

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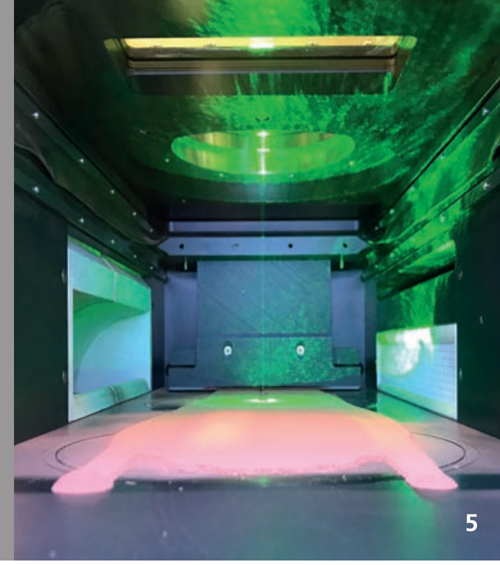
1 Topology-optimized component.
2 Sectioned component with internal lattice structures.



ADDITIVE MANUFACTURE OF HIGHLY CONDUCTIVE COPPER BY LPBF

Task

Fraunhofer ILT is currently working on a project funded by the AiF (The German Federation of Industrial Research Association »Otto von Guericke e.V.) and the DVS (German Welding Society) to implement system technology with a beam source emitting in the green wavelength range for the additive manufacturing process laser powder bed fusion (LPBF). The use of the green laser beam source makes it possible to process pure and electrically highly conductive copper. In comparison to copper alloys and other materials, pure copper is characterized by a low absorptivity for the conventionally used infrared wavelength and, due to its high thermal conductivity and low melt viscosity, poses a challenge for stable process control in LPBF's melting process. Conventionally processed copper alloys have a maximum of 80 percent of the conductivity of pure copper after additive manufacturing. However, for electrotechnical applications, full conductivity of the pure copper material is necessary to develop more efficient and functional components and to take advantage of additive manufacturing.

Method

Fraunhofer ILT characterized the available laser beam sources emitting in the green wavelength range in terms of their suitability for the LPBF process; then they were evaluated and used to develop the initial process parameters.

A systematic variation of the process parameters as well as adjustments of the powder material and shielding gas atmosphere shows how they influence the relative material density as well as the achieved material properties.

Results

By varying the process parameters, the institute was able to process pure copper using LPBF, achieving a relative material density > 99.8 percent. Controlled oxygen reduction in the atmosphere makes it possible to build up material samples that achieve the full specific conductivity of pure copper at 58 MS/m. Currently, the institute is focusing on developing process management suitable for the production of components.

Applications

Copper and its alloys are predominantly used in mechanical, plant and electrical engineering, where high electrical or thermal conductivity is required. When the advantages of additive manufacturing are fully exploited, new possibilities emerge for more efficient or functionally optimized components.

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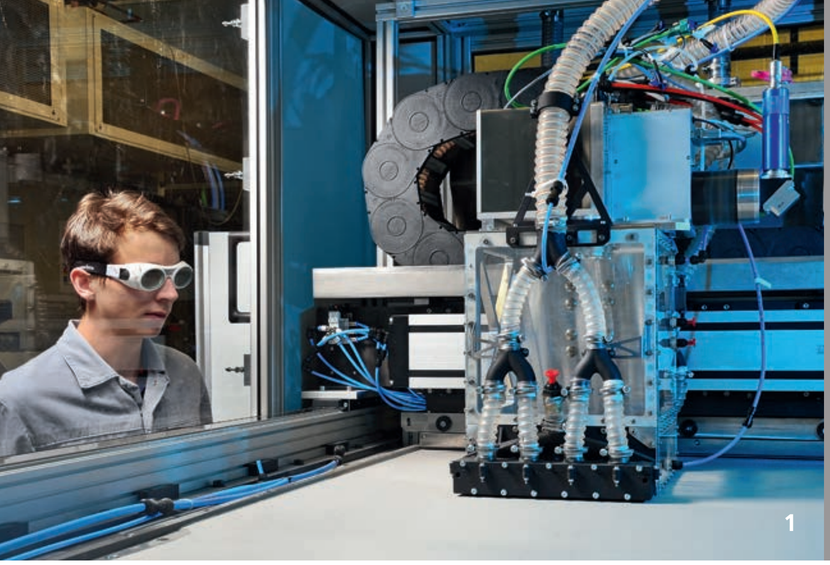
3 Induction coil made of pure copper.
4 Micrograph of a pure copper sample.
5 Process picture: LPBF of copper using green laser radiation.



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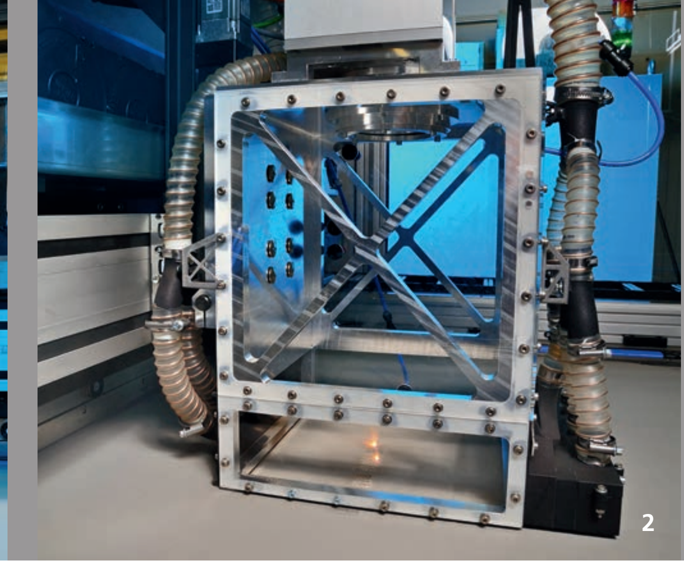

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SCALABLE MACHINE CONCEPT FOR LASER POWDER BED FUSION

Task

Currently, conventional laser powder bed fusion (LPBF) machines are restricted in terms of the size of their build volume. Critical here is the shielding gas flow, which is needed for the extraction of process by-products. As build volume increases, previous shielding gas systems no longer work effectively, which limits component quality and process stability. As part of the Fraunhofer focus project »futureAM«, Fraunhofer ILT will develop a scalable LPBF machine concept which can eliminate current limitations of the build size.

Method

The innovative machine design is based on a movable processing head equipped with local shielding gas flow and an optical system (laser scanner). The processing head is significantly smaller than the build volume and is positioned above the powder bed by means of linear axes. Thanks to the relatively small dimensions of the processing head, the shielding gas system can be set and controlled more easily than a gas flow over the entire powder bed. Thus, an increase in build volume does not require an adaptation of the shielding gas system; solely the axis system must travel longer distances.

Results

To test the machine concept, Fraunhofer ILT developed and built a prototype machine with a build volume of 1,000 x 800 x 500 mm³. On the basis of CFD simulations, components for the local inert gas guidance were designed. With regard to the coupling of linear axis scanner and laser scanner system, the institute has developed a control system and methods for data preparation for LPBF with a movable processing head. In manufacturing tests, the quality of the protective gas flow was proved to be independent of the machining head position in the build volume. In addition, processing strategies for the new kinematics concept were developed and the achievable accuracies and component properties determined.

Applications

With the developed machine and process technology, comparatively large LPBF components can be produced reliably. The insights gained can be transferred to the development of novel commercial systems. The work was carried out as part of the Fraunhofer focus project »futureAM«.

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1 LPBF machining head and process.

2 Building space of the prototype machine.

INFLUENCE OF THE GALVANOMETER SCANNER ON LASER POWDER BED FUSION PROCESS TIME

Task

In laser powder bed fusion (LPBF), highly complex components are produced layer-by-layer by melting the starting material, which is in powder form. The laser radiation is typically positioned over two movable mirrors of a galvanometer scanner in the xy plane to selectively melt the powder. It is known that the non-productive times of the scanner (including jump times and drag delay of the mirrors) have an influence on the process time. As part of a series of tests, Fraunhofer ILT is investigating various types of galvanometer scanners and their influence on the LPBF process time and component quality.

Method

In the examinations, the institute uses three different scanners with different apertures (one 30 mm, two 14 mm) - and thus different sizes and inertia of the mirrors – as well as various control technologies (constant control parameters, dynamic adjustment of the control parameters in the process). With each scanner, identical test components of varying complexity are manufactured with the same process parameters from stainless steel 1.4404 by means of LPBF. The components were examined quantitatively with regard to the resulting process times and qualitatively with regard to the detail resolution of the manufactured components.

Results

As component complexity increases, the processing times between the scanners differ significantly. While the process time from the 30 mm to 14 mm aperture (constant control parameter) is reduced by approx. 5 percent for simple cube geometries, this reduction increases to 28 percent in a complex lattice structure typical of LPBF. With 14 mm aperture scanner and dynamic adjustment of the control parameters, the process time can be reduced by a further 20 percent from a 14 mm aperture scanner with constant control parameters. The manufactured specimens have no visible differences among each other with regard to detail resolution or surface roughness.

Applications

The findings can be used in the design of the optical systems for LPBF systems and make it possible to optimize the control parameters of existing optical systems. In both cases, there is great potential for increasing efficiency, especially when complex components are manufactured.

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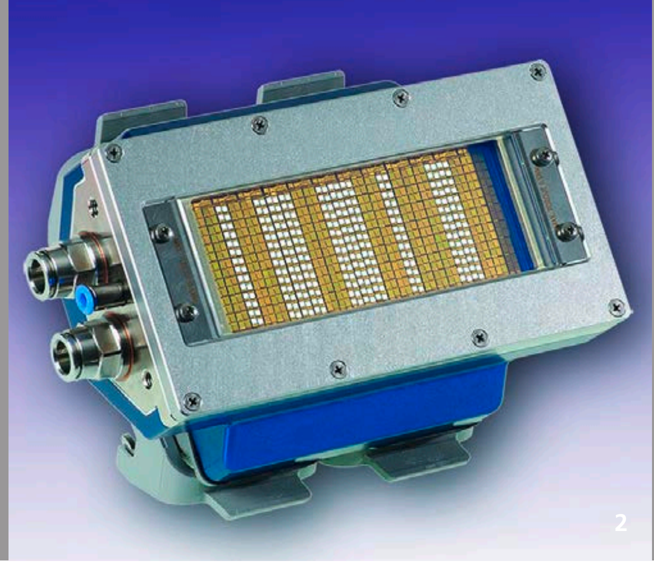
3 Galvanometer scanner »excelliSCAN 14« with dynamic control, source: Scanlab GmbH.

4 Test specimens made with different scanners.



VCSEL PREHEATING FOR LASER POWDER BED FUSION

Task

A preheating system is commonly used in laser powder bed fusion (LPBF) to process crack-susceptible materials and reduce component distortion. Preheating reduces thermal gradients and, thus, internal stresses. Conventional preheating systems heat the substrate, but are insufficient due to the layered process inherent in LPBF: the distance between substrate and working plane increases in the course of the process, whereby the temperature decreases in the working plane. To compensate for this, the substrate temperature is increased. However, the melting temperature of the substrate must not be exceeded, so that in the final analysis the build height is limited.

As part of the Digital Photonic Production DPP research campus, Fraunhofer ILT and the Chair for Technology of Optical Systems TOS at RWTH Aachen University and Philips Photonics GmbH are investigating the use of vertical-cavity surface-emitting lasers (VCSELs) for direct pre-heating of the working plane.

Method

The core of the 808 nm wavelength VCSEL module used is made of six single emitters consisting of thousands of synchronized micro diode lasers. The laser power per emitter can be adjusted in two zones for each. These individually controllable emitters have 400 W and enable an adapted energy distribution in the working plane. The module was installed in an LPBF laboratory system with inductive preheating system. An infrared camera was used to measure the temperature of the working plane. With this setup, samples were made for density and distortion measurement.

Results

At 500 °C substrate plate temperature, the difference between the substrate plate and the component surface of Inconel 718 ($\Delta T_{BT, SP}$ = 100 °C, height 10 mm) samples can be compensated for within 20 seconds by switching on the VCSEL. Specimens made of IN718, which were preheated with the VCSEL module to T = 500 °C, achieve a density of > 99.95 percent and have a distortion of up to 2 mm less compared to room temperature processing.

Applications

With a preheating system based on VCSEL technology, it is possible to maintain consistent temperatures in the working plane regardless of the height. In addition to a significant reduction in distortion, this system can also be used to process materials difficult to additively manufacture such as TiAl with LPBF.

The R&D project underlying this report was commissioned by the Federal Ministry of Education and Research (BMBF) under grant number 13N13476.

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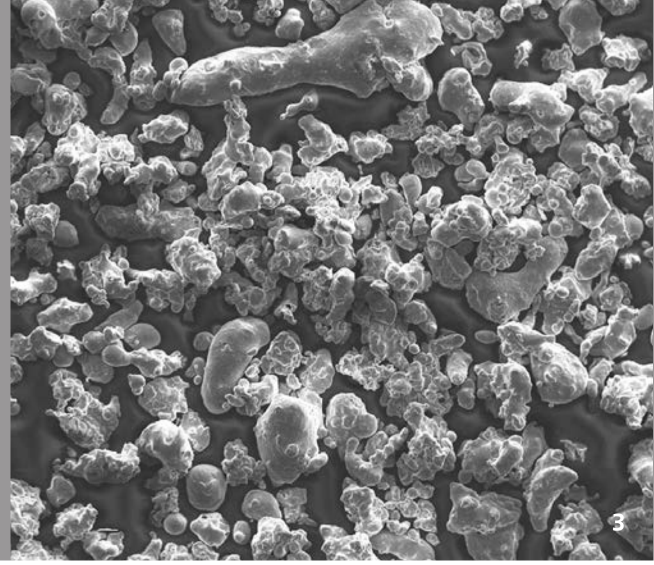
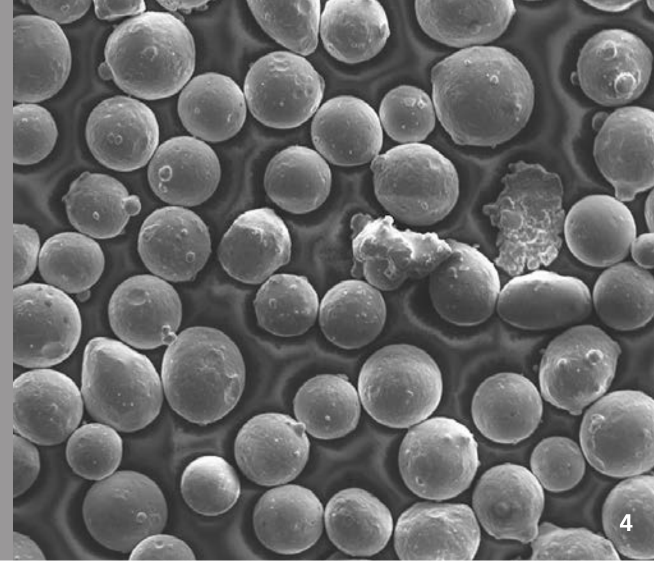
1 Exposure at local preheating using VCSEL.
2 VCSEL module, source: Philips Photonics GmbH.





INVESTIGATIONS FOR THE USE OF »LOW-COST« POWDER IN LASER POWDER BED FUSION

Task

In laser powder bed fusion (LPBF), components are produced by layer-by-layer remelting of starting material in powder form. The share of powder costs in component costs, however, will increase for future plant concepts that have significantly increased productivity. Therefore, research is investigating how low-cost powder can be used in the LPBF process. The powder characteristics (e.g. sphericity, grain size distribution) are largely determined by the powder manufacturing process. By default, gas-atomized powder is used because its higher sphericity makes it easier to process.

Method

Fraunhofer ILT is investigating how well standard powder and low-cost powder can be processed with LPBF using stainless steel 1.4404 as an example. For this purpose, two powder batches (water-atomized and gas-atomized) are first analyzed and compared in terms of powder characteristics, such as flowability or morphology. Subsequently, the materials are processed with the same process parameters on a commercially available system and the resulting component density and surface roughness of the as-built specimens are analyzed. Finally, tensile tests are made and the two types of powder are then compared.

Results

For both starting powders, the institute showed that the powders could be successfully processed, resulting in component densities > 99.5 percent. Despite distinct differences in the powder characteristics, especially in terms of flowability, no influence was found on the process window, the process stability and the resulting mechanical properties of tensile specimens. The resulting surface roughness has tended to show that the processing of water-atomized powder results in a rougher surface due to the different particle morphology.

Applications

The findings show that standard powder can be replaced by low-cost powder without having to accept a disadvantage in terms of the resulting characteristic values of the components. For industrial applications, for example, the »low-cost« powder can be used to produce components particularly cheaply, which is of particular interest to the automotive industry.

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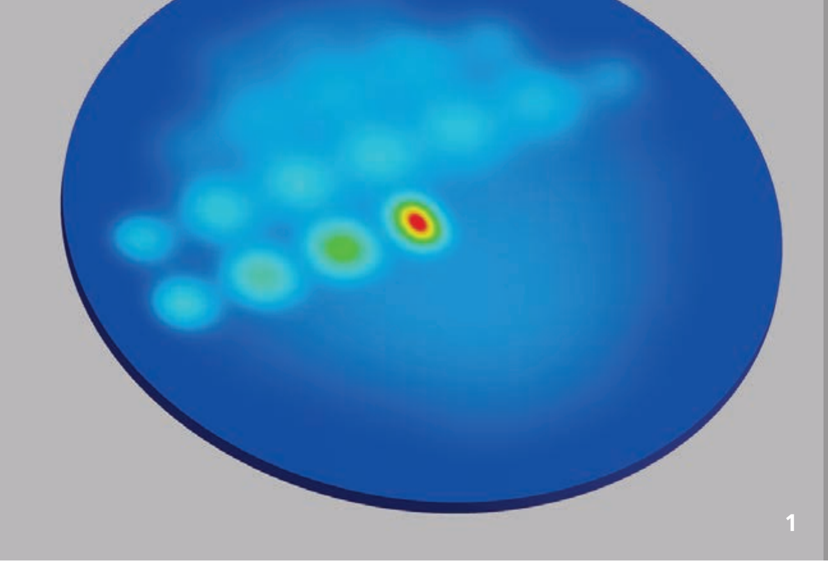
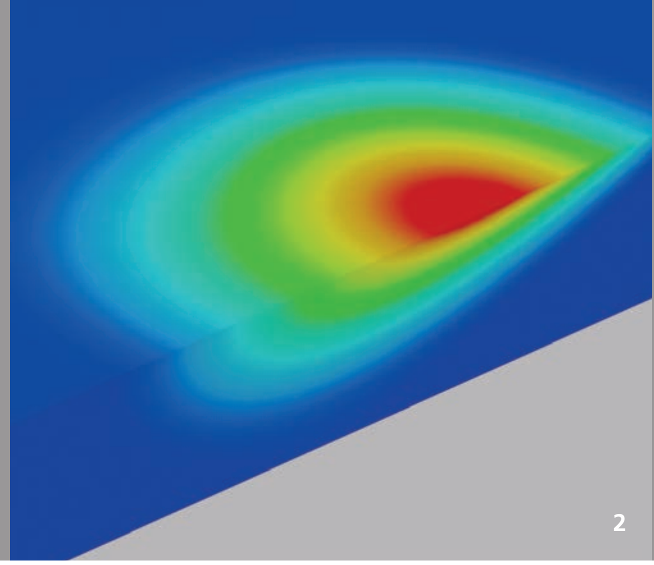
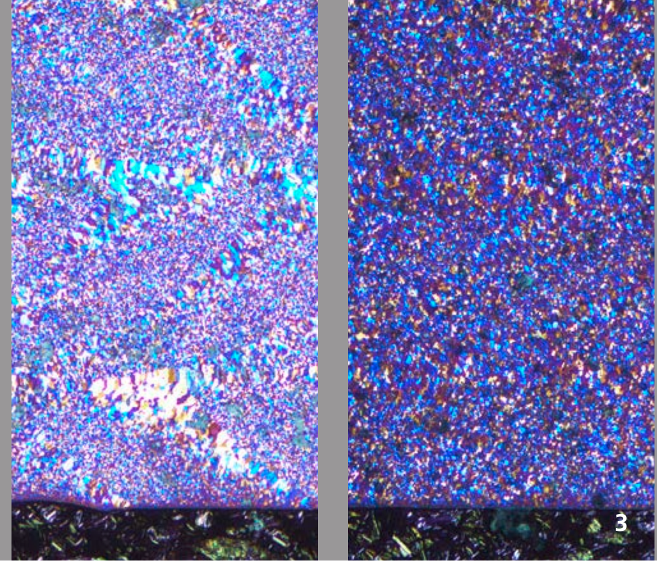
3,4 SEM images of gas- (right) and water-atomized (left) powder made of stainless steel 1.4404.







MULTIPHYSICAL SIMULATION OF THERMOOPTICAL EFFECTS IN THE LPBF PROCESS

Task

In the additive manufacturing process laser powder bed fusion (LPBF), the protective glass, which separates the optical unit from the building chamber, can become contaminated since condensate and powder particles can gather there, depending on the process and shielding gas guidance. This contamination increases the degree that the protective glass absorbs light and induces thermo-optical effects. Since the protective glass heats up, the focus position shifts and the scan vectors deviate from the desired positions, which in turn reduce process stability and contour accuracy. Due to the highly dynamic process control, the scan vectors cannot be determined experimentally. To counter these adverse effects, the Fraunhofer ILT in cooperation with the Chair for Technology of Optical Systems (TOS) at RWTH Aachen University has carried out multiphysical simulations to evaluate such thermal influences.

Method

The processing of cube structures is modeled in a multiphysical simulation. The optical system consists of a variable focusing optics and a galvanometer scanner. By coupling thermomechanical finite element analysis (FEA) and optical analysis with ray tracing, scientists at ILT/TOS can analyze how the transient heating of the protective glass influences the focus position. The simulations investigate the influence of contaminated protective glass. The assumed degree of absorption is 0.5 percent. In addition, the distance between galvanometer scanner and protective glass is varied.

Results

If the protective glass is placed approx. 40 mm behind the galvanometer scanner, the thermally induced focus shift of approximately one Rayleigh length is approximately eight times greater than if it is placed halfway between the scanner and the powder bed. The reason: the thermal load on the protective glass is spatially and temporally more evenly distributed in the second case than in the first. In addition, the simulations predict a shift in the scan vectors. For cubes at the edge of the construction field, the shift amounts to seven track distances. In addition, thermo-optical effects cause a shrinkage of the cube area by about 2 percent.

Applications

The multiphysics simulations help to make the LPBF process more robust and optimize scanning strategies for reducing thermo-optic effects.

The R&D project underlying this report is being carried out under the grant number 13N13710 as part of the »Digital Photonic Production DPP« research campus.

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1 Temperature distribution of the protective glass calculated by FEA.

2 Detailed view of the temperature distribution.

LASER MATERIAL DEPOSITION OF AL-MG-SC-ZR ALLOYS MODIFIED WITH NANOPARTICLES

Task

Al-Mg-Sc-Zr alloys are well suited for additive manufacturing (AM) technologies with their inherent high cooling rates because they have grain refining and precipitation hardening properties. However, the scope of these alloys is limited because the cost of scandium is so high. To lower the price, an aluminum matrix composite can be produced by adding ceramic nanoparticles to reduce the Sc content. In the place of scandium, the nanoparticles should serve both as nuclei for the aluminum matrix structure and hinder the movement of the lattice dislocations. A sub-target of this research is to produce a modified composite powder with a suitable process capability for laser material deposition.

Method

Fraunhofer ILT prepared a composite powder of TiC nanoparticles and an Al-Mg-Sc-Zr alloy (AA5024) having an Sc content of 0.4 wt% by mechanical alloying while varying the addition amount of the nanoparticles and the mechanical alloying time in a ball mill . Evaluation criteria for the powder are sphericity, particle size and nanoparticle distribution in the powder mixture. Volume built-ups were produced by laser material deposition to develop suitable process windows for defect-free processing.

Results

When the amount of nanoparticles and the mechanical alloying time are varied, suitable composite powders for laser material deposition can be produced. Volume build-ups with a density of more than 99.8 percent could be manufactured by adjusting the process parameters. The uneven grain structure within the solidified melt pool, which is typical for the additive production of Al-Mg-Sc-Zr alloys, could be clearly homogenized by the addition of nanoparticulate TiC during laser material deposition.

Applications

Laser material deposition can be used to additively manufacture samples, defect-free, out of Al-Mg-Sc-Zr alloys with TiC nanoparticles. Future application areas for AM are to be seen where complex lightweight design must be combined with high mechanical strength, such as in aerospace and automotive engineering.

The work was carried out as part of a Sino-German Research project under grant number GZ 1217.

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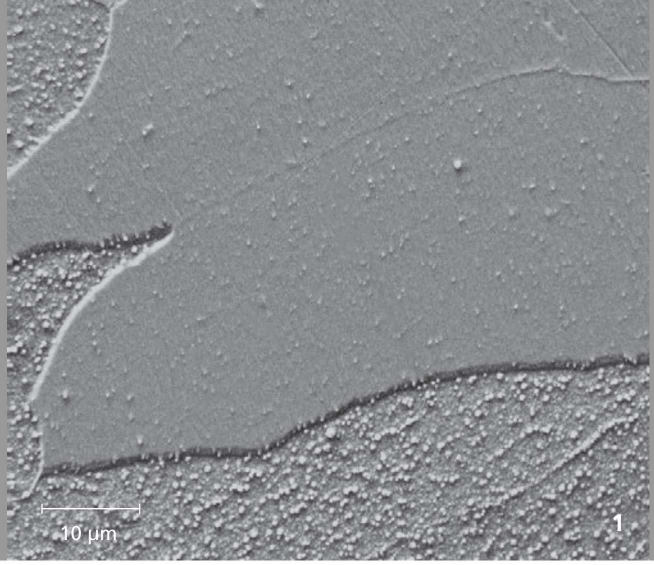
3 Grain structure of the samples without (left) and with TiC (right).

4 Solid body out of AA5024 without (left) and with TiC (right).



ADDITIVE MANUFACTURE OF NANOPARTICULAR-REINFORCED MATERIALS

Task

Nanoparticle-reinforced alloys are composite materials that consist of nanoscale, ceramic particles embedded in a metallic matrix. Since the ceramic particles are distributed homogeneously, this class of materials offers not only high strength and excellent creep resistance in the high-temperature environments, but also increased resistance to high-energy neutron radiation in nuclear reactors. In cooperation with the Max-Planck-Institut für Eisenforschung (MPIE), Fraunhofer ILT is developing the process technology using the additive manufacturing processes laser material deposition (LMD) and laser powder bed fusion (LPBF) as an alternative to the conventional powder-based metallurgical production route.

Method

On the basis of a steel alloy, the partners have developed a process chain using LMD and LBPF; the chain consists of a short grinding process for producing a powder composite of metallic and ceramic powder materials (for example, Y_2O_3, starting size approx. 45 nm) and of a subsequent final consolidation via laser based additive manufacturing.

Results

The process times for producing a powder composite with a grinding process were significantly reduced so that a powder material suitable for additive manufacturing processes could be produced. LMD was used to produce dense bodies with homogeneously dispersed ceramic particles with diameters from 50 to 150 nm. The enlargement of the particles is caused by agglomeration, yet materials strength in the high temperature regime increases significantly. In LPBF, particles of a few nanometers in size are also found in a homogeneous distribution so that increased radiation resistance is to be expected in addition to a further increase in materials strength.

Applications

The field of application lies primarily in nuclear technology, for increasing radiation resistance, but also in turbomachinery, for enhancing the creep strength of turbine blades along with good corrosion resistance.

The work is being funded jointly within the framework of the strategic Fraunhofer/Max-Planck cooperation.

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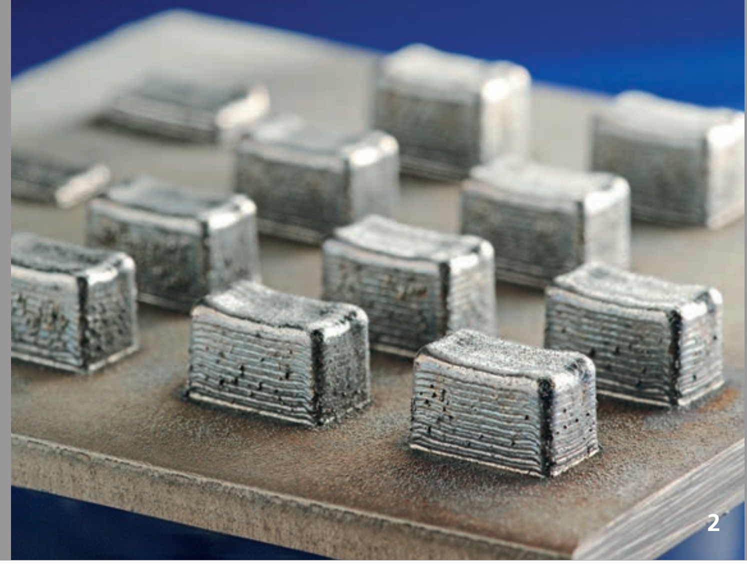
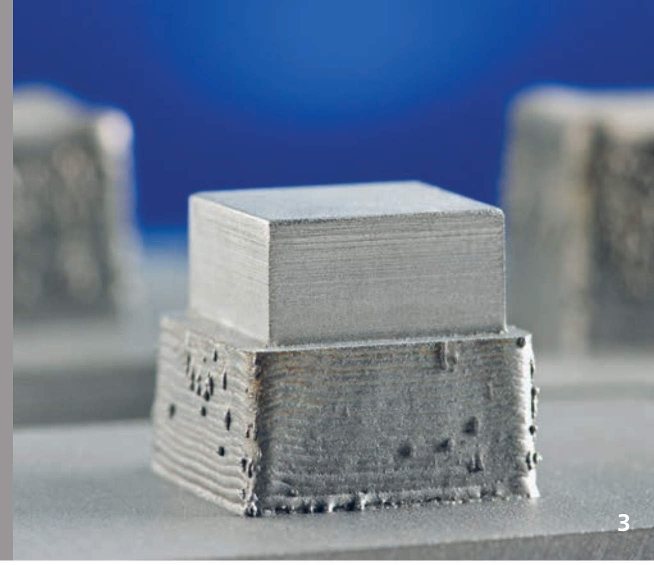
1 Finely dispersed Y_2O_3-based nanoparticles in a steel matrix after consolidation by LMD, source: ACCESS e.V..





LASER MATERIAL DEPOSITION AS A METHOD FOR RAPID ALLOY DEVELOPMENT

Task

Today, it normally takes many years to introduce a new alloy to the market, from the first screening to the finished component. Powerful software tools to simulate promising alloy compositions and their properties have accelerated the development process. To validate this simulation, the production of test specimens by casting, however, still consumes a great deal of time and material. Here, an additive process can significantly accelerate the screening with minimal use of materials.

Method

Thanks to powder-based laser material deposition (LMD), a tool for rapid alloy development (RAD) is established, one that uses powder blends to rapidly make numerous alloys as solid bodies. The different alloy variants are mixed in advance from element powders or fed directly into the process via two or more powder containers. The latter also makes it possible to produce various compositions in a single test specimen by grading. The powder mixture is completely melted in the laser beam so that the alloy is formed during solidification. Within a few hours, about 20 to 30 smaller specimens (e.g. 10 x 10 x 10 mm^3) of different compositions can be produced.

Results

The process has already been successfully used to make various alloys (including high entropy alloys, Fe-Si, high manganese steels). The microstructure of the test specimens was analyzed and their properties were also evaluated, but they were also subject to, if necessary, additional process steps such as heat treatment or forming processes.

Applications

An essential area of application is the development of process-adapted materials for additive manufacturing. So far only a few materials have been qualified for this still young production technology. Other fields of application include the screening of novel alloys (e.g. high entropy alloys) for a first property evaluation or the development of high-performance materials for turbine components (e.g. silicides).

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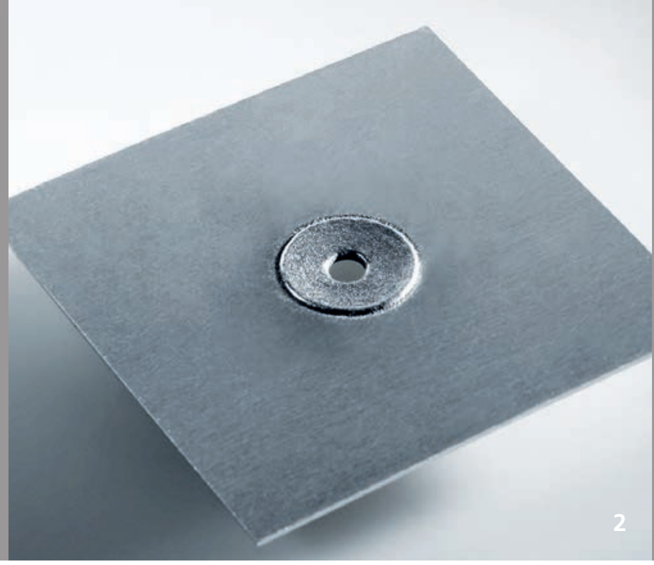
2 Test specimens of different compositions constructed with LMD.

3 Test specimens for compression test (partially mechanically reworked).



LOCAL REINFORCEMENT OF SHEET COMPONENTS THROUGH ADDITIVE MANUFACTURING

Task

Today, load-adapted sheet metal components are often made out of tailored blanks. For smaller series, a freely configurable, additive applied reinforcement, which has a full metallurgical connection to the base plate, provides an alternative. The combination of sheet metal forming and additive manufacturing makes it possible to produce load-adapted variants based on serial components without modification or new production of forming tools. The method can be used before or after the forming. In cooperation with the Chair of Design and Production of the Brandenburg University of Technology Cottbus-Senftenberg, Fraunhofer ILT has been developing process foundations for the local reinforcement of thin metal sheets.

Method

The optimal shape of a reinforcement structure (patch) can be determined by simulation of the load case. Laser material deposition (LMD) is then followed by local production or application of the patch on the same or similar material. The process is adjusted for high order rates and minimal distortion. The patches are examined for mechanical properties and formability. The materials to be investigated are steel (ZE630) and aluminum (Al6016) with sheet thicknesses of 2 and 1 mm, respectively.

Results

When the sheets are cooled and clamped, the distortion can be minimized. Post processing the applied patches is not required for the forming. On simple specimens, the stiffness increase can be proven. The transferability to real components has been checked, based on demonstrator components (steel gearbox housing and aluminum collar flange).

Applications

The findings gained from the project can be used for future applications in the automotive industry, but also in the aerospace industry.

The R&D project underlying this report was commissioned by the Federal Ministry for Economic Affairs and Energy BMWi at the AiF under grant number 1929BG.

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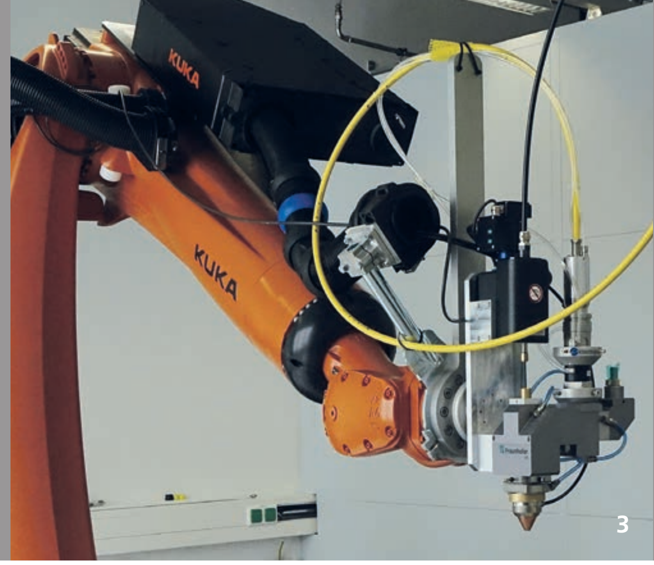
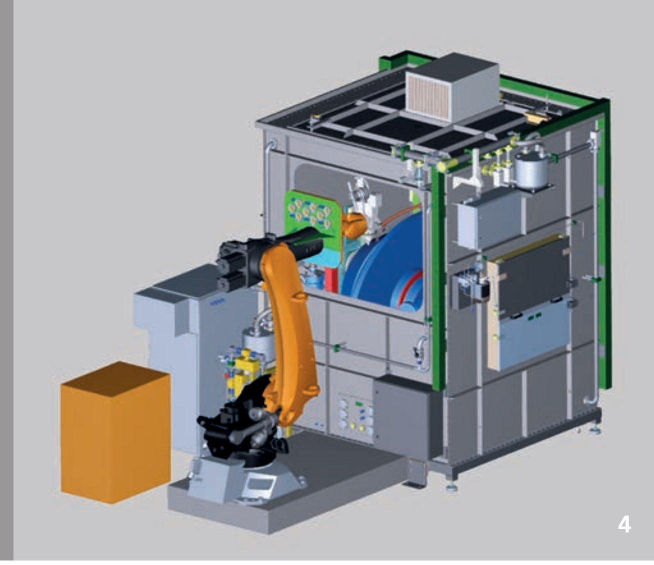
1 Reinforcement of an aluminum collar flange using LMD.

2 Reinforced collar flange before forming.





ROBOT-BASED HYBRID ADDITIVE MANUFACTURING

Task

In the future, new approaches will be needed to produce components with increasing complexity, but also cost and resource efficiently. A promising concept to accomplish this is the combination of conventional and additive manufacturing processes. This so-called hybrid additive manufacturing is being qualified at the Fraunhofer ILT as a cost-effective, flexible and high-quality process. In order to enable economic use, Fraunhofer ILT is developing suitable processes as well as robot-based system technology and software solutions in the BMBF-funded project »ProLMD«.

Method

Laser material deposition (LMD) is a process suitable for hybrid additive manufacturing because it has geometric flexibility and can use a wide range of alloys. In the ProLMD project, Fraunhofer ILT is investigating LMD processes with increased deposition rates of up to 2 kg/h and additives in wire and powder form as well as the local functionalization of conventionally manufactured components.

The use of robot-integrated, geometric measurement technology is intended to implement precise adaptive path planning for the deposition process. For this purpose, the ProLMD consortium is developing an innovative robot-based system setup with a flexible shielding gas solution as well as a novel processing head for laser material deposition. Processes are being developed for materials such as iron and nickel based as well as titanium alloys.

Results

Robot-integrated line scanning for digitization and quality assurance was successfully demonstrated. After the path accuracy of various robot configurations was investigated, one configuration was set up and tested with a flexible inert gas cell. Fraunhofer ILT has already manufactured and analyzed material samples with build rates of up to 1.5 kg/h. An adapted adaptive CAM solution is currently under development.

Application

The hybrid additive manufacturing processes have been studied for use in aerospace, tooling and turbo machinery, but can also be applied in many other applications.

The R&D project underlying this report is being carried out on behalf of the Federal Ministry of Education and Research (BMBF) in the program »Innovations for the Production, Services and Work of Tomorrow«.

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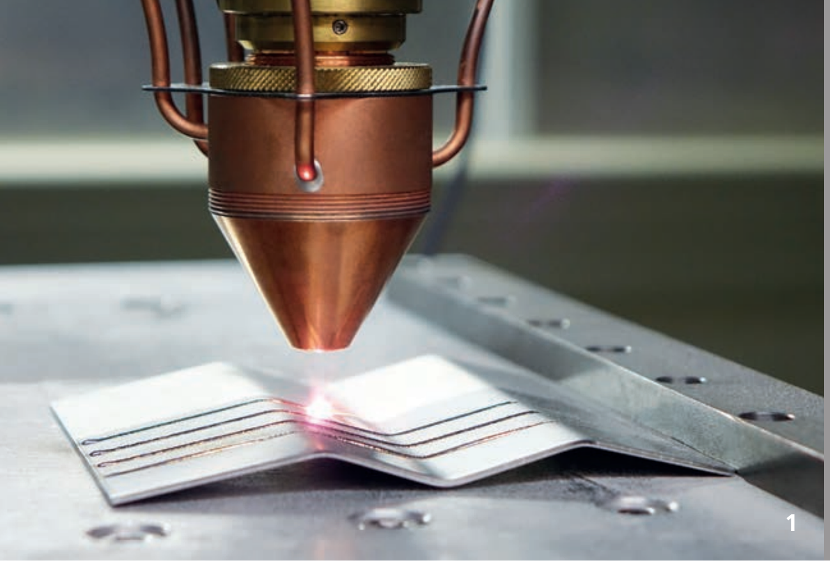
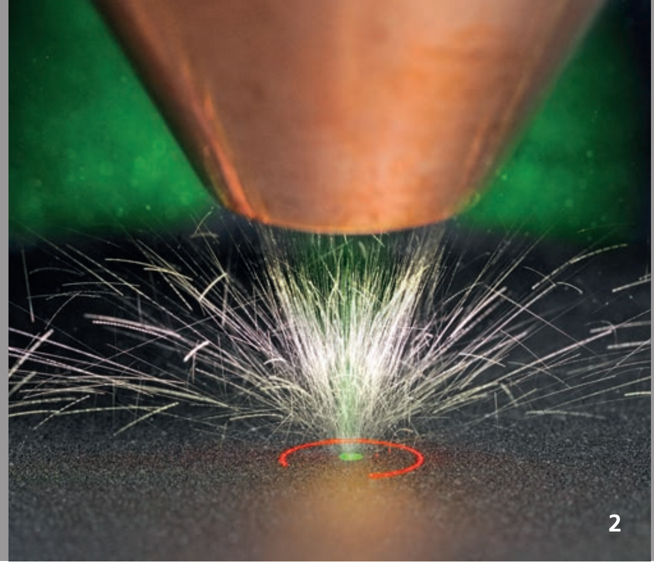
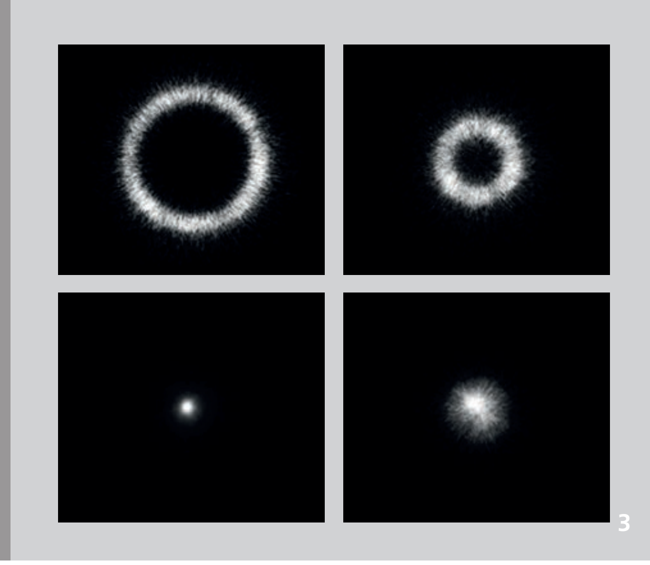
3 Robot test cell with ProLMD machining head.

4 CAD model of a flexible shielding gas cell.







TESTING AN INLINE MEASURING SYSTEM FOR DISTANCE MEASUREMENT IN LASER MATERIAL DEPOSITION

Task

When laser material deposition (LMD) is set up, the working distance is typically determined and adjusted mechanically by means of various gauges. A disadvantage of this method is its limited applicability. It can only be used with good accessibility and not during the LMD process itself. Fraunhofer ILT has tested a newly developed coaxial in-line measuring system as to whether the distance to the surface can be detected during the process.

Method

The distance detecting system consists of an interferometric laser measuring system guided coaxially through the processing head. The measuring beam is projected as an ellipse around the processing point (Figure 2, red line) with a rotating mirror. As a result, the distance to the surface at all points of the elliptical orbit can be determined. The project aims to determine how robust the measuring system is against interference caused by the LMD process. For this purpose, Fraunhofer ILT investigated the extent to which the measurement was impaired by the injected metal powder and the process radiation. Subsequently, in a laboratory test, a distance control was implemented on an LMD robot system and tested on a demonstrator component (Fig. 1).

1 LMD process with distance control.

2 Projected ellipse of the measuring beam around the process point.

Results

The inline measuring system proves to be tolerant to disturbances caused by the LMD process. At powder feed rates of up to 100 g/min for IN718 powder, the distance can still be determined. The track geometry could be successfully measured offline and the distance control online during an LMD process with 750 W laser power in the laboratory on the demonstrator component. The measurement of the control resulted in a distance deviation of ± 0.1 mm, which is sufficiently accurate for the LMD process.

Applications

Since the distance is measured along a contour rather than just a single point, the surface can be scanned online around the process point during the process. Thus, the distance in front of the process point as well as the achieved track height can be measured simultaneously. Based on this data, for example, a control of the layer thickness can be installed. The system has particular advantages for inaccessible areas, distance-sensitive processes and components with deviations from the desired geometry (CAD data).

This project was funded by the internal MEF program of the Fraunhofer-Gesellschaft.

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POWDER JET MONITOR

Task

In powder-based laser material deposition, the supply of filler material into the melt pool plays a crucial role. It influences the dimensional accuracy of the applied layer, the quality of the layers and volumes produced as well as the cost-effectiveness of the process. Both the adjustment and wear state of the powder feed nozzles used and the parameters of the powder feed – such as particle size of the powder, powder mass flow and conveying or protective gas streams – determine the formation of the powder gas jet. In order to ensure high process quality, there is a need to characterize and document this tool, the »powder gas jet«.

Method

Fraunhofer ILT has developed a method that allows users to calculate parameters for characterizing a powder gas jet on the basis of the particle density distribution. The method can be used, on the one hand, to determine the position of the powder focus relative to the nozzle tip and, on the other, the diameter of the particle distribution. To use the method, the institute has developed a system based on industrial standards, one that makes it possible to carry out the measurement automatically. The standardization and automation of the measurement process is the prerequisite for users to compare characteristic features of the powder feed.

Results

For the first time, the measuring method makes it possible to fully characterize a powder gas jet. On the one hand, this allows the certification of coaxial powder feed nozzles and, on the other, investigations on influencing variables on the powder gas jet. This way, an industry-standard system is provided for measuring the tool, »powder gas jet«.

Applications

Areas of application include all activities in the field of laser material deposition, where exact knowledge of the powder gas jet is required, such as in the process and nozzle development and the production of components.

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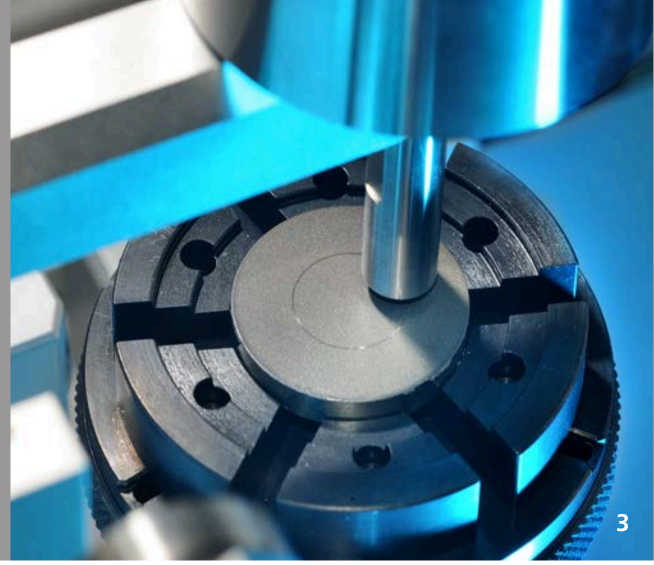
3 Particle distribution in different distances to the nozzle tip.

4 System for measuring the tool »powder gas jet«.



EVEREST – INTELLIGENT PROCESS AND SYSTEM TECHNOLOGY FOR THE EHLA PROCESS

Task

The aim of the »EVEREST« project is to develop intelligent process and system technology for future production machines for resource effective coating, repair and hybrid additive manufacturing of components using the EHLA process (Extreme high-speed laser material deposition), an innovative variant of laser deposition welding.

Method

The work focuses on developing suitable process parameters and coating and build-up strategies for coating and repair as well as for hybrid additive manufacturing, e.g. of sealing surfaces. Here, Fraunhofer ILT is investigating layers with thicknesses of 50 to 300 µm and process speeds in the range of 20 to 200 m/min. In the field of system development, hardware and software modules are being developed that enable a robust, economical and highly flexible EHLA process. Central modules of the project are the optical acquisition of geometric features of components and applied layers, a CAM module for adaptive path planning and a module for process monitoring. The CAM module makes it possible to intelligently respond to geometric deviations from the target state.

Results

Two corrosion-resistant nickel- and cobalt-based powders were selected for the coating process and suitable process parameters were developed to produce metallurgically bonded, dense and crack-free coatings. For repair and additive manufacturing applications, process parameters have been developed for an iron-based powder with which defect-free solid bodies can be produced: volumes that meet or even exceed the requirements for static-mechanical properties.

Applications

In addition to the paper and chemical industries, EHLA has the potential to adequately meet the challenges of various industries, such as in the offshore sector, automotive or aerospace – in terms of quality, time and costs.

This project is being funded by the European Regional Development Fund (ERDF) under grant number EFRE-0800790.

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1 Cooling roller (ø = 1830 mm, length = 5900 mm), source: DRINK & SCHLÖSSERS GmbH & Co. KG.

2 Coating of a shaft using EHLA.

TRIBOLOGICAL COATINGS FOR METALLIC 3D COMPONENTS

Task

A variety of individual components, especially in the machinery and automotive industry, are subject to friction and wear stress; reducing it presents great challenges. Since conventional coatings based on bonded coatings often no longer meet the industry's growing requirements, in particular with regard to temperature and wear resistance, there is a need for innovative and sustainable coating concepts and processes. Tribological coatings constitute one possibility to significantly increase the service life of the components and increase process efficiency.

Method

In cooperation with partners from the industry (ELB, Arges), Fraunhofer ILT is developing a laser process and the corresponding plant technology for coating 3D components made of light metal. First, in powder form or as a dispersion, the high-performance polymer polyetheretherketone (PEEK) is applied to the component by spraying or printing. In a subsequent method step, the PEEK layer is melted with laser radiation. Thanks to the temporally and spatially controllable energy deposition, in contrast to conventional furnace processes, the component does not need to be completely heated to temperatures above the melting temperature of PEEK (340 °C). Thus, it is possible to selectively coat temperature-sensitive components.

Results

Using the innovative laser process, Fraunhofer has produced dense and adherent PEEK coatings on aluminum components. In tribological studies, the laser-based coated test specimens show a greater wear resistance of up to a factor of 50 compared to conventional antifriction coatings; Friction coefficients < 0.1 are generated. In addition, the energy required to functionalize the layers can be reduced by up to 90 percent compared to furnace processes.

Applications

The developed process contributes significantly to increasing not only process-side energy efficiency but also a longer service life and efficiency of mechanically stressed components. The potential fields of application include primarily mechanically stressed metal components in the machinery and automotive sector (e.g. pistons or bearing shells). The R&D project »TriboLas3D« underlying this report is being carried out on behalf of the Federal Ministry of Education and Research BMBF under grant number 01LY1601A-C.

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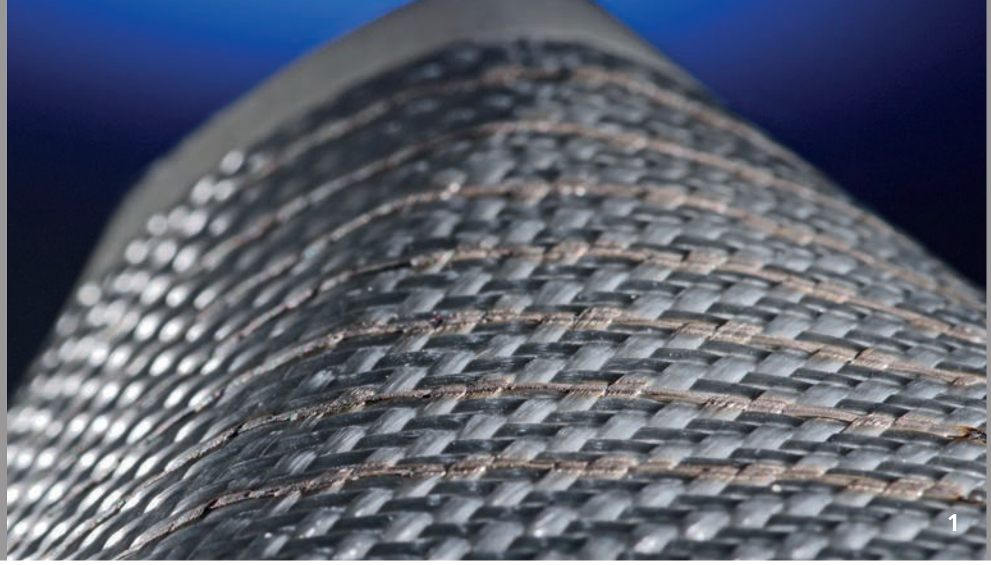
3 Tribological analysis of the coated specimens.

4 Selective laser processing.



ADDITIVE MANUFACTURING OF ELECTRICAL FUNCTIONAL LAYERS IN FIBER COMPOSITES

Task

As the demand for fiber-reinforced composite materials (FRP) grows and functional integration in components (»Internet of Things«) advances, there is an increasing need for integrated sensors for this material class. To date this has been achieved, for example, by placing prefabricated sensors in the composite material or by manually attaching them to components. These processes represent a major cost factor, however, due to their poor automation and negative effects on mechanical properties; in consequence, critical components must be dimensioned larger. When such functions are integrated through automated, digital printing and laser processes, manufacturing can be accelerated and done cheaper. In addition, new features such as moisture measurement can be integrated into products.

Method

In order to integrate such functions into FRP, researchers of Fraunhofer ILT have developed laser processes that, in combination with digital printing processes (e.g. dispensing, aerosol jet), enable sensors, heating elements and the required electrical interconnects to be manufactured on semi-finished products (fiber fabrics) or finished FRP components. For this purpose, functional materials are first printed onto glass fiber fabrics and then thermally treated by means of laser radiation (hardened, sintered, etc.). These modified fiber fabrics are subsequently incorporated into a fiber composite by a partner, such as Fraunhofer IFAM. Alternatively or in combination, the finished FRP component's surface is laser pretreated, functional materials are then printed and finally post-treated by means of laser radiation.

Results

By combining digital printing and laser techniques, Fraunhofer ILT can apply electrical functions (heaters, interconnects, sensors for measuring strain, etc.) to and into fiber composites. Compared to layers made with furnace-based post-treatment processes, the laser-based manufactured layers show better electrical properties while the thermal impact on the component is reduced. The insertion of the electrical functional layers does not impair the component's mechanical properties.

Applications

The functions produced and integrated by means of digital printing and laser processes can be used in various fields of application (e.g. automotive, aerospace). The functional layers produced with this method are particularly relevant in the area of »Internet of Things« and »Structural Health Monitoring«. The »Go Beyond 4.0« lighthouse project is financially supported by the Fraunhofer-Gesellschaft.

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1 Printed electrical interconnects produced by means of printing and laser processes on a glass fiber semi-finished product.

ADDITIVE MANUFACTURING OF INDIVIDUALIZED, EMBEDDED STRAIN GAUGE SENSORS

Task

The demand for intelligent sensors for digital solutions is steadily increasing – for use in autonomous vehicles, for the Internet of Things or Industry 4.0. The suppliers of such sensors are confronted with price erosion, increased requirements and increasing competition, all of which raise the pressure to develop new market strategies. Conventional strain gauges are mass-produced and glued onto components; gauge position and adhesive film thickness can vary, which can influence the measurement results. Conventional strain gauge production is designed for mass production so that individual sensor designs for special measuring tasks generate high costs.

Method

Fraunhofer ILT is currently developing the additive manufacturing of individualized sensors connected to the component. To accomplish this, it successively prints the necessary layers and structures of different materials directly on the component and then thermally post-treats them by means of laser radiation (sintering, melting, curing, etc.). For strain gauges, the insulation layer, measuring grid and encapsulation are applied layer by layer. A previous cleaning and activation of the surface is also possible by means of laser radiation. Due to the temporally and spatially controllable energy deposition, in contrast to conventional thermal processes, it is not required to completely heat the component (furnace) or to irradiate the entire surface (flash lamps). Thus, temperature-sensitive components can be selectively coated.

Results

Using the innovative laser process, the institute can apply printed multi-material layer systems directly on the component to produce sensors for the measurement of strains etc. Thanks to the inline-capable, automatable process and its digital nature, individual measuring grid geometries down to lot size 1 can be generated without the need for masks or tool change. The coating is possible on polymers, glass and also metals.

Applications

Strain gauge sensors are used wherever mechanical load conditions should be measured and production equipment and sensitive products protected against mechanical overload. The data can be used for a wide spectrum of applications: to increase the productivity or quality of the production systems, to plan maintenance cycles, to monitor load scenarios or even just discrete conditions of loads (on/off).

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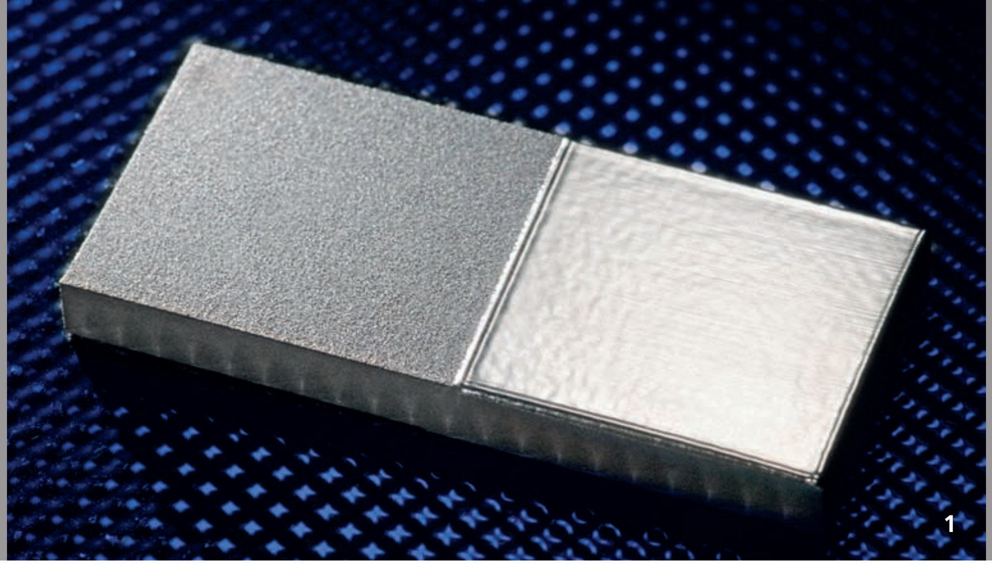
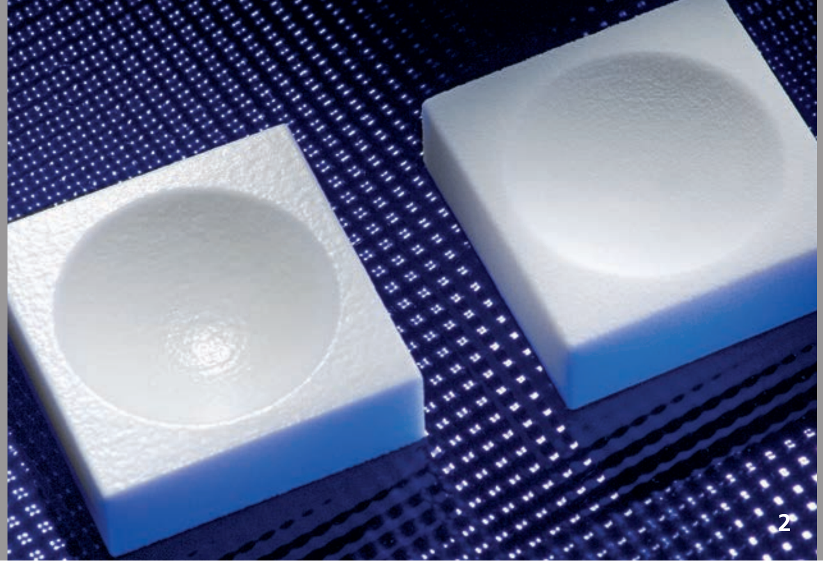
2 Printed and laser-functionalized strain gauges on polymer films.
3 Printed and laser-functionalized strain gauges of different designs.





LASER MICROPOLISHING OF ADDITIVELY MANUFACTURED METAL COMPONENTS

Task

Additively manufactured metal components are gaining more and more importance in industrial production since they offer many advantages. A disadvantage, however, is their surface quality: It is insufficient for many applications, making a reworking of the functional surfaces necessary.

Laser polishing can, however, provide a possible solution to this issue. So far, the polishing of additively manufactured metallic surfaces has been developed with continuous laser radiation. Although a significant reduction in the roughness has been achieved, there is a high heat input into the work piece so that a risk of distortion remains (especially in the case of small work pieces or lightweight structures). For this reason, Fraunhofer ILT is investigating laser micropolishing with pulsed laser radiation since the heat input in this process variant is significantly lower.

Method

To adapt the laser micro polishing process to the material and the surface, the institute determined how different process parameters influenced the surface roughness. The process parameters were adjusted successively.

Results

The surface roughness of a work piece made of TiAl6V4 by laser powder bed fusion (LPBF) was reduced, for example, with laser micro polishing from Ra = 11.7 µm to Ra = 0.9 µm. There is no distortion of the work piece and the processing time is only 5.3 s/cm².

Applications

The result can be transferred to a variety of other materials, such as steels or nickel-based alloys. In addition, the process is not limited to additively manufactured components, but can also be applied to differently produced surfaces (e.g. Metal Injection Molding MIM, EDM).

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1 Selectively laser-micropolished surface.

»QUASI TOP-HAT SCANNING STRATEGY« FOR LASER POLISHING OF 3D-PRINTED PLASTIC PARTS

Task

Achieving a homogeneous smoothing of the surface roughness is a key challenge when lasers are used to polish 3D-printed plastic parts. Due to plastic's low heat conductivity, conventional laser polishing strategies (e.g. meandering with focused laser radiation and scanning speeds in the range of 50 to 200 mm/s) both overheat the surface and shorten the existence of the melt pool. This leads to long process times and also has a negative impact on the resulting roughness of the surface.

Method

The problem can be solved by creating a homogeneous, constant surface temperature field using the newly developed »quasi top-hat scanning strategy« and temperature control.

In the quasi top-hat scanning strategy, the Gaussian intensity distribution of the commonly used CO_2 laser radiation is defocused and guided at high scanning speeds (5 - 10 m/s) over the surface to be polished in many passes. The surface temperature is measured by pyrometry and the laser power controlled so that the temperature in the processing zone remains constant for a certain duration. Surfaces between 1 to 1,000 mm² can be melted coherently and, thus, laser polished.

Results

On flat samples of the material PA12, which were produced by the SLS method (selective laser sintering), a molten bath of the size 10 x 10 mm² could be produced homogeneously and at a constant temperature at the surface, without the sample becoming deformed. The roughness can flow out so steadily until the desired smoothing is achieved. Typical roughness of the SLS process of Ra ≈ 10 µm can be reduced to Ra ≤ 0.5 µm. PEEK samples prepared using the FDM method (fused deposition modeling) could be smoothed from Ra ≈ 15 µm to Ra ≤ 1 µm.

Applications

The laser polishing of 3D printed plastic parts may, for example, be applied in industries such as the automotive industry, energy or medical technology and can unlock great potential there.

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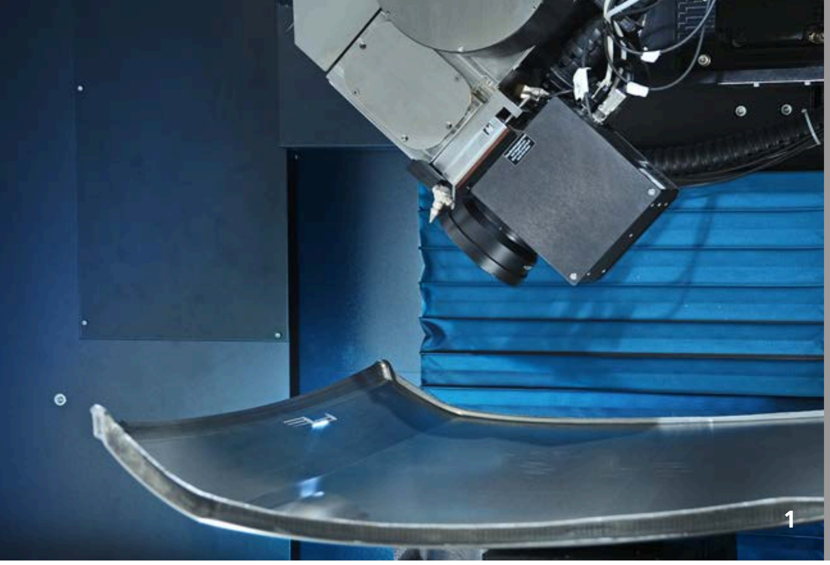
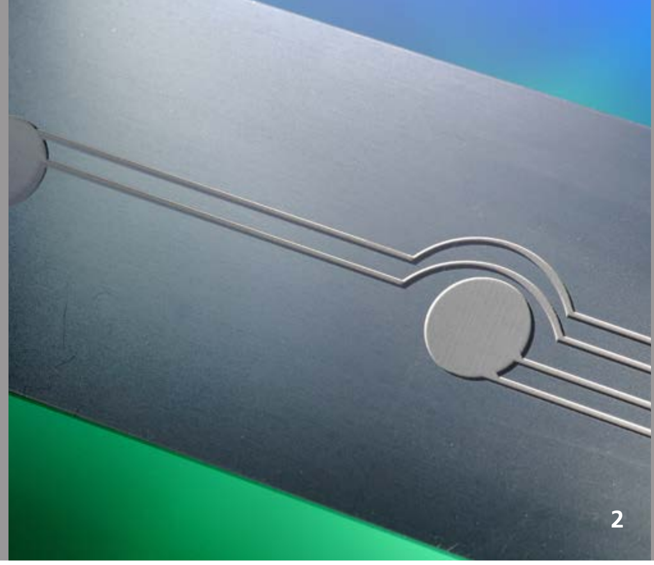
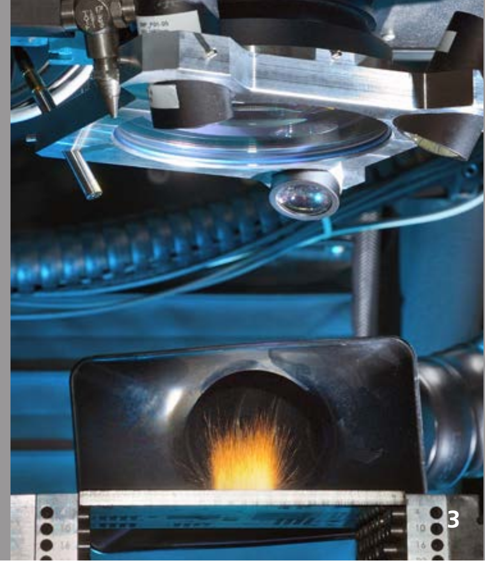
2 SLS-made component made of PA12, initial condition (right), laser-polished (left).







DIGITIZATION OF LASER-BASED MANUFACTURING PROCESSES FOR INDIVIDUALIZED SERIAL COMPONENTS

Task

Various industries have a growing need for innovative, individualized components for the future markets of automotive, aerospace, photonics and manufacturing. For the first time, the lighthouse project »Go Beyond 4.0« is aiming at dissolving the contradiction between product flexibility and cost-effectiveness of the respective manufacturing processes at a series production scale. By integrating digital production steps into an analog tool-bound process chain, the project will make it possible to produce highly complex products in a highly individualized manner.

Method

The digital production steps are optimized for different substrates (aluminum/thermoplastics) and analyzed for integration into existing process chains (sheet metal forming/injection molding). The functional components to be integrated – in addition to electrical conductors – are printed piezoelectric elements as controls and hybrid integrated piezoelectric elements as ultrasonic-based proximity sensors. In preparation for the integration, structures can be introduced by laser ablation in a location-specific manner, all of which contribute to expanding the functions of the component.

1 Structured car door with incorporated, individualized functional elements.

2 Structure generated by ultrashort pulsed laser radiation for print preparation.

Results

With a high-performance ultrashort pulse laser (400 W), ablation rates of up to 100 mm³/min in aluminum can be reached, thus making it possible to create 3D surface structures. Simultaneously, the component surface is prepared for a subsequent printing process. This way, individualized functional elements can be selectively introduced, even in large-sized components such as a car door. The assembly for additional modules, such as a wiring harness, is currently very cumbersome. The degree of functional compression, while reducing the component complexity, can be significantly increased in this way.

Applications

The trend towards individualization can be recognized all across the market. In particular, high-tech industries such as the automotive, aerospace and the lighting industry are playing a pioneering role here and are translating the idea of »mass customization« into industrial production.

This project is being financially supported by the Fraunhofer-Gesellschaft.

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MICROSTRUCTURING AS PART OF THE NETWORKED ADAPTIVE PROCESS CHAIN

Task

As part of the High Performance Center »Networked Adaptive Production«, laser-based microstructuring is being integrated as a final step in a process chain for tools for automotive applications produced in lot sizes of one. Here, a distinction is made between two processes: faster ns- and more precise ps-structuring. During the production process, it is decided which process combination provides the best results – on the basis of important criteria such as machining time, costs and accuracy, surface roughness and the current machine condition.

Method

In addition to previously known processing criteria, real-time information about the machine and the process is of great importance for production. As part of the project, Fraunhofer ILT is developing a multi-sensor system that collects and analyzes the necessary data in order to enable users to detect defects and make decisions based on them in real time.

Results

The microstructuring plant was equipped with the multi-sensor system and for data acquisition with a hybrid FPGA- (field-programmable gate array) and PC-based monitoring system. The following data can be collected in real time:

Machine condition monitoring, data rate < 1 Hz - 10 kHz
- Temperature of the machine and environment
- Vibrations of the machine and environment
- Actual position of the machine axes
- Laser power and beam caustic

Process monitoring, data rate 100 kHz
- Actual positions of the scanner axes
- IR process emission
- VIS process emission
- Acoustic emission
- Reflection of the laser radiation

Applications

In addition to microstructuring with applications in the automotive, lighting and aerospace industries, other manufacturing processes can be integrated into I4.0 process chains in a similar manner. The real-time process monitoring system is also suitable for other scanner-based laser applications.

The project is being carried out as part of the Fraunhofer- and NRW-funded project »High Performance Center Networked, Adaptive Production«.

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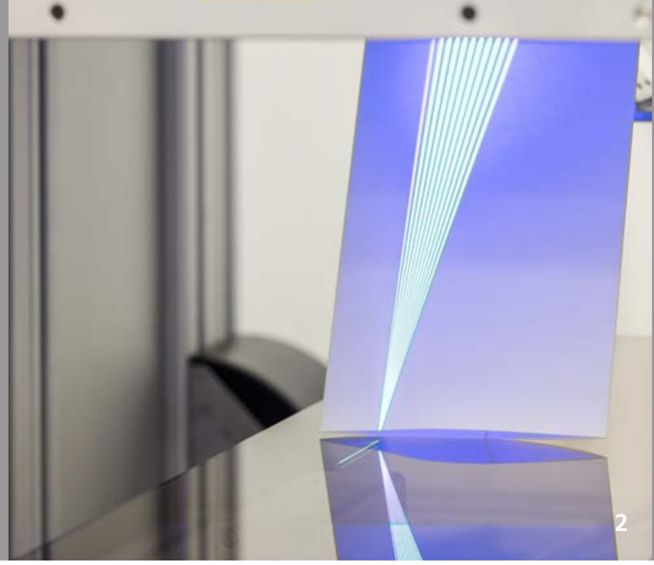
3 Multi-sensor system for process monitoring.

4 Plant with integrated sensors and hybrid evaluation system.



LARGE SURFACE MICROSTRUCTURING WITH UV LASER RADIATION

Task

Using UV laser radiation to selectively ablate and modify micro- and nanometer-scale layers is an established process in display production. Since it has low optical penetration depth and short pulse duration, pulsed UV excimer laser radiation has a negligible thermal influence on the components; thus, it is qualified for the precise and gentle thin layer functionalization of conductive, semiconducting or insulating materials. In order to transfer these processing properties to a variety of coating systems especially for large area production, Fraunhofer ILT has installed and operates a UV laser-line beam system in close cooperation with Coherent.

Method

The line beam concept dispenses with movable optical components, such as classical scanners, and features pulsed UV excimer laser radiation at a wavelength of 248 nm and a pulse duration in the ns range. At a mean output power of 150 W, the system achieves pulse energies of up to 1 J. Moreover, with a fixed line focus of 155 mm length, it reaches surface rates of up to 0.5 m^2/min. Depending on the application, the pulsed laser radiation used can be combined with a high-resolution mask image having rectangular field geometry. Due to the power data and the combination of the two system concepts, a location-selective structuring with a depth resolution below 0.1 µm is possible for a wide range of materials and for a large number of processes.

Results

The line beam concept has already been used to develop a process for the large-scale ultrafine cleaning of chemically treated metal surfaces. Furthermore, Fraunhofer ILT has demonstrated the application potential of the plant for the stripping of carbon fiber components. In the process, the matrix material consisting of epoxy resin was removed in a location-selective manner.

Applications

This laser beam system provides small and medium-sized companies, across industries, with the technological basis for developing new products with innovative layer functionalities. This practice-oriented approach gives a wide range of users access to a novel, optical production process for the large-area machining of functional surfaces.

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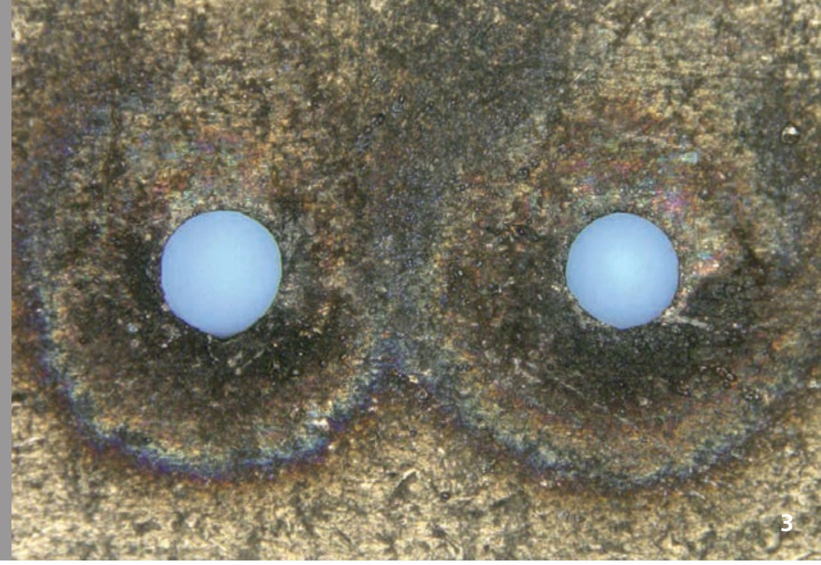
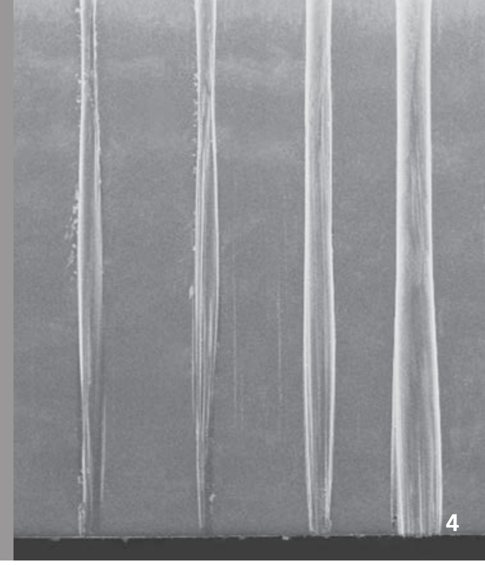
1 LEAP excimer laser with an LB155 optics system.

2 Line beam with 155 x 0.3 mm field size.





LASER-BEAM HELICAL DRILLING OF MICRO-HOLES WITH A HIGH ASPECT RATIO

Task

Laser-beam helical drilling is a suitable technology for producing precision-shaped holes, but the achievable aspect ratio is limited to about 20:1 owing to beam propagation in the drilling channel. Several factors limit the aspect ratio of a precision drill hole with high roundness at the entrance and exit when drilled by ultrashort pulse (USP) laser radiation. In particular, the drilling technology or optics used are relevant as is the available maximum pulse energy of the USP laser radiation. The removal rate decreases sharply with increasing drilling depth due to the beam divergence and multiple reflections. Therefore, making high aspect ratio micro-holes in thick material poses a major challenge to manufacturing.

Method

Using a helical drilling optics it developed, Fraunhofer ILT conducted studies on micro-holes with an ultrashort pulsed laser beam source and high pulse energy. The laser beam source has a wavelength of 532 nm, a pulse duration of 12 ps and a maximum single pulse energy of 650 µJ. The focus diameter is 25 µm. The angle of incidence, position and rotational speed of the laser radiation are dynamically adjusted during the helical drilling process, whereby the degree of multiple reflections of the laser radiation and the temporal and spatial energy deposition in the drill hole can be adjusted selectively.

Results

The large single-pulse energy results in high ablation rates. This way, a throughput time of less than 25 s was achieved for 3 mm thick steel. The aspect ratio is limited to about 50:1 by the diameter of the hole entry and exit of about 60 µm. The roundness of entry and exit is > 0.92. The longitudinal section shows that holes can be drilled vertically to the material surface with an edge angle of almost 90° in the entry area. The roughness R_a at the borehole wall is less than 0.5 µm.

Applications

For example, high aspect ratio precision micro-holes in steel, glass, and ceramic can be used as spinning nozzles, injector nozzles, injectors, or vent holes. Increasingly, such precision holes will also be used in sensor and filter technology.

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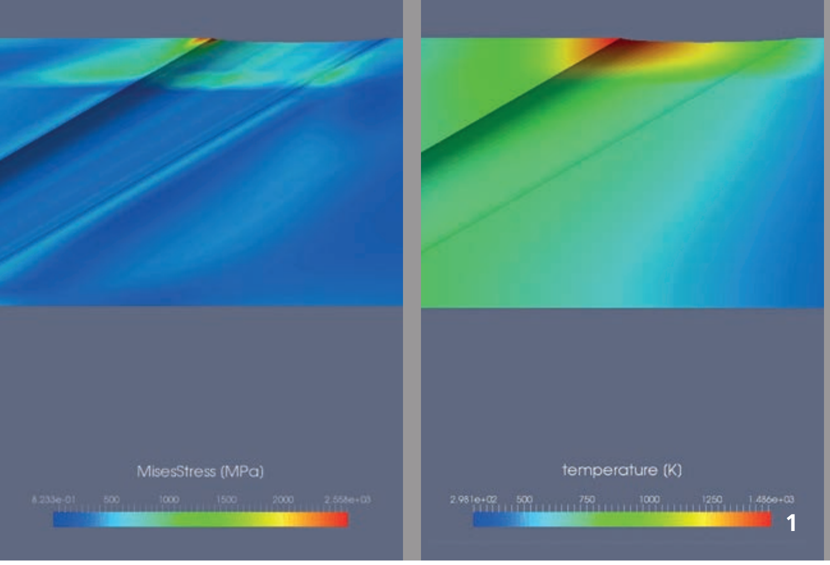
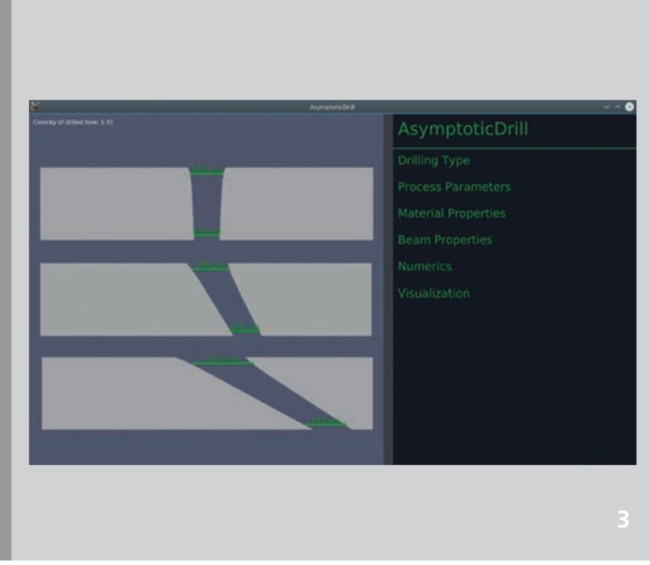
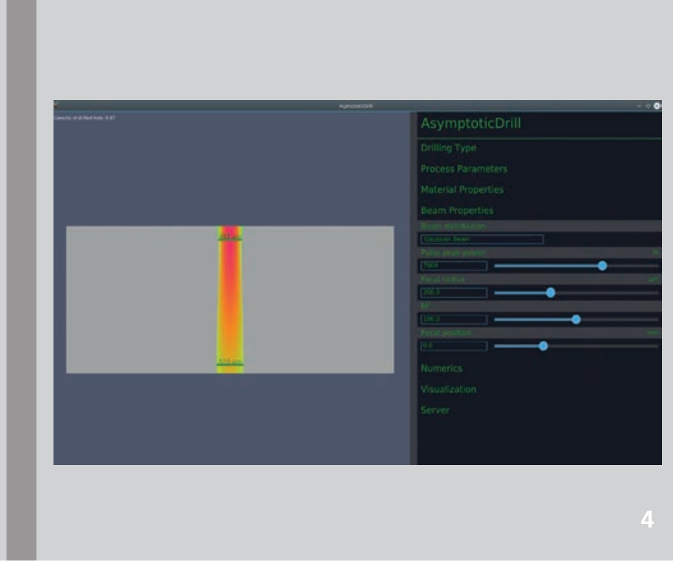
3 Drill hole entry with 60 µm diameter.

4 SEM image of longitudinal bore holes in 3 mm thick stainless steel.







DELAMINATION AND EJECTION OF MELT FOR LASER DRILLING OF MULTILAYER SYSTEMS

Task

Highly stressed components of today's gas turbines are manufactured out of thermal barrier coating systems. These consist of a high-temperature-resistant base material, a primer layer and a ceramic thermal barrier coating. In the film cooling, a cooling fluid flows through the introduced cooling holes and then forms a cooling film on the side acted upon by the hot gas component. If the cooling channels are produced by laser drilling, delamination cracks can occur between the layer components. Furthermore, a pronounced melt ejection at the hole entry can damage the optical system. In this context, the project aims to identify suitable process settings to optimize the drilling process.

Method

With the aid of reduced models, fast process simulations have been developed which allow users to analyze large areas of the parameter space and to create process maps for process setting on this basis.

Results

To describe delamination cracks, Fraunhofer ILT first simulated the thermo-mechanical behavior of the multi-layer system as the drill hole formed (Fig. 1). Based on this, it developed a reduced model that provides a substitute criterion for the formation of cracks. Furthermore, the institute developed a model for the melt ejection at the drill hole entrance. In particular, three different modes of melt ejection could be identified and experimentally confirmed (Fig. 2).

Applications

In addition to applications in laser drilling, the developed models can also be used in other manufacturing processes. The substitute criterion for delamination cracks can be transferred, for example, to the cracking of additively manufactured components. The melt ejection model may be expanded, for example, to describe the dynamic properties of the absorber layer in »laser-induced forward transfer« (LIFT), a process for the site-selective transfer of biomaterials and cells.

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1 Thermomechanical properties: stress distribution (left) and temperature distribution (right).
2 Three different melt ejection modes.

SIMULATION APP FOR DRILLING WITH LASER RADIATION

Task

The simulation app »AsymptoticDRILL«, developed by Fraunhofer ILT, describes asymptotic drill forms when metallic materials are drilled with long-pulsed laser radiation – for Rayleigh lengths significantly larger than the drill depth. However, as this constitutes a relatively severe limitation on describable drill holes, the task here is to extend the scope of »Asymptotic DRILL« to laser radiation with Rayleigh lengths less than or equal to the drill hole depth.

Method

The underlying reduced model for asymptotic drilling has been extended to describe the radiation absorption in any propagation direction. Like the initial model, the extended model is based on equations that allow simple numerical methods to be applied with good solution properties and that can be solved on a seconds scale.

Results

The extended model equations have been implemented in the simulation app so that the new version allows asymptotic drilling to be described even with strong beam divergence. The latter can be set within the user interface using sliders. A strong beam divergence can, in particular, lead to drill holes whose outlet diameter is greater than the inlet diameter. The description of such undercuts is also possible in the new version (Fig. 4). In addition, »AsymptoticDRILL« now also allows the user to describe drill holes made at an angle to the surface of the workpiece (Fig. 3).

Applications

The app's current field of application is the process development for the production of cooling channels in turbine components. In the future, it is planned to use »AsymptoticDRILL« also in the field of screen and filter production as well as in the structuring of lightweight components.

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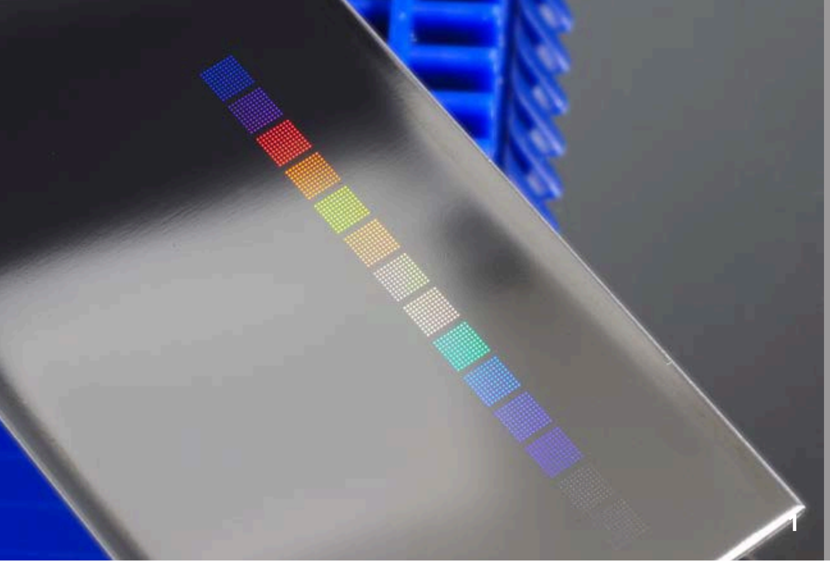
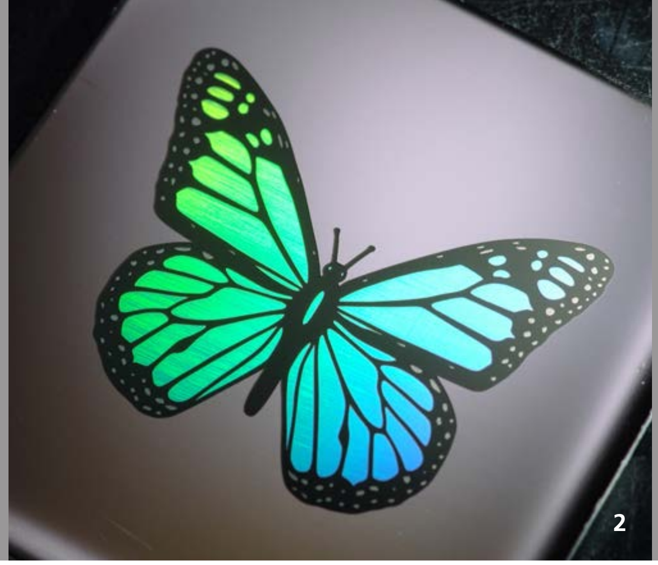
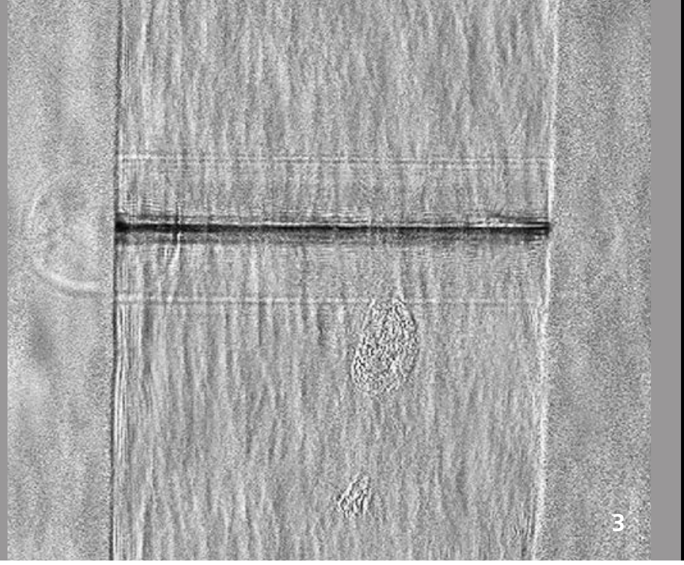
3 Drill hole oriented transverse to the top of the workpiece.
4 Undercut and new user interface with sliders to adjust the beam divergence.







COLOR CODING THROUGH MICRO AND NANOSTRUCTURES

Task

The visible color spectrum between 400 nm and 800 nm is a section of the electromagnetic spectrum whose individual spectral components are perceived as color by the human eye. If the spectrum of a light source strikes the periodic pattern of a micro- or nanostructured surface, its spectral components are diffracted under different angles. Therefore, the surface appears in a different color depending on the angle of view. With ultrashort pulsed laser radiation, defined structures can be generated on surfaces that reflect or absorb specific parts of the color spectrum. This project aims to generate a predefined colored pattern through an automated microstructuring process on different materials.

Method

»Laser interference structuring« or direct structuring with ultrashort pulsed laser radiation can be used to generate deterministic and self-organized statistical structures on different materials. Deterministic interference structures are generated by the superposition of two partial beams on the surface of the material. The intensity profile on the surface allows a linear structuring on the material surface. By using ultrashort pulsed laser radiation, the institute can process and thus structure metals, plastics or semiconductor materials. Statistical, self-organizing structures result from an electro-magnetic excitation of the surface by the laser pulse. Depending on wavelength and material, structure sizes from 500 nm to 5 µm can be generated. In addition to the optical properties, surface properties such as haptics or adhesion by the surface structures can be selectively influenced.

Results

The interference structures with a sinusoidal topography can be structured with surface rates of up to 60 cm²/min. The laser, the optical system and the sample movement are synchronized so that, section by section, different structure patterns can be generated. Here, every single pattern appears under a defined viewing angle as matt grey or a defined color. In this manner, any color images can be generated depending on the arrangement of the different structural sections.

Applications

In contrast to color pigments, microstructures do not fade, thus resulting in a long-term stable color effect. In addition to decorative applications, the structures can be used for the production of technical surfaces in the medical, biotechnological field or security marking in production.

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1 Color effects generated by interference structuring.

2 Microstructured metal surface.

GLASS PROCESSING WITH APPLICATION-SPECIFIC BEAM SHAPE

Task

Advances in global digitalization are driving the demand for highly individualized glass components in applications such as consumer electronics, automotive construction, and telecommunications. Conventional methods, such as mechanical scribe and break, cannot meet the high requirements for novel glass components without costly post-processing since they either lack flexibility or generate a high concentration of defects. Here, the tool »laser« makes a contactless, efficient and highly flexible glass processing technology possible. For this, the laser radiation for a specific application of the glass component must be customized. Fraunhofer ILT is developing innovative spatial and temporal beam shapes and evaluating their potential for specific applications.

Method

To generate application-specific modifications of glass, the energy deposition must be adjusted selectively. For this, the influencing factors must be determined and their dependence on the used laser and material parameters understood.
The energy deposition in the glass volume can be displayed with »in-situ pump-probe microscopy« and analyzed in a time-resolved and spatially resolved manner. By adapting the spatial and temporal intensity distribution by beam shaping, Fraunhofer ILT can adjust energy deposition for a specific application.

Results

Pump-probe microscopy makes it possible to develop process-specific beam shapes for cutting, structuring and modifying surfaces and volume elements of transparent materials. Thus, for example, by adapting the spatial beam shape, Fraunhofer ILT has developed a separation process of large-area glass with speeds of ~ 100 mm/s for glass thicknesses ≥ 500 µm. The cut edge has a surface roughness of R_a ~ 1 µm with negligible conicity. With pulse durations in the range of ~ 100 fs, the process can selectively ablate the glass surface. An influence on the glass volume is almost completely avoided thanks to an appropriate choice of intensities.

Applications

A separation process can be used, in particular, to cut displays for consumer electronics. Moreover, the haptic properties of a glass surface can be adjusted selectively with laser ablation. When modifications with structure sizes of ~ 1 µm are generated, spots are created that are only visible at a defined illumination angle. Such modifications can be used as scattering spots for the illumination of functional display elements.

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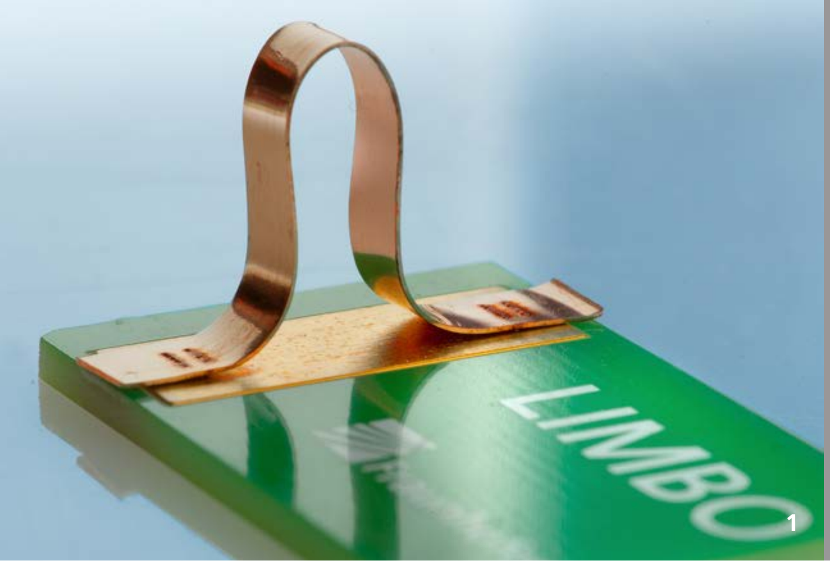
3 Laser-cut and -structured glass component.

4 Time-resolved image of energy deposition in glass..



LASER IMPULSE METAL BONDING (LIMBO) WITH BEAM SOURCES IN THE 515 NM WAVELENGTH RANGE

Task

As demands in high-performance electronics and electromobility constantly grow, power electronic components are increasingly required with high robustness and thermal stability. »Laser Impulse Metal Bonding (LIMBO)« enables a cohesive and, therefore, high-temperature-stable joint between thick copper connectors over 200 µm and thin copper metallizations below 100 µm on sensitive substrates. The melting process of the copper material, however, presents a challenge since this material absorbs laser radiation in the IR range to a low degree.

Method

Compared to laser beam sources in the IR range, a laser beam source in the green range (λ = 515 nm) can be used to facilitate the absorption behavior of the copper material in the welding process. The increased absorption of the laser radiation results in targeted control over the energy input and, thus, makes it possible to increase reproducibility and robustness during the melting of the copper connector. With the LIMBO process, an energetic separation between the melting and the connection has been developed, whereby the thermal influence on sensitive substrates is clearly minimized.

Results

The process enables 200 µm copper sheets to be welded on copper-metallized PCB substrates with a reproducible bond. Compared to that of IR laser sources, the process time with beam sources in the wavelength range 515 nm is reduced by a factor of three due to the increased absorption and the targeted energy input in the LIMBO process.

Applications

In semiconductor technology (silicon-based components) or in electrical engineering (FR4), the LIMBO process allows thick connectors to be joined to sensitive substrates with thin metallizations. In addition, the method is applicable for cohesive joining of metallic components with high gap tolerances.

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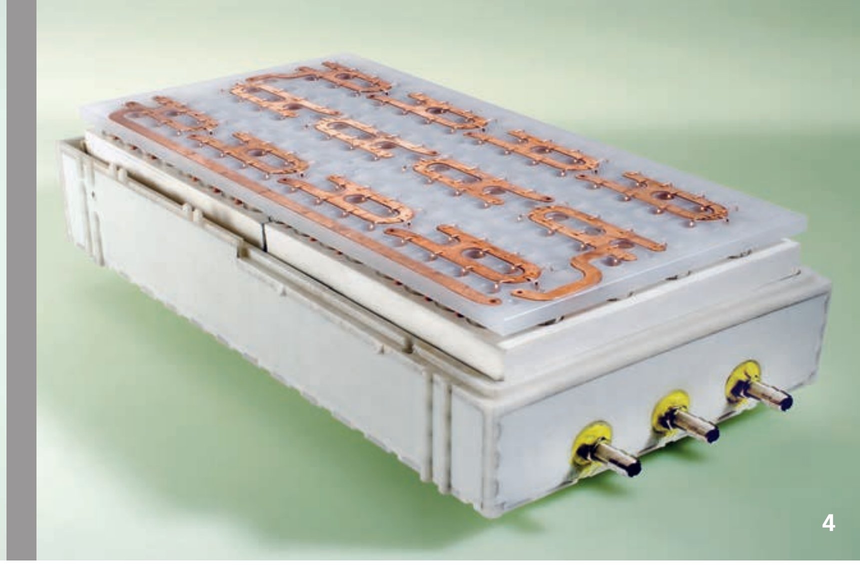
1 Copper connector contacted on metallization.

2 Cross-section of a weld of copper on a PCB metallization.



LASER-BEAM MICRO JOINING OF CYLINDRICAL BATTERY CELLS

Task

As the pressure on cities increases to reduce exhaust pollution, so too does the demand for alternative automotive drive concepts. Electromobility is an approach to solve this issue, but is still expensive and not efficient enough. As a central and costly component of electric cars, the battery cell and its connection to battery systems are the focus of this research. Joining processes with a high degree of automation and a low process time are required to electrically contact individual battery cells, such as type 18650 or 21700 cylindrical cells. At this point, brilliant laser beam sources for welding cells to cell connectors can offer new highly automated manufacturing solutions.

Method

In the »OPTEMUS« project, Fraunhofer ILT is developing core battery module technologies for electromobility to reduce manufacturing costs and, at the same time, to increase efficiency. A subproject deals with the development of a battery module that can store and provide not only electrical, but also thermal energy. At Fraunhofer ILT, a laser-based joining technology has been developed for contacting the battery cells with minimal energy input and component load.

Results

The battery module consists of 144 round cells (model 18650) with 12 parallel and 12 serial levels. The cells are welded to a 0.2 mm thick sheet (CuSn6) at the negative pole. For this purpose, a single-mode fiber laser is used in combination with local power modulation. In this case, the feed movement is superimposed with a circular oscillation movement so that the weld geometry can be adjusted as needed. The positive pole of the battery cells is contacted by means of laser bonding (laser beam welding with automatic ribbon supply) on a bus bar.

Applications

Laser-beam micro-joining is suitable for contacting different battery formats (pouch, prismatic and round). The advantages are the low and controlled energy input into the thermally sensitive battery cells as well as the high degree of automation of the process.

The work was carried out under the EU project »OPTEMUS« under grant number 653288.

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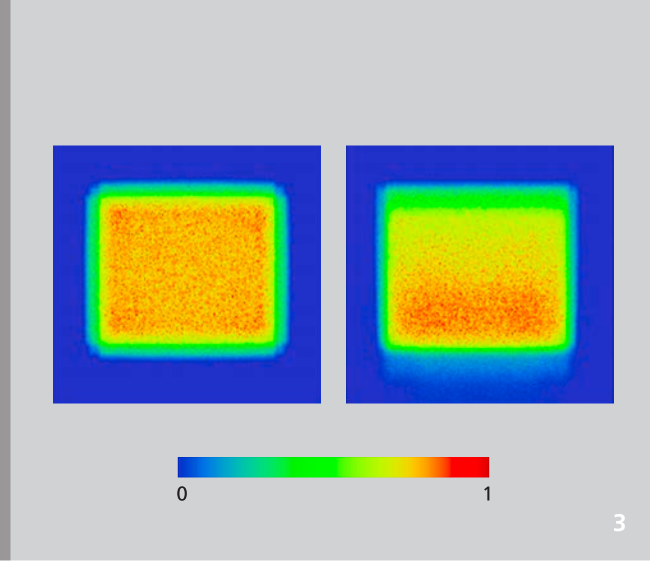
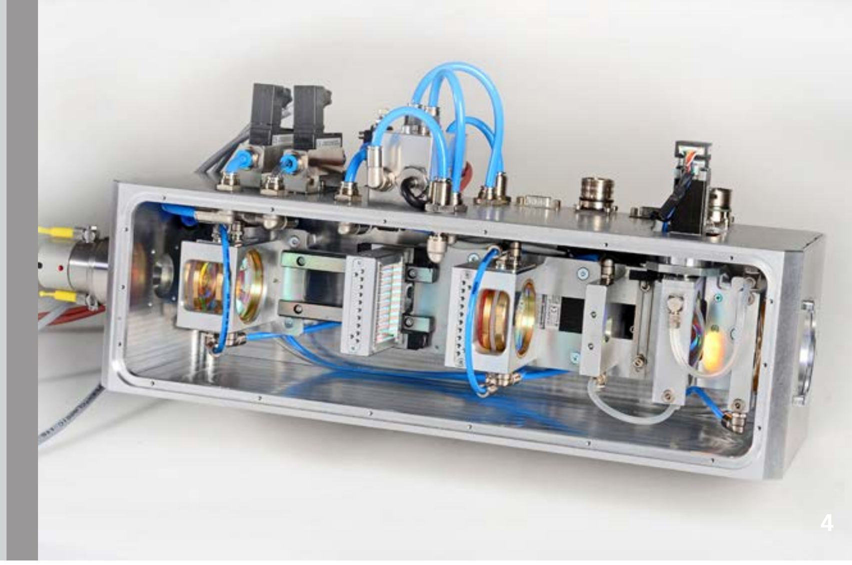
3 Submodule with 12 battery cells (type 18650).

4 Battery module consisting of 12 submodules.





LASER-BEAM WELDING OF BIPOLAR PLATES

Task

Fuel cells are the new hope for energy production in the future. They make it possible to convert the chemical energy stored in fuels (especially hydrogen and methanol) directly into electrical energy. They have a theoretical efficiency of up to 83 percent and only emit water vapor. The central element of the fuel cell is the bipolar plate, which usually consists of two formed thin-walled nickel sheets in its metallic variant. This project aims to weld these sheets by means of laser-beam welding. Doing this, however, poses particular challenges in terms of hermeticity, process time and reproducibility.

Method

In order to weld pure nickel sheets, especially with longer seams, both hermetically sealed and free of errors, a laser-compatible clamping device is needed, one that allows the sheets to be pressed over the entire seam length without gaps. The energy input into the component is precisely controlled by means of local power modulation using a single-mode fiber laser with high beam quality and a beam diameter of < 30 µm. An important design parameter is the degree of overlap, which results from the oscillation parameters in conjunction with the feed rate.

Results

By developing a complex fixture and adjusting the weld geometries in terms of arrangement and sequence, Fraunhofer is able to prevent process errors and reproducibly weld bipolar plates that are hermetically sealed. With adapted oscillation parameters (amplitude and frequency), high feed rates of up to 140 mm/s can be achieved. This results in a low energy input and a minimal heat distortion of the thin-walled nickel component. The mandatory use of argon as protective gas improves the welding pattern and allows oxidation-free surfaces.

Applications

The results of the process development can be used primarily to produce metallic bipolar plates, but can also be transferred to other applications such as the welding of sensor membranes in pressure measurement or the welding of rupture discs in battery cell production.

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1 Metallic bipolar plate with hermetically sealed weld seams.

2 Cross-section of a weld.

OPTICAL SYSTEM FOR LASER-ASSISTED FRP-TAPE LAYING

Task

The increasing use of fiber-reinforced plastics (FRP) is making flexible production strategies for customers' individual requirements more and more significant. For such a flexible process, the processing optics is an essential component since the laser radiation is deliberately introduced through it to heat the tape. When the intensity distribution is adapted, the laser radiation can be introduced in an application-adapted and energy-efficient manner, depending on the material condition or winding geometry.

Method

To optimize the tape-laying process, research needs to develop an optical system that allows the laser beam to be shaped from a rotationally symmetrical input distribution to a homogeneous, rectangular intensity distribution in the working plane. In addition, a variable zoom and a function to generate linear intensity gradients are required. When several partial beams with cylindrical lens arrays are divided and superimposed, a homogeneous intensity distribution in the working plane can be produced. The zoom functionality is ensured when the cylindrical lens arrays are shifted. The generation of the intensity gradient is based on the Scheimpflug principle. When the focusing lens is tilted selectively, the desired intensity gradient can be set.

Results

Fraunhofer ILT has developed the optical system in cooperation with the Chair for Technology of Optical Systems (TOS) at RWTH Aachen University and the company IXUN GmbH. Since it can be adjusted flexibly, the system makes it possible to ideally introduce heat into the workpiece and thus to optimally process FRP.

Applications

In principle, all laser processing methods that profit from a change between a homogeneous and a linearly increasing intensity profile can also benefit from this newly developed optical system. The innovative system is particularly interesting in the field of laser hardening and softening. The newly gained degree of freedom of the variable intensity distribution opens up new possibilities for process control.

The work was carried out as part of the EU project »ambliFibre« under grant number 678875.

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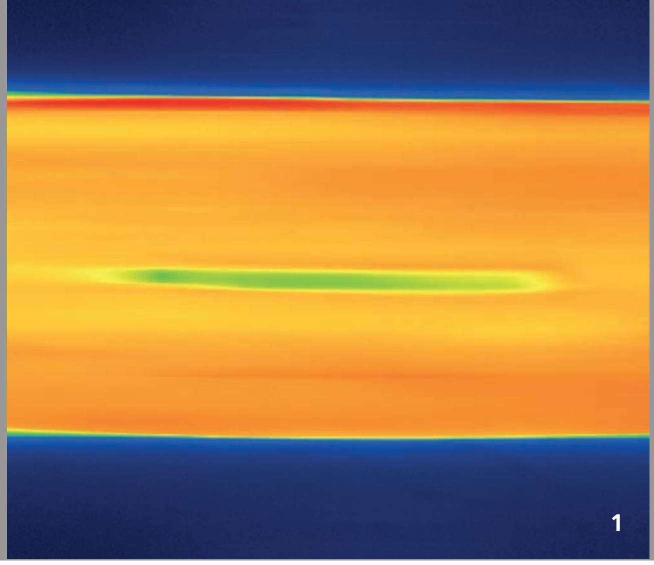
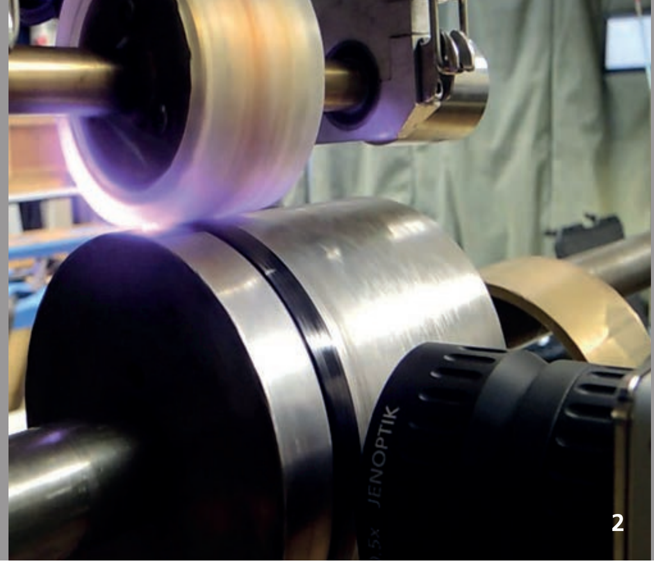
3 Change in the intensity distribution in the working plane.

4 Laboratory setup of the optical system.





PROCESS MONITORING IN THE LASER-BASED TAPE-LAYING PROCESS FOR FRP COMPONENTS

Task

Automation, flexibility and resource efficiency all play a key role in the production of fiber-reinforced plastic (FRP) components based on a laser-based tape-laying process. In the system development, this project is focusing on the process-controlled laser-beam welding of fiber composite tapes in order to detect inline defects in the component reliably and safely.

Method

The process control is implemented using imaging thermography and machine learning. For the control to detect insufficient lamination during the tape laying process, the institute has introduced artificial micro-embossments in FRP tapes in advance. Thanks to »live« thermography images from the joining process, the system can recognize and then evaluate the embossments with regard to the remaining geometry after welding. This is then used to derive the welding quality. The process control algorithm is based on machine learning: In the first step, the embossments on the tape are recognized and in the second step, the quality assessment is carried out. The process monitoring learning required in this process was performed using reference lamination of known quality. After the learning phase, process monitoring is able to evaluate new unknown laminations.

Results

The developed process monitoring is capable of working in real-time and easy to integrate due to the existing interfaces. The system was evaluated with 150 available datasets. To train the model, 75 percent of the data was used and 25 percent as test records. As a result, 98 percent of the existing embossments on the FRP tape were recognized and the quality of the lamination was correctly evaluated for all recognized embossments.

Applications

The »ambliFibre« monitoring system is suitable for all applications whose goal is to detect structures on surfaces with different temperature controlled areas. The method can be easily adapted and flexibly expanded by machine learning. The secure object recognition not only recognizes known imperfections, but also new ones created in the process.

The work has been carried out as part of the EU project »ambliFibre« under grant number 678875.

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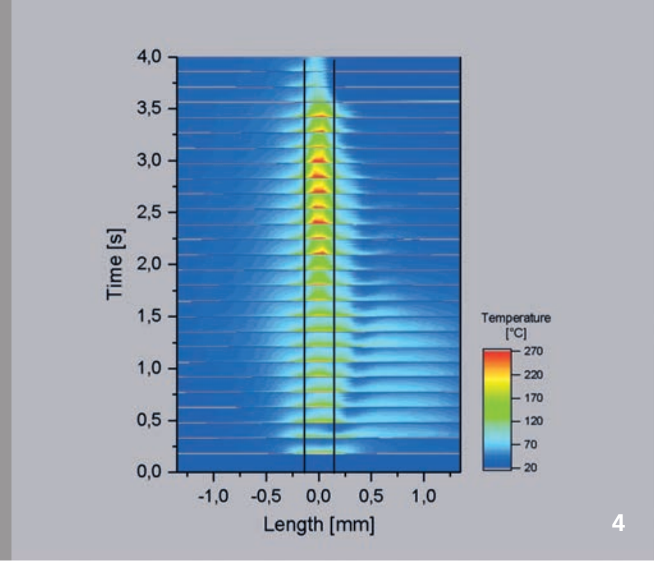
1 IR photograph of a FRP tape with imprinting applied.

2 Laser welding process for tape laying of FRP tapes with thermographic camera, source: Fraunhofer IPT.



CUTTING FIBER COMPOSITE MATERIAL WITH HIGH EFFICIENCY AND QUALITY

Task

When lasers are used to cut fiber composite material – in particular, carbon fiber-reinforced plastics (CFRP) – the process design aims to minimize the heat affected zone (HAZ) while maintaining a productive and short processing time. To accomplish this, repeated, fast scanning of the laser beam along the cut path produces successive, gentle material removal. The scanning speed and the cooling time between the scans influence the HAZ and the processing time. Fraunhofer ILT has applied and investigated optimization rules on a demonstrator for the cycle-time-optimized cutting of CFRP and GFRP hybrid materials with a 5 kW single mode laser.

Method

With the aid of thermovideography, the institute analyzed the heating and cooling behavior. Thus, the heat accumulation was quantitatively recorded from scan to scan. For a broad parameter field, the temperature curves were correlated with the resulting HAZ and systematic characteristic curves determined.

Results

Not the fastest possible scan speed, which always delivers the lowest heat input in a single scan, will result in a minimum HAZ, for a given processing time. Rather, optimal scan speeds may be specified where the number of scans required and the duration of the cool down time between scans are adjusted such that reduced heat accumulation results in a minimum HAZ. In this specific case, a HAZ < 50 µm was achieved with unidirectional CFRP cut in the fiber direction.

Applications

The optimization rules developed provide valuable process design support in all applications where glass or carbon fiber-reinforced composite material is cut in a multi-pass process. The heat input is systematically adjusted on the different time scales, within one scan and from scan to scan, for an optimal processing result.

The R&D project underlying this report was commissioned by the German Federal Ministry of Education and Research (BMBF) as part of the »HyBriLight« project under grant number 13N12718.

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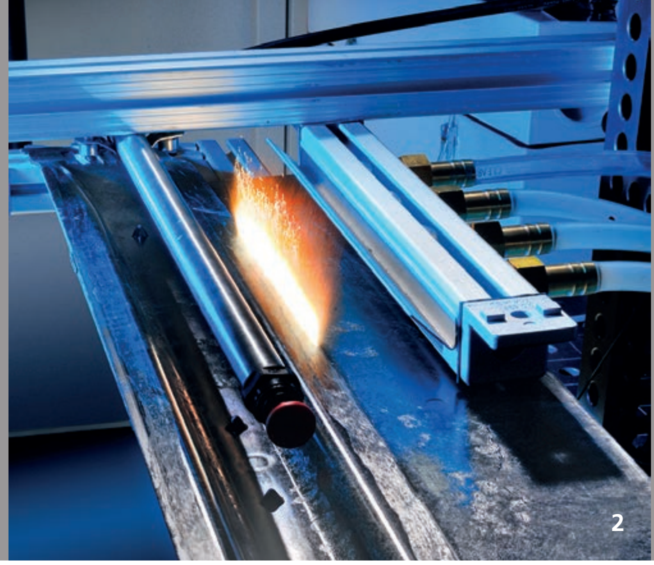
3 Laser-trimmed car roof bow made of a CFK-GFK metal composite.

4 Streak plot of the temperature profile during cutting.



LASER PROCESSES FOR THE PRODUCTION OF LIGHTWEIGHT HYBRID COMPONENTS

Task

By combining different materials and integrating several process steps in the manufacturing process, research has developed approaches to optimize the weight of components in lightweight construction and to manufacture them inexpensively. In order to produce multi-material components in processes suitable for series production, however, the industry needs appropriate joining and separation processes for selected materials.

Method

As part of the BMBF project »HyBriLight«, Fraunhofer ILT has developed a hybrid component that demonstrates the successful implementation of new, innovative laser processes in lightweight construction. They were used for a so-called car roof bow, based on the original component of the BMW 7 series, which consists of a fiber-reinforced plastic strut with two metal connecting sheets. Using ultrashort pulsed laser radiation, Fraunhofer ILT generated sponge-like microstructures on the connecting sheets, which enable the plastic to claw into the metal surface. The parts are actually joined as the plastic component is produced in the compression molding process: here, the structured connecting sheets are inserted into the variothermal mold and then pressed with the glass fiber-reinforced plastic and local carbon-fiber reinforcing tapes. Finally, the excess overhang of the GFRP-CFRP material mix is trimmed using a fiber laser in a multi-pass process.

Results

The generated plastic-metal hybrid compounds, which are based on mechanical clawing mechanism in the generated microstructures, can withstand shear forces of up to 50 MPa. The multi-pass method with fiber lasers makes it possible to cut and trim material combinations of glass and carbon fiber-reinforced plastics with a minimized heat affected zone. Since the joining process is integrated into the primary molding process of the plastic component, the process chain has been shortened and the process time reduced significantly.

Applications

Joining and trimming of multi-material composites are process steps required in all areas of lightweight construction, especially in the automotive and aerospace industries.

The R&D project »HyBriLight«, which underlies this report, was carried out on behalf of the Federal Ministry of Education and Research BMBF under grant number 13N12718.

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1 Roof bow with plastic-metal hybrid connection.

2 Remote laser cutting of CFRP-GFRP material mix.

LASER BLANKING OF FLEXIBLY ROLLED STEEL

Task

Laser cutting from coil has increasingly become established as a flexible manufacturing method – as an attractive and sustainable alternative to punching – for cutting car body components as seen in numerous such systems installed worldwide by different manufacturers in mass production. By switching from a tool-based process to a flexible laser contour cutting process, known as laser blanking, these manufacturers can enjoy great economic benefits. These include, in particular, the savings in investment costs for tools and their storage, the simple modification in the cutting contour in product development or for product change and the potential for considerable material savings through the flexible distribution and nesting of the production program. The flexibility of the laser cutting process is not limited to the easily adaptable, software-supported definition of the cutting contour, but can also be used to process material with locally different properties during the process. Fraunhofer ILT is developing a laser blanking process for cutting flexibly rolled steel of locally varying thickness.

Method

In order to process material with variable thickness reliably, the institute is pursuing two approaches. On the one hand, it has given the robustness of the process high priority. On the other hand, it is adjusting process parameters dynamically, depending on the sheet thickness. The thickness-dependent control of the cutting speed is a decisive parameter and ensures compliance with quality criteria and productivity.

Results

The institute has been able to fully achieve high standards of laser blanking of material with constant properties even with coil material with locally varying thickness.

Applications

For material with constant as well as variable properties, the highly productive laser cut from coil has reached a level which allows the industry to economically mass-produce sheet metal products in ever-changing variants. Thanks to its higher available laser power, this technology is also becoming increasingly interesting for industries that need to process larger thicknesses above 3 mm.

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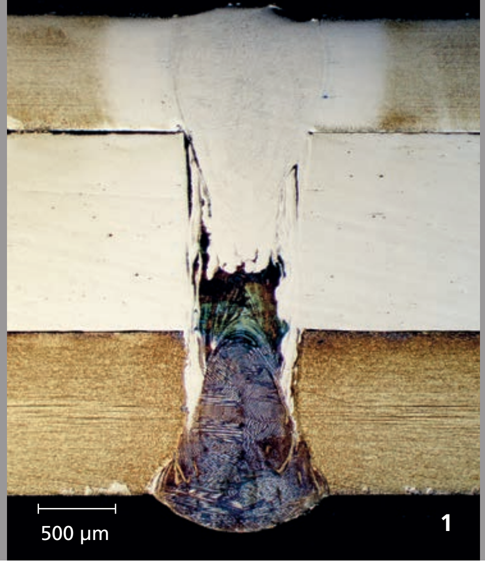
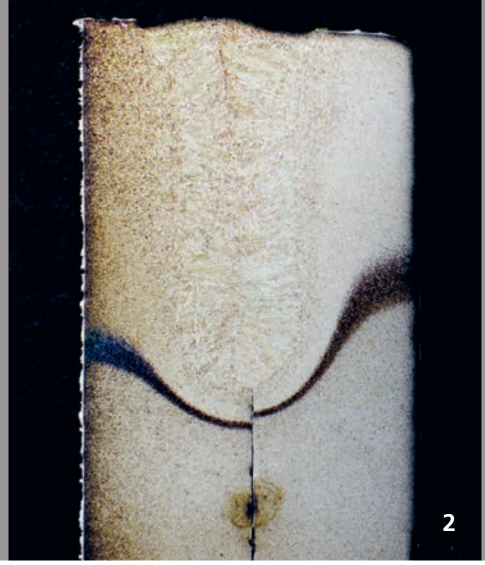
3 High-speed cutting of a B-pillar.

4 Sample component.





LASER BEAM WELDING OF PRESS-HARDENED CHROMIUM STEELS WITH MARTENSITIC MICROSTRUCTURE

Task

After determining that press-hardened chromium steels with a martensitic-austenitic microstructure are principally suitable for welding, Fraunhofer ILT is now continuing the research heading to safeguard weldability. It is focused on similar and dissimilar bonds in overlap joints. Based on the dissimilar bonding of these steels with other ultra-high-strength grades, the institute is pushing forward the development of welded components.

Method

Taking into account the suitable heat treatment, Fraunhofer has determined the parameters for achieving a homogeneous distribution of strength across the weld. The bond is made by contoured stitching and by abutting face seams. The mechanical properties are determined in quasi-static and dynamic KS2 tests. Fatigue tests are also used to determine how the welded joints behave in operation.

Results

After metallurgical basics were clarified, the first parameter fields for welding and heat treatment were identified, so that a first iteration was initiated by determining the mechanical properties.

Non-die hydroforming trials have shown that the failure limits of welds without heat treatment are still too low to ensure reliable fabrication. Further experiments will serve to improve the mechanical and technological properties.

Applications

The results of the project can be used directly in vehicle construction for road and rail. Indeed, these industries can fully exploit the potential for lightweight construction resulting from the high strengths. Manufacturers of welding equipment and laser technology can expand their offers for demanding welding tasks in the field of ultra-high-strength steels.

The IGF project 19556 of the Research Association for Steel Application (FOSTA) has been funded by the Association of Industrial Research Associations AiF within the framework of the program for the promotion of industrial joint research IGF by the Federal Ministry for Economic Affairs and Energy BMWi.

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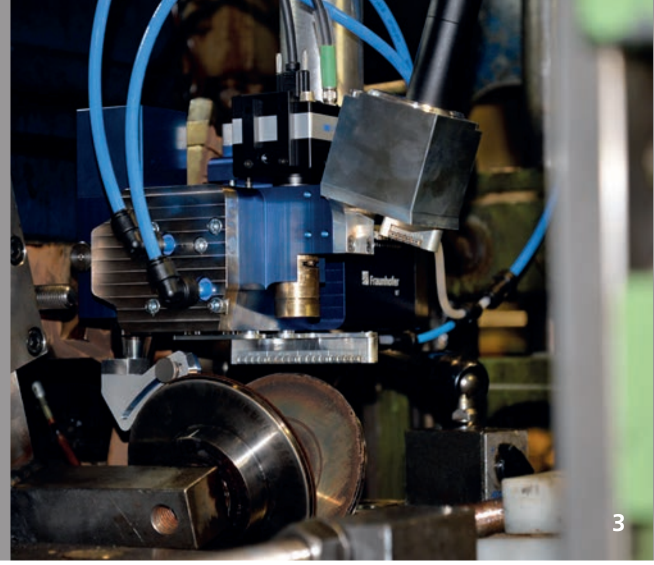
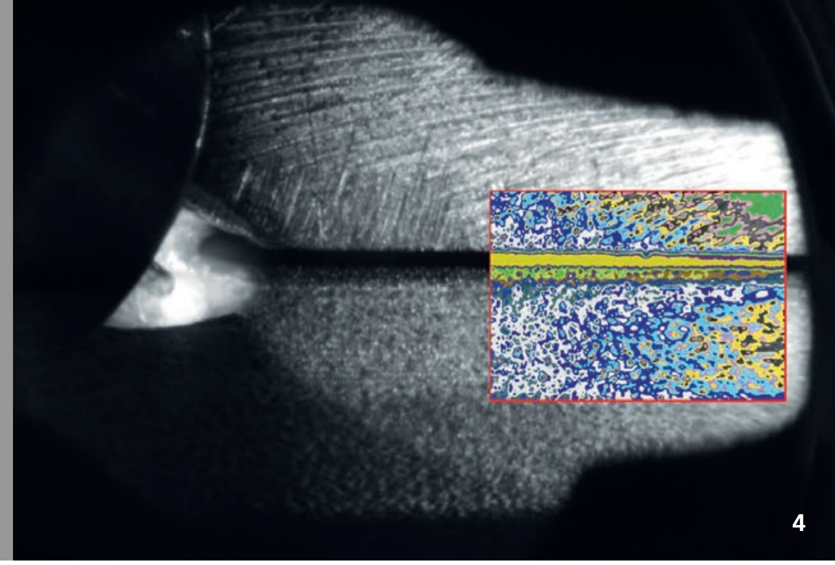
1 Weld seam at the overlap of three materials (1.5528, 1.4034, 1.4678).
2 Abutting-face seam in 1.5528.





JOINT TRACKING AND ADAPTIVE CONTROL BY REAL-TIME IMAGE PROCESSING

Task

In laser beam welding, the laser processing tool has to be guided continuously and precisely in relation to the joining partners since the working steps are mechanized to such a high degree. The sensors used in the image processing systems act as sensory organs, which, for example, function as visual guiding for machines and robots or detect the position of workpieces. Simple laser triangulation methods no longer meet the requirements today, as technical zero gaps are necessary in manufacturing processes or can occur in the process. In the case there are varying gap dimensions, the amount of filler introduced has to be adapted flexibly.

Method

Fraunhofer ILT has developed a system with which the distance between butt joint and laser beam (TCP) as well as the joint width during joining can be adaptively controlled by real-time image processing. In this system, an image sensor is arranged coaxially in the beam path of the processing optics for the fiber-guided laser beam or laterally in CO_2 welding optics.

Results

The institute's engineers have implemented the computationally intensive image processing algorithms required for joint tracking control on field-programmable gate arrays (FPGA) or on a graphics card (GPU) for the texture-based approach with a large number of parallel working graphics processor cores. A real-time process monitoring and control system has thus been created in conjunction with a programmable logic controller for communication with peripheral devices and systems.

Applications

Thanks to the developed real-time image processing, an inline-capable joint tracking system is now available for applications in shipbuilding, steel or rail vehicle construction as well as in profile production. The connection to production machines is independent of the machine type. A transfer of the system to other configurations is supported by modular interfaces.

The underlying R&D work was carried out in the »ShipLight« project on behalf of the Federal Ministry for Economic Affairs and Energy BMWi under grant number 03SX389M and funded as LEA »SPOTnSEAM« by the EU in the project »LASHARE« under grant number 609046.

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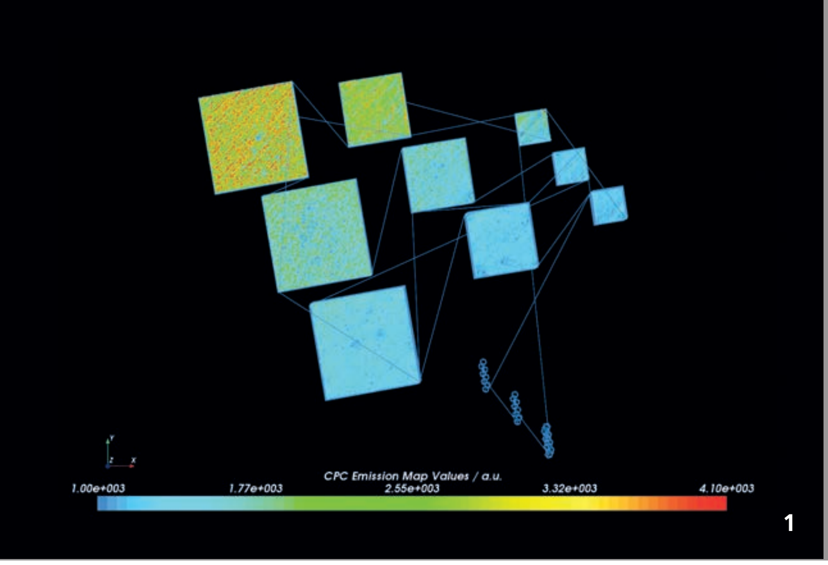
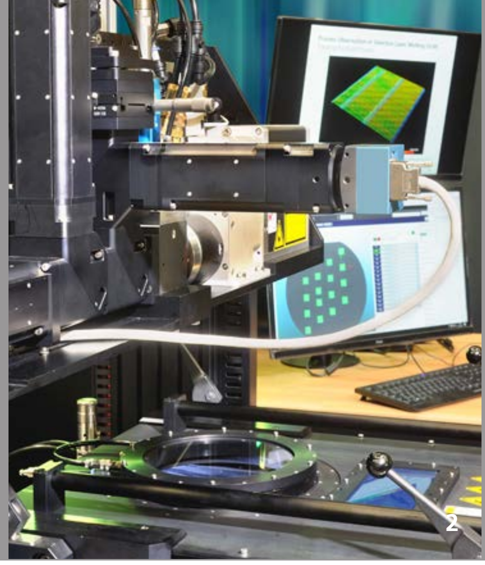
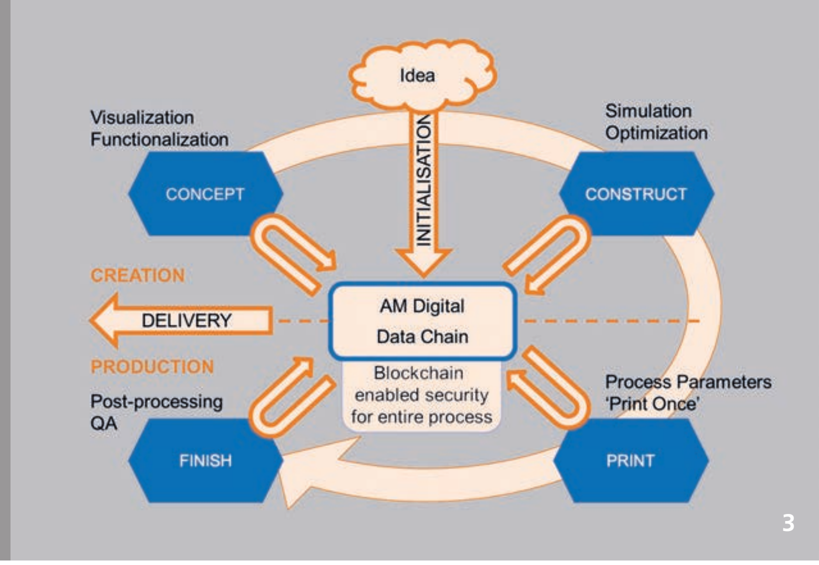
3 CO_2 profile roll forming plant with laterally arranged joint control.
4 Process image with texture-based joint segmentation.







DEEP LEARNING FOR QUALITY DIAGNOSIS IN LASER MATERIAL PROCESSING

Task

Today's process observation systems make it possible to capture the interaction zone in laser material processing in multiple dimensions. This multi-dimensionality is achieved by high-resolution camera systems, which observe the process zone locally and/or resolve it spectrally. The resulting large amounts of data must be evaluated in a suitable manner in order to identify the current process status unequivocally.

Method

Today, neural networks can be used to processing sensor data because appropriate data processing systems have become available. Above all, graphics processing units (GPUs) make it possible to process large amounts of data in parallel and, thus, to create complex models.

After the neural network is defined structurally, a training phase is performed. In this phase, a large number (> 10,000) of process-specific examples of combinations of multidimensional measurement data and the associated process state are given to the algorithm. The free parameters of the model are optimized until the required prediction accuracy is achieved. The resulting model is then able to classify multidimensional measurement data into previously defined process condition classes based on specific learned characteristics. In the case of laser material processing, the process data can be divided into different classes, such as, for example, different process errors or quality gradations.

Results

For the simultaneous detection of the focus position and the supplied laser power, a convolution neural network (CNN) was defined and trained on a high performance GPU cluster. The IR image data was recorded during a welding process and combined with the corresponding process parameters, all of which serve as a database for model training. The application of the generated model shows that Deep Learning can extract specific image features that can predict the focus position and the laser power independently of each other.

Applications

In situ measurements and analyzes in the process zone make it possible to respond to deviations in the process by means of a downstream control strategy. For example, seam imperfections during welding can be identified in multi-dimensional process data. Overall, this sensor system enables users to develop data-intensive process monitoring concepts for different industrial applications.

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1 In-situ pyrometer data from one component layer.

2 LPBF system with integrated sensor system.

BLOCKCHAIN – DATA PROTECTION AND DIGITAL TRANSPARENCY ALONG A PRODUCTION CHAIN

Task

From designing to delivering a product, inventors and creators generate a multitude of different data. In the course of a product evolution, however, information about both the author and file content is often lost at a given time such that details cannot be reconstructed later. To safeguard data inventory and its integrity, Fraunhofer ILT is developing a solution for complete digital transparency along a production chain in the »AMable« project.

Method

The development of the »AMable IDS-Connector App« based on blockchain technology enables simple and tamper-proof documentation of data sets. The application uses hash algorithms to generate a digital fingerprint of a file and connects it to metadata such as the author's identification. This fingerprint, along with the metadata, is integrated into the chain as a block, setting the time and ownership of the block. To quickly integrate new blocks into the chain at low computational cost, the blockchain implementation is based on Hyperledger and hosted at multiple independent entities.

Results

With the »AMable IDS-Connector App«, the owner of the data can create digital transparency as needed. If he wants to check himself or prove to a third party that his file has not been tampered with, he will again generate a digital fingerprint and compare it with the fingerprint from the blockchain. If both agree, proof of the author, time and content are provided all at once. This ensures the integrity of the data. By implementing a blockchain to document data along the process chain, the EU project »AMable« demonstrates how to secure authorship, to comply with documentation and proof obligations and not least to protect data against manipulation.

Applications

The »AMable Blockchain« can be used as a basis to perform a logging function in special areas of production as a trusted system, thus ensuring manipulation security for process data.

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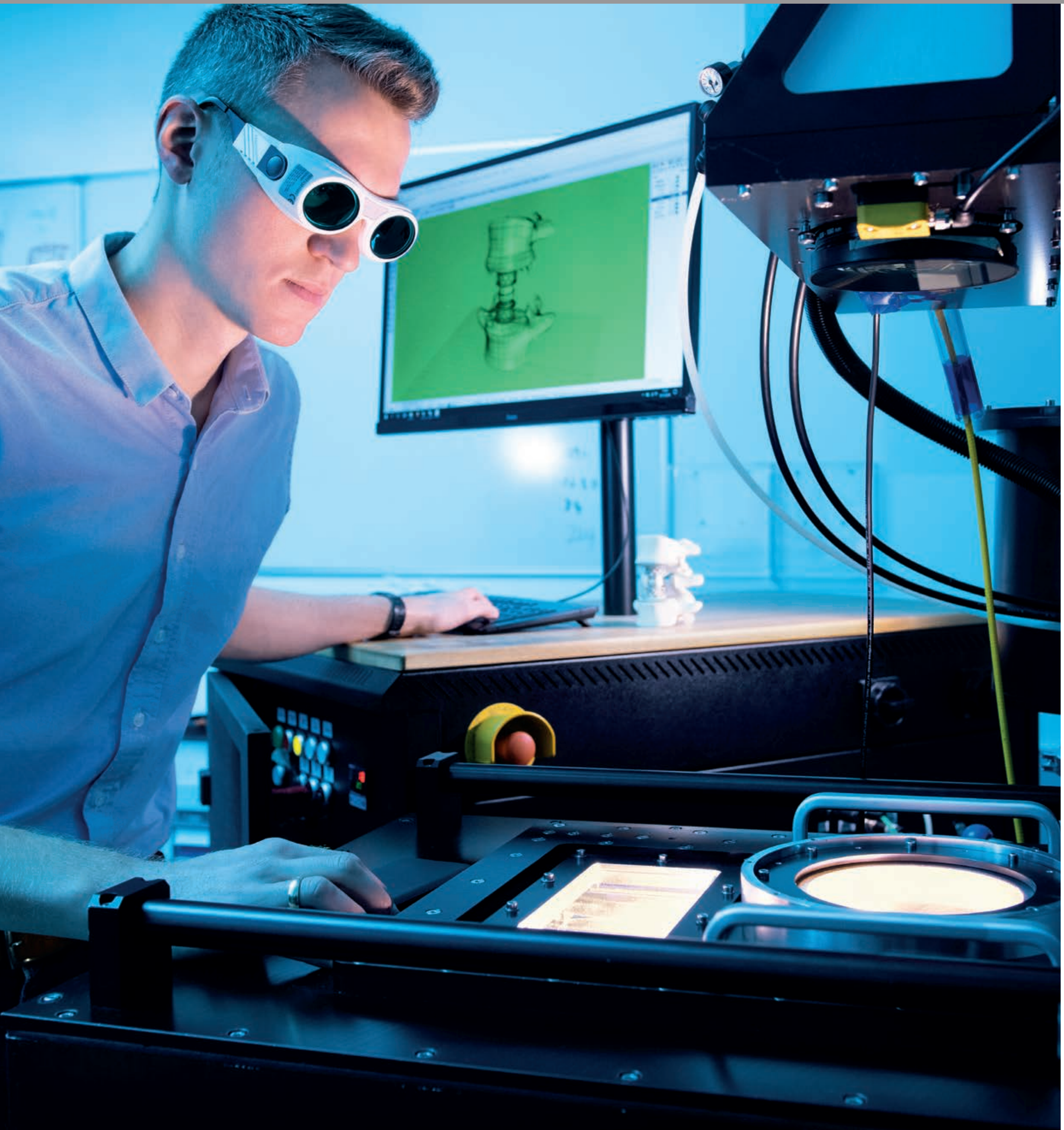
3 Blockchain to secure the digital data chain.

MEDICAL TECHNOLOGY AND BIOPHOTONICS



Laser beam melting of
a vertebral-body implant.

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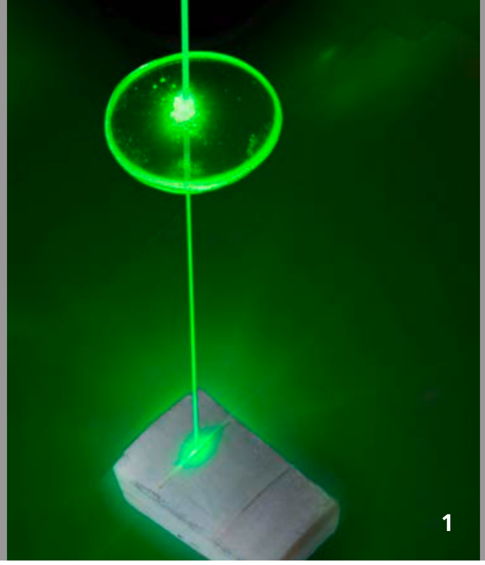

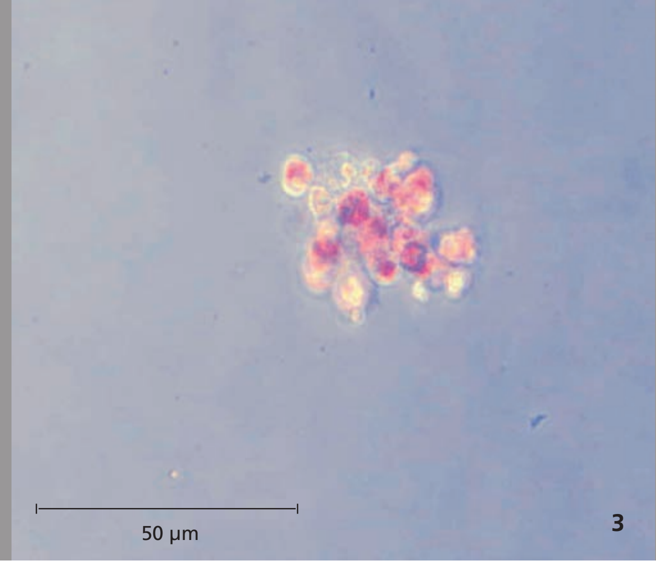

LASER SURGERY FOR THE DECOMPRESSION OF SPINAL CANAL STENOSIS

Task

Every year 55,000 surgeries are performed in Germany to decompress lumbar spinal stenosis. These are bony growths that narrow the spinal canal of the lumbar spine and, through mechanical pressure on the neuronal structures, cause severe pain and imitations in the mobility of affected patients. In advanced stenoses, surgeons use a procedure in which they gain access through the affected vertebral body with a high-speed drill and remove the bony growths in the spinal canal. In one out of 200 patients, the spinal cord or the nerve root are injured, which results in significant physical disabilities for the patient.

Method

For this reason, Fraunhofer ILT, in cooperation with the neurosurgical clinic of the Freiburg University Hospital, has developed a surgical procedure with which the vertebral body can be opened with the help of short-pulse laser radiation of high power. The laser radiation is coupled via a beam guiding system into a handpiece. In addition to the laser cutting function, the handpiece has an observation unit and an interferometric cutting depth measurement, both of which monitor and control the process inline. As a result of this, the surgeon can terminate the laser process free of inertia after the vertebral body has been opened, without causing injuries to the underlying neuronal structures.

Results

In the laboratory, the project partners have developed a laser cutting process with ps laser radiation that can be used to treat hemorrhages under water rinsing. Furthermore, they have developed a handpiece that distributes the laser pulses on the tissue surface via an integrated mini-scanner so that tissue can be removed both efficiently and with no thermal influence. The handpiece includes not only a depth measurement with optical coherence tomography (OCT) but also a rinsing and suction function. In the laboratory, removal rates of $\Delta V/\Delta t = 1\ mm^3/s$ were achieved with an average laser power of $P = 55$ W and pulse durations of $\tau = 2$ ps.

Applications

The laser surgery system is designed for use in neurosurgery and can be used in particular for spinal surgery and craniotomies.

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1 Laser cut in bone.

2 Handpiece for spine surgery with ps laser radiation.

CELL-PRESERVING SINGLE CELL TRANSFER

Task

In various medical studies worldwide, different bioprinting methods are being investigated for the research and production of artificial tissue. One promising method is laser-induced forward transfer (LIFT), in which single cells can be printed in a hydrogel matrix. For this purpose, a metallic absorber (e.g. titanium) has to be evaporated by means of laser radiation in order to transfer material. This results in metallic nanoparticles whose influence on living cells is unknown.

Method

Since the LIFT process is currently based on the vaporization of a metallic absorber, Fraunhofer ILT is investigating whether other substances can be used as absorbent material. To ensure a sufficiently high laser absorption, the institute is testing a tunable laser-beam source for the LIFT process. For Chinese hamster ovary (CHO) cells embedded in a 5% gelatin gel, single-cell transfer into 96-well microtiter plates was studied and the growth rate determined.

Results

The results of the new LIFT process show that CHO cells can be transferred reliably. The transferred single cells survive and proliferate to more than 95 percent. In comparison, the same cells proliferate at only 60 percent when transferred with ultraviolet laser radiation and a titanium absorber layer.

Applications

The use of new absorbers and tunable laser beam sources in the LIFT process opens up new opportunities in the area of tissue engineering through targeted single-cell transfer. In biotechnology, single cells are used when cell clones need to be produced. The absence of metallic absorbers makes it possible to combine LIFT with other analysis methods and to establish new process chains.

The »MAVO OptisCell« project was funded by the Fraunhofer-Gesellschaft as part of an internal research project.

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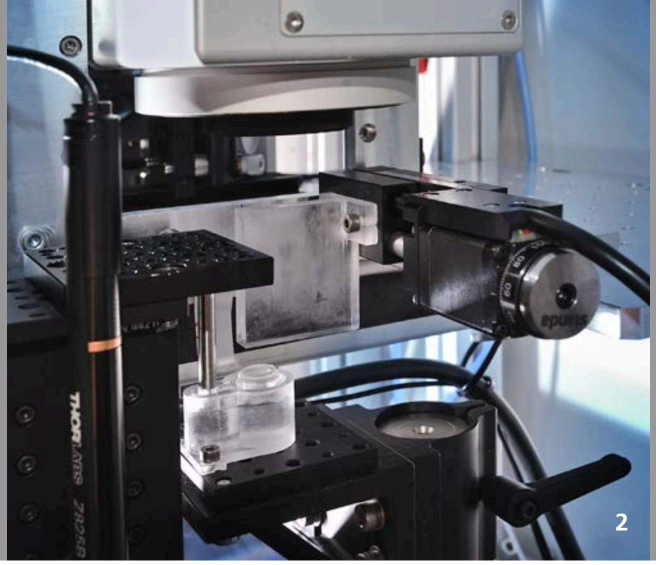
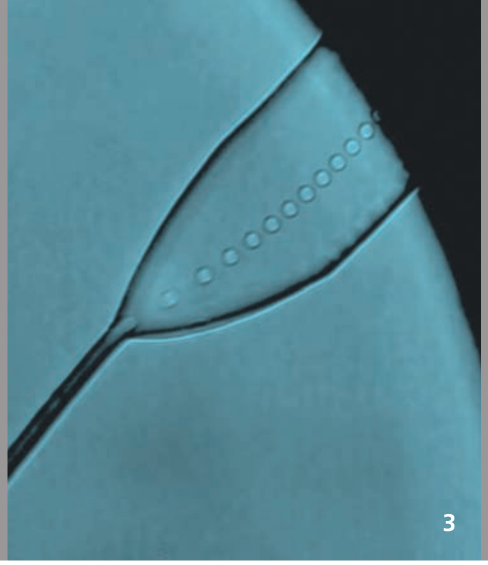
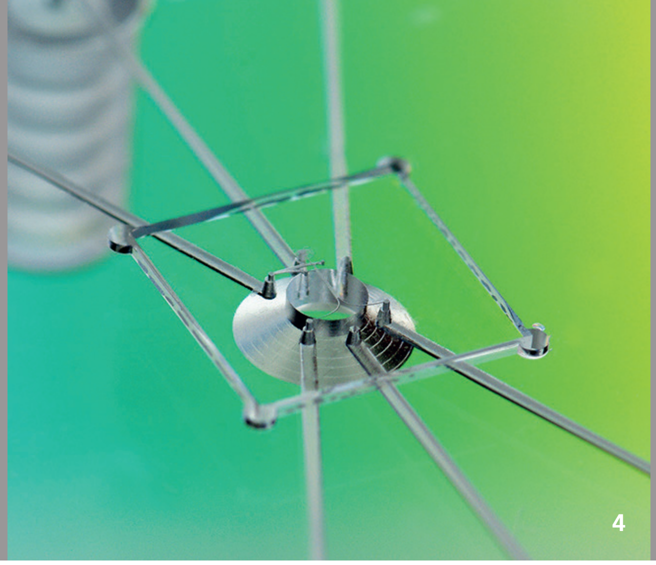
3 Transferred live cells after seven days.







ADDITIVE MANUFACTURING OF HIGH-INDEX POLYMERIC OPTICS

Task

Lenses, prisms, waveguides and other optical components are preferably made of transparent plastics because of their low weight and ease of molding in mass production processes. In particular, several parameters are essential for use in optics: transparency, color, spectral transmission and reflectance, refractive index and optical dispersion. Producing such optics in small batches and individual components is cost-intensive, but they can be made with additive manufacturing significantly cheaper, more flexibly and with more design options. As part of the BMBF-funded VIP+ project »ThIOLens«, Fraunhofer ILT is studying the additive production of polymeric optics with high refractive index for use in ophthalmology.

Method

Fraunhofer is investigating novel photoresists with a high refractive index for the additive production of optical components by means of UV crosslinking. This is where thiol-ene-click chemistry lends itself so well. Here, thiol groups react with unsaturated hydrocarbons by photo-excitation and form sulfur-containing thioether, which contribute to forming high-index polymers with good dispersion properties thanks to their high electron density. In addition to directly influencing the optical properties, thiol-ene-click chemistry also eliminates the need for photoinitiators. Residues of the initiator in the polymer may negatively influence the ageing behavior and biocompatibility of the material.

Results

So far, the institute has developed various materials with refractive indices greater than 1.53 and Abbe numbers greater than 40. These materials show elongations at break of up to 30 percent and E-modules of up to 750 MPa. Components with a chemically active surface could be produced from a non-stoichiometric photoresin. Remaining functional groups allow a subsequent chemical coating of the surface. This way, for example, antireflective coatings or coatings to increase the scratch resistance can be applied in an uncomplicated manner.

Applications

The main application area is ophthalmology. Standardized cell biological evaluations in direct contact show that these materials have no cytotoxic effect. In addition, an application in the field of technical optics is particularly suitable for the harder materials. Here, curing could be directly done on active structures, such as sensor chips. This makes it possible to produce coupling and decoupling structures or beam collimators as well as to write optical fibers on optical chips.

The R&D project underlying this report was carried out on behalf of the Federal Ministry of Education and Research BMBF under grant number 03VP00841.

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1 User interface of the modular software.

2 Laboratory setup of the stereolithography system with scanner, construction platform, resin basin and scraper.

PROTOTYPING AND MANUFACTURING 3D MICROFLUIDIC CHIPS IN FUSED SILICA

Task

The range of applications of microfluidic systems is diverse and often specific to a customer. Conventional manufacturing processes for microfluidic chips use molding or lithographic methods; however, both of these limit the designs to planar structures. Creating free-form, three-dimensional microstructures directly from the digital design is fast and cost effective when prototypes need to be developed, and it significantly shortens innovation cycles for new designs. In addition, the 3D process makes it possible to implement completely new functionalities in a microfluidic system.

Method

Fraunhofer ILT has developed a laser process for the production of 3D channel structures in fused silica. In this process, complex structures from the digital design data with ultrafast laser pulses are written directly into fused silica. The process locally changes the physical and chemical properties of the glass. The irradiated structures can, therefore, be etched wet-chemically selectively with micrometer precision so that cavities are formed inside the glass substrate as written channel structures (selective laser etching). The CAD-based design and precise volume fabrication make it possible to design fluidic channels as well as interfaces for the positioning of optical components in a single opto-fluidic system in a very compact and cost-effective manner.

Results

Currently, microfluidic chips can be produced with channel structures of 10 µm in width and several centimeters in length. The roughness of R_z = 2 µm can be reduced by thermal remelting processes so strongly that the surfaces attain optical quality; this way, diagnostic laser measurement methods can be used in the microfluidic chip.

Applications

For high-throughput screening, microfluidic glass chips were developed for the generation and screening of segmented flows of smallest droplets with a diameter of 5 µm and used for the cell-free biosynthesis of enzymes. In addition, the 3D microfluidic chips are used in multispectral screening systems with scattered and fluorescent light detection, in which three-dimensional structures are used for the highly accurate hydrodynamic focusing of cells and particles.

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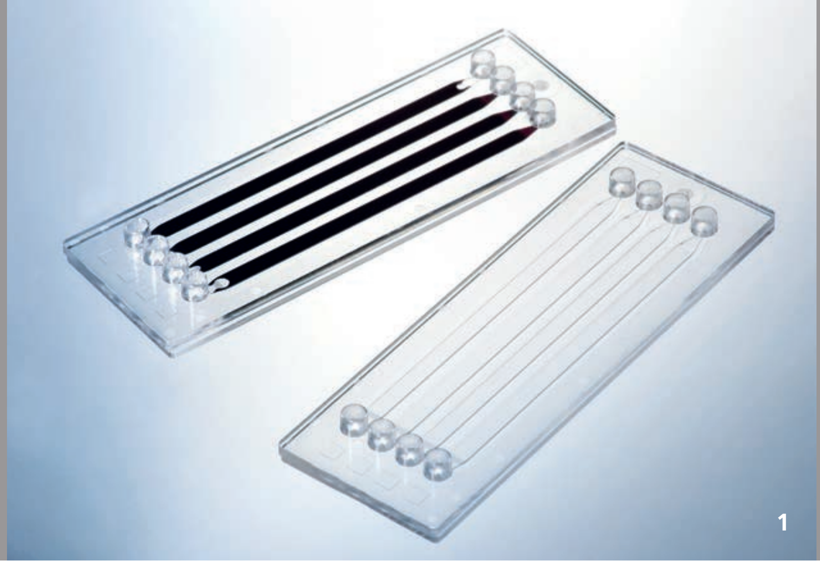
3 Generation of droplets with Ø 10 µm.

4 Carrier structure for plug and play connection of microfluidic chips via plug connectors made of fused silica.



MEDIA-TIGHT WELDING OF 50 µl REACTION CHAMBERS FROM TRANSPARENT POLY-CARBONATE

Task

Chips having the dimensions 1.5 x 75 x 25 mm, channel structures and made of transparent PC, PP, COC or COP polymers are widely used in analytics and microfluidics. The channels in them are made during the injection molding process; in the next step, adhesives are used to close them with a lid or a film. For approximately three years, laser radiation has been successfully tested to weld these chips, thereby providing an additional joining means with small, temperature-resistant, contour-adapted seams. The wavelength used is in the range of 2 µm, which exploits the intrinsic radiation absorption of transparent plastics. The challenge here is to encapsulate the microchannels in both a media-tight and damage-free manner.

Method

In a contact pressure device, the polycarbonate chip, which contains four reaction chambers each having a volume of 50 µl and a cross section of 2.8 × 0.35 mm, is welded along the individual chambers to a 1 mm thick polycarbonate cover by using a galvo scanner head. The wavelength of the thulium fiber laser is 1940 nm and the focal length of the F-theta focusing scanner lens 120 mm.

Results

The seams could be produced at a laser power of 20 W and with the galvo scanner speed set to v = 15 mm/s. The focal depth of the laser beam is $z_R = 4.3$ mm due to the 5,5 mm raw beam diameter and the lens with 120 mm focal length. This is equivalent to a divergence half angle of only θ = 2.75 mm / 120 mm = 23 mrad.

Applications

Microfluidic chips with small channel spacing due to their complex structure often cannot be permanently bonded because high temperatures endanger the tightness of the adhesive bond. In these cases, NIR laser radiation can be used to seal the joint. If the upper joining partner has material thicknesses of about 1 mm, the focusing can be done with long-focal-length lenses and is thus resistant to changes in adjustment.

The work was carried out within the framework of the »AFRELAS project« funded by the Association of Industrial Research Associations »Otto von Guericke e. V.« under the funding number IGF-No. 19395 N.

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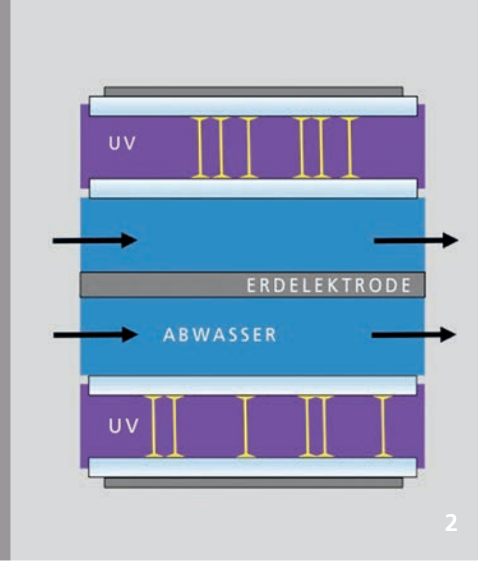
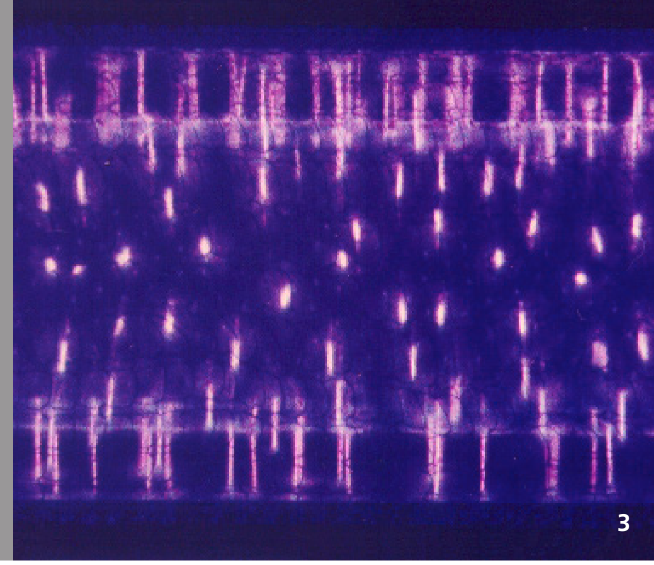
1 Media-sealed four-channel polycarbonate reaction chamber chip, channels 50 µl, 50 mm x 2.8 mm x 350 µm each.





INNOVATIVE PLASMA PROCESS FOR THE REMOVAL OF POLLUTANTS IN WASTEWATER

Task

Society faces new challenges and needs innovative processes for wastewater treatment as our waters are becoming more polluted and thus our drinking water supply threated by pollutants that are difficult to decompose. Today, pollutants resistant to biodegradation in the classical activation process can only be degraded in very few sewage treatment plants, ones that treat the wastewater with ozone or the use of activated carbon.

Method

In cooperation with the Institute of Environmental Engineering (ISA) at RWTH Aachen University, Fraunhofer ILT carried out initial experiments to degrade diclofenac (DCF) and the X-ray contrast medium amidotrizoic acid (ATZ) in a new process with combined plasma and UV treatment. Bombarding a reactor of the wastewater with reagents from the plasma (ozone, OH radicals) and UV radiation (here, excimer radiation at 222 nm) promises to consume significantly less energy to degrade pollutants while avoiding chemical substances due to the synergistic effect. In a reactor, a cascade of plasma filaments is generated in the electrical field of the applied high voltage in both, the UV chamber and the chamber with the wastewater to be treated (see Figure 2).

Results

First experiments showed a decomposition rate of 80 percent for ATZ in a mixture of DCF and ATZ for an estimated energy requirement of 4 kWh per cubic meter of wastewater. The simultaneously determined rate of degradation of DCF was significantly greater, and the energy requirement for an equal rate of degradation of 80 percent significantly lower. The target value of 0.2 kWh/m^3 seems realistic, based on the data from the preliminary experiments and the optimization potential, e.g. with the electrical parameters or the reactor geometry. This target value results from a comparison to wastewater treatment with ozone, which is currently the state of the art. Pollutants such as DFC or ATZ are only degraded at a much lower rate.

Applications

Possible fields of application of this method are in sewage treatment plants or decentralized facilities of heavily polluted wastewater.

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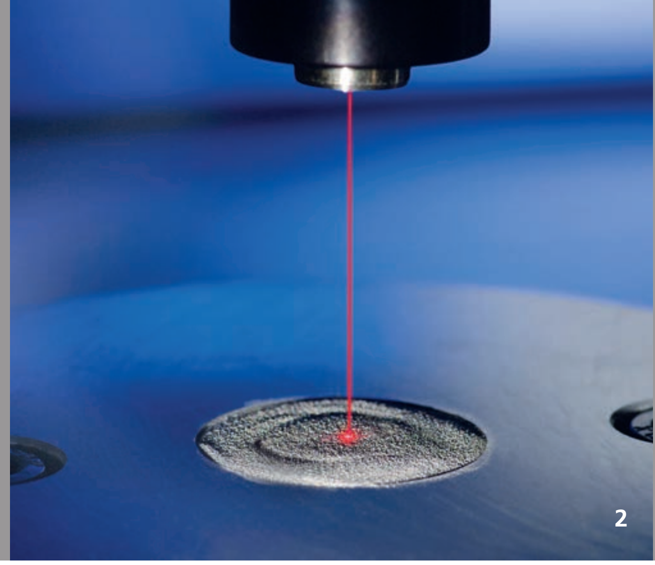
2 Schematic diagram for wastewater treatment with cascaded barrier discharge.
3 Coaxial reactor with barrier discharge.

LASER MEASUREMENT TECHNOLOGY AND EUV TECHNOLOGY

CONTENTS

Optical measurements made on bone models for laser surgery.



»bd-1« SENSOR FOR INLINE MEASUREMENTS OF GEOMETRIC PARAMETERS

Task

Non-contact inline measurement of geometric parameters opens up a variety of possibilities for process control and optimization when metallic components and materials are machined. Examples of such parameters to be measured inline are the thickness of rolled sheets, the welding depth during laser welding, the height of applied traces in laser material deposition or the microtopography of structures produced by ultrashort pulse laser. Fraunhofer ILT has developed an absolute-measuring interferometric sensor system with which these parameters can be determined quickly and precisely. Currently, the institute is investigating whether the scope of application of this sensor technology can be extended to inline measurement tasks for the Laser Powder Bed Fusion (LPBF) process.

Method

The »bd-1« sensor has a compact measuring head with bidirectional beam guidance. The outward and return beams run along the same line. The wavelength of the measuring radiation is chosen so that it can be guided coaxially to the processing laser radiation. The measurements can be triggered and synchronized with the machining process flow. Thus, measurement results are available in real time for process control.

Results

Special features include a measuring frequency of up to 70 kHz and a measuring accuracy better than 1 µm in a measuring range of 8 mm. The measuring beam is moved relative to a powder bed surface to measure the microtopography of the powder bed. Different powder forms of the same material result in varying local bulk densities, which can be detected with the help of the »bd-1« sensors and used for process control.

Applications

Their compact design makes it easy to integrate »bd-1« measuring heads into laser processing systems like LPBF. The working distance is up to a few hundred millimeters. Thus, geometric parameters can be selectively measured in the processing field in real time, at the powder bed as well as in the melting zone and on the solidified parts.

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1 Measuring head of the »bd-1« sensor.

2 Measurement of the microtopography of a metal powder bed.

LASER DETECTION OF ELECTRONIC COMPONENTS

Task

To recover valuable raw materials from old electronics, the industry must be able to identify the electronic components in which these raw materials are present in high concentrations. This chemical, component-based information is generally not available on the marketable electronic devices themselves. For this reason, automated solutions to recognize components and evaluate their recyclable content are necessary to extract these parts selectively and process them in separate fractions.

Method

Fraunhofer ILT is coordinating the joint European project »ADIR«, in which technological solutions are being developed in order to efficiently recover the recyclable materials. For this purpose, the project partners are developing automated processes to identify the physical and chemical properties of valuable assemblies and selectively extract corresponding electronic elements.

Results

A combined method is used to detect the composition of an electronic component without contacting it. First, a pulsed laser beam penetrates the housing of the components locally. The subsequent analysis of the internal structures is carried out by the process of laser-induced breakdown spectroscopy (LIBS). The beam paths for laser excitation and detection are aligned quickly and precisely to individual positions of an electronic circuit board. As a result, a large number of electronic components can be examined in a short period of time. The positions of the components to be examined are obtained from high-resolution two- and three-dimensional imaging. The inline measured data on size, position and chemical composition are finally used for evaluation, targeted sampling, sorting and subsequent processing. The developed inspection procedures were combined in one machine and linked together. The ADIR demonstrator is currently undergoing field trials at a recycling company.

Applications

Since the fast and non-contact analysis can capture location-dependent physical and chemical quantities inline, it opens up a new data space for both production as well as inverse production. The application potential ranges from characterizing natural raw materials through inspecting the quality of metallic components and semi-finished products all the way to discovering recyclables themselves.

The work is being carried out as part of the EU project »ADIR« under grant number 680449.

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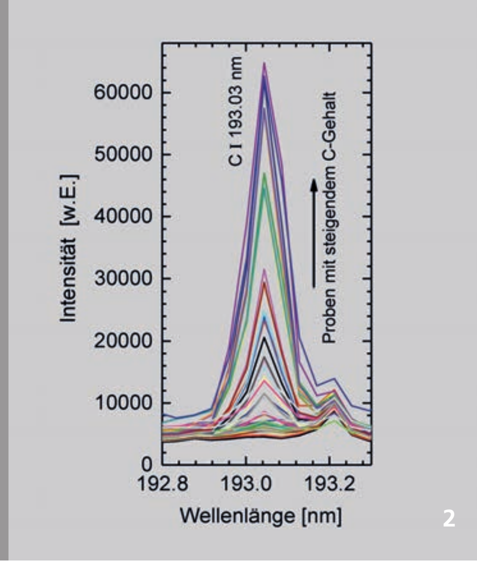
3 Measuring machine for the EU project »ADIR«.

4 Laser spectroscopic measurement on a circuit board of a mobile phone.



MOBILE SPECTROSCOPY FOR THE ANALYSIS OF CARBON IN STEEL

Task

To better analyze the elements of metals with mobile analyzers, such as cordless handheld devices, this project aims to develop the process and conceptual design for laser-induced breakdown spectrometry (LIBS) with small, highly integrated components and to investigate its analytical performance in the laboratory. Due to the economic importance and technical challenges, it will mainly focus on detecting carbon in steel. Its goal is to detect carbon down to the range of 0.01 percent, while remaining compact for a handheld device.

Method

In close connection between laser development and measurement technology, the project partners are developing a passive Q-switched laser, the spectral detection and the guidance of the laser and measuring radiation under the specifications for a mobile application. Size, weight and energy management play a decisive role in addition to the achievable analytical performance. Key points of the development are manifold: determining the compromise between these boundary conditions and the conflicting requirements on the spectral resolution, the inert gas atmosphere at the interaction site as well as the duration, sensitivity and reproducibility of the measurements. The parameters of the LIBS detection must be adjusted in such a way that the carbon spectral line is effectively detected and the detection of low content is possible.

Results

In a laboratory setup, carbon in steel can be detected with optimized measurement parameters; the setup's core components are designed for a mobile system. On steel samples with carbon contents in the range of 0.01 percent, the carbon line at 193 nm is detected significantly at a laser repetition rate of 1 kHz.

Applications

Mobile analysis devices for rapid elemental analysis of metals are commonly used in metal production and processing as well as in the recycling industry. Compact, integrable measuring systems also make it possible to continuously monitor production processes or conduct identification tests as well as to inspect incoming raw materials or semi-finished products.

This project is financially supported by the Fraunhofer-Gesellschaft.

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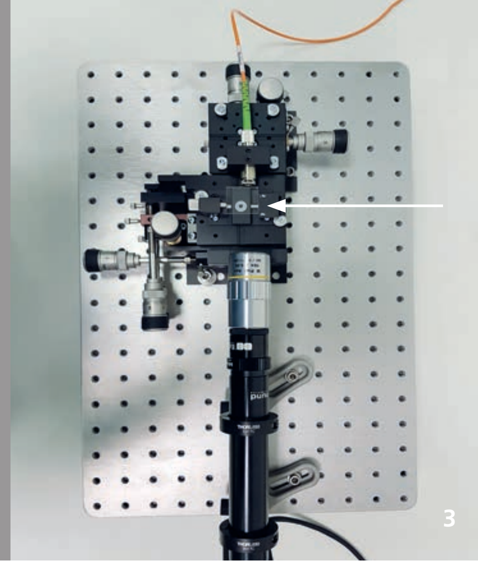
1 Reference samples of steel with certified carbon content.

2 Spectral line of carbon at 193 nm for a set of reference samples with varying carbon content.



WAVE GUIDES FOR ANGULAR RESOLVED LIGHT SCATTERING

Task

Angular resolved light scattering is an analytical method that can be used to determine not only particle sizes, but also approximate particle forms. This so-called static laser light scattering analyzes particles with a size between a few 10 nm and several 100 µm with laboratory equipment. However, the process is not yet suitable for inline-capable, process-analytical immersion probes. In a research project with partners from industry, Fraunhofer ILT is developing a compact, inline-capable immersion probe for particle analysis in which the scattered light is measured with angular resolution.

Method

Waveguides transport the light scattered by the particles with angular resolution so that the optics can be miniaturized and integrated into a submersible probe. A short pulse laser is used to inscribe the waveguides in glass chips. A CCD line detector on an outer surface of the glass chip detects the stray light guided through the waveguides.

Results

Waveguides are written with different laser parameters and then examined for their applicability to scattered light guidance. For the characterization of waveguides, Fraunhofer has developed different optical measuring methods. In addition to transmission microscopy, it also uses laser-based methods. A test stand with an adjustable laser beam source and a CCD camera with a microscope objective visualizes the laser beam guided through the waveguide. It and its direct neighborhood can be examined with a laser scanning microscope detecting in the transmission direction. This way, shapes and structures of the waveguides can also be analyzed.

Applications

The scattered light probe can measure the size of particles in the range of a few 10 nm up to many µm. It can be applied, for example, in bioprocess and chemical process analytics. Growth processes in biofermenters or particle formation in chemical crystallizations should be recorded inline during an ongoing process.

The R&D project underlying this report has been carried out on behalf of the Federal Ministry of Education and Research BMBF under grant number 13N14176.

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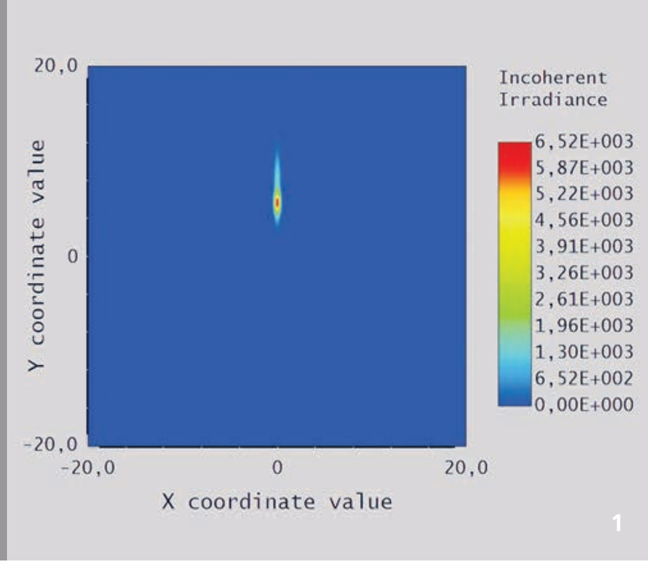
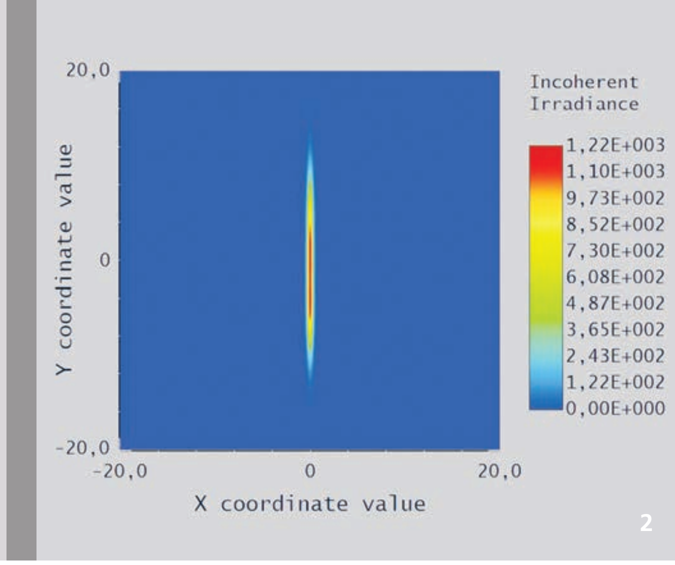
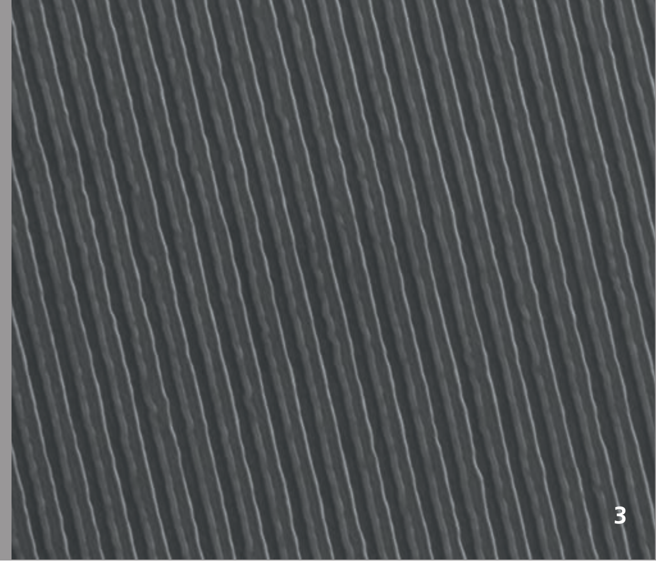
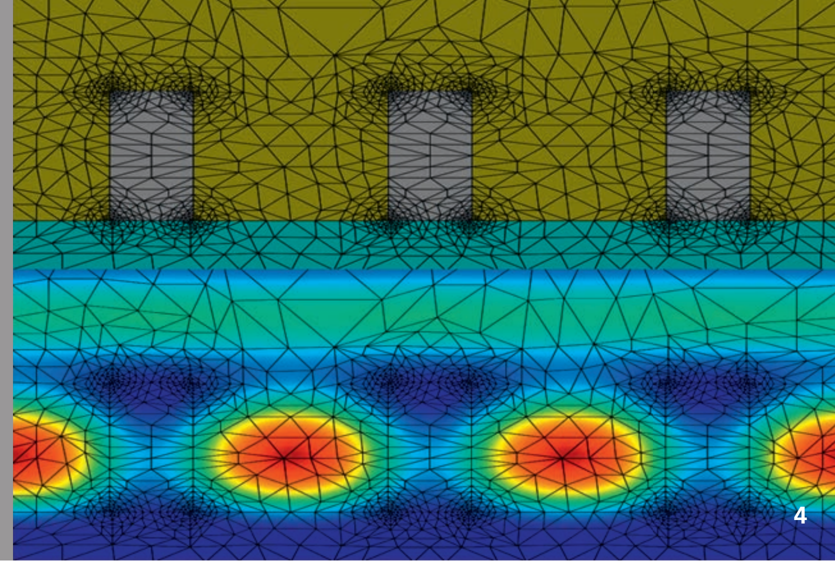
3 Test stand for the characterization of waveguides; the arrow marks the glass chip with waveguides.

4 Laser scanning microscope image of a laser-structured waveguide.









GAS DISCHARGE PLASMA AS MEDIUM FOR XUV LASER

Task

Dense, hot, and cylindrical plasmas with a high aspect ratio of length to diameter are of interest as a medium for enhanced spontaneous emission (ASE) or for brilliance optimization in the axial viewing direction. Elsewhere in the past, argon-based gas discharge plasmas have been successfully demonstrated with ASE at 46.5 nm. In this case, electron densities of 10^{18} - 10^{19} per cm^3 at temperatures in the range of 50 - 200 eV must be achieved. Fraunhofer ILT is working on discharge concepts in which such plasmas can be generated in the future with a higher repetition rate in the range of several kilohertz, with higher average radiation power and long-term stability.

Method

To generate plasmas with longer axial expansion of several centimeters, Fraunhofer has modified the electrode system using an existing gas discharge concept. Systems based on this concept are in commercial use in many places today. The approach the institute has chosen provides the technical prerequisites for scaling ASE-capable plasmas to a higher emission output and longer service life.

Results

The typical length of the plasma is approximately 3 - 4 mm for a state-of-the-art electrode geometry (see Figure 1). The diameter is between 300 and 500 µm in the axial direction of observation. In a first step, the length could be increased to about 20 - 30 mm with a modified electrode system. Figure 2 shows the reconstructed intensity distribution of an argon plasma. From the emission spectra, electron density and temperature can be estimated to be about 10^{18} per cm^3 and 50 eV, which means that the ASE conditions can be maintained after further optimization steps.

Applications

Highly brilliant, incoherent and partially coherent (ASE) radiation plasmas in the spectral range of the extreme ultraviolet (XUV) can be applied in microscopy or structuring on the nanometer scale, for example, in mask inspection in future semiconductor production.

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Intensity distribution of the EUV emission:
1 ... in the electrode system for geometry optimized for short plasmas (edge length 40 mm).
2 ... in the electrode system for a longer discharge channel (edge length 40 mm).

RIGOROUS OPTICAL SIMULATIONS IN EUV FOR SEMICONDUCTOR TECHNOLOGY

Task

The metrology of nanoscale gratings of semiconductor technology requires the application of new, more powerful metrology methods because they are becoming not only increasing complex, but structural dimensions are becoming smaller, below 100 nm. EUV radiation offers promising contrasts in the investigation of nanoscale gratings, whose structural dimensions are in the same order of magnitude or below the wavelength of the probing radiation. Advantageous are shorter wavelengths and a stronger light-matter interaction compared to methods that work in the UV or VIS range.

Method

To adequately interpret the results of EUV metrology, Fraunhofer ILT is using rigorous optical models to completely simulate the interaction of EUV radiation with investigated nanoscale gratings. It is applying two different simulation methods – Rigorous Coupled Wave Analysis (RCWA) and Finite Element Method (FEM) – both of which provide shorter computation time and/or more accurate results, depending on the design of the gratings studied.

Results

Through rigorous optical simulations, both near-field and far-field scattering of a nanoscale grating can be calculated when illuminated with EUV radiation. If these results are compared with real measured values, both the structure and the material parameters of the examined gratings can be reconstructed precisely.

Applications

Applications of EUV metrology can be found in the field of supporting metrology for semiconductor production, since it needs high-performance metrology methods for ever more complex structures and smaller structural dimensions.

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3 SEM image of nanoscale test grating.
4 Simulated near-field optical distribution in the EUV.

NETWORKS AND CLUSTERS

THE FRAUNHOFER-GESELLSCHAFT AT A GLANCE

THE FRAUNHOFER-GESELLSCHAFT

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. The majority of the more than 26 600 staff are qualified scientists and engineers, who work with an annual research budget of 2.6 billion euros. Of this sum, almost 2.2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

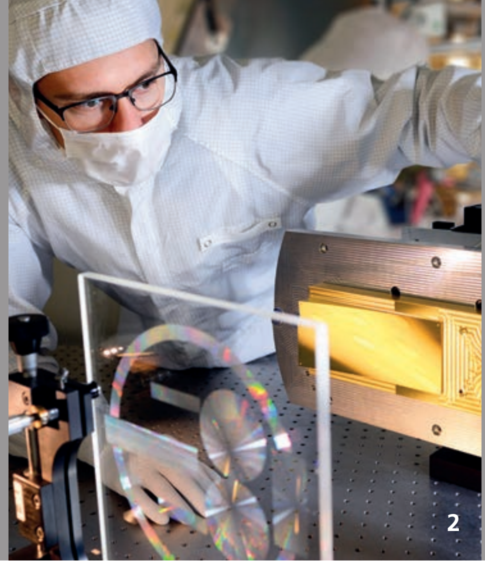
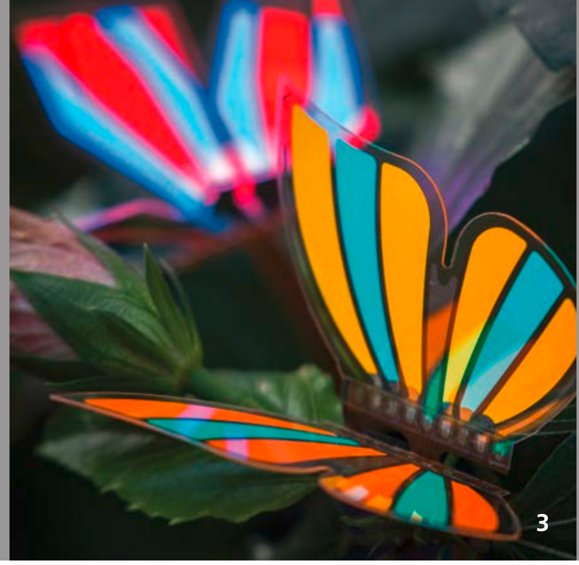
As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

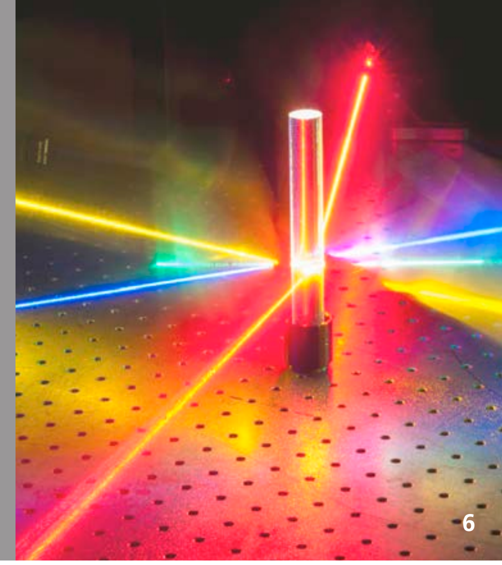
The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

FIELDS OF RESEARCH

The Fraunhofer-Gesellschaft concentrates on research in the following fields:

- Materials technology, component behavior
- Production and manufacturing technology
- Information and communication technology
- Microelectronics, microsystems engineering
- Sensor systems, testing technology
- Process engineering
- Energy and construction engineering, environmental and health research
- Technical/economic studies, information transfer

FRAUNHOFER-GROUP LIGHT & SURFACES

Competency by networking

Six Fraunhofer institutes are cooperating in the Fraunhofer Group »Light & Surfaces« in the fields of laser, optics, measurement and coating technology. Building on their basic research in the various fields of application, the institutes work together to supply fast, flexible and customer-specific system solutions in these fields. Strategy is coordinated to reflect current market requirements, yielding synergies that benefit the customer. The institutes also collaborate with their local universities to provide the full range of student education, up to and including doctoral studies. As a result, the Fraunhofer institutes are not only partners to technological development, but also a continuous source of new talents in the fields of coating technology and photonics.

www.light-and-surfaces.fraunhofer.de/en/html

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1 Fraunhofer IWS
2 Fraunhofer IOF
3 Fraunhofer FEP
4 Fraunhofer ILT
5 Fraunhofer IST
6 Fraunhofer IPM

Core competencies of the group

The Fraunhofer institutes' competencies are coordinated to ensure that research can be quickly and flexibly adapted to the requirements of the various fields of application:

- Laser manufacturing
- Beam sources
- Metrology
- Medicine and life sciences
- Materials technology
- Optical systems and optics manufacturing
- Micro- and nanotechnologies
- Thin-film technology
- Plasma technology
- Electron beam technology
- EUV technology
- Process and system simulation

THE INSTITUTES

Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP

The Fraunhofer FEP works on innovative solutions in the fields of vacuum coating, surface treatment as well as organic semi-conductors. The core competencies electron beam technology, sputtering, plasma-activated deposition and high-rate PECVD as well as technologies for organic electronics and IC/system design provide a basis for these activities. Fraunhofer FEP continuously enhances them and makes them available to a wide range of industries: mechanical engineering, transport, biomedical engineering, architecture and preservation, packaging, environment and energy, optics, sensor technology and electronics as well as agriculture. www.fep.fraunhofer.de/en

Fraunhofer Institute for Laser Technology ILT

With more than 540 employees the Fraunhofer ILT develops innovative laser beam sources, laser technologies, and laser systems for its partners from the industry. Our technology areas cover the following topics: laser and optics, medical technology and biophotonics, laser measurement technology and laser material processing. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and additive manufacturing. Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modeling as well as in the entire system technology. www.ilt.fraunhofer.de/en

Fraunhofer Institute for Applied Optics and Precision Engineering IOF

The Fraunhofer IOF develops innovative optical systems to control light from the generation to the application. Our service range covers the entire photonic process chain from opto-mechanical and opto-electrical system design to the manufacturing of customized solutions and prototypes. The institute works in the five business fields of Optical Components and Systems, Precision Engineering Components and Systems, Functional Surfaces and Layers, Photonic Sensors and Measuring Systems and Laser Technology. www.iof.fraunhofer.de/en

Fraunhofer Institute for Physical Measurement Techniques IPM

The Fraunhofer IPM develops tailor-made measuring techniques, systems and materials for industry. In this way the institute enables its customers to minimize their use of energy and resources while at the same time maximizing quality and reliability. Fraunhofer IPM makes processes more ecological and at the same time more economical. Many years of experience with optical technologies and functional materials form the basis for high-tech solutions in the fields of production control, object and shape detection, gas and process technology as well as thermal energy converter. www.ipm.fraunhofer.de/en

Fraunhofer Institute for Surface Engineering and Thin Films IST

As an innovative R&D partner the Fraunhofer IST offers complete solutions in surface engineering which are developed in cooperation with customers from industry and research. The IST's »product« is the surface, optimized by modification, patterning, and/or coating for applications in the business units mechanical engineering, tools and automotive technology, aerospace, energy and electronics, optics, and also life science and ecology. The extensive experience of the Fraunhofer IST with thin-film deposition and film applications is complemented by excellent capabilities in surface analysis and in simulating vacuum-based processes. www.ist.fraunhofer.de/en

Fraunhofer Institute for Material and Beam Technology IWS

Light and layer: Fraunhofer IWS works wherever lasers and surface technology meet. The Dresden institute comes into play if the task is to deposit different materials layer by layer, to join, cut, functionalize or analyze. Services range from developing new techniques via integration into manufacturing, up to user-oriented support – in single-source responsibility. The Fraunhofer IWS is meeting the challenges of digitization with a focus on researching and developing solutions for »Industry 4.0«. www.iws.fraunhofer.de/en

STRATEGIC FRAUNHOFER PROJECTS

Kick-off of the Fraunhofer lighthouse project »futureAM« in Aachen.

FRAUNHOFER LIGHTHOUSE PROJECT »futureAM«

With »futureAM«, the Fraunhofer-Gesellschaft is systematically promoting the further development of additive manufacturing of metallic components. For this purpose, six experienced institutes in the field of additive manufacturing have entered into a strategic project partnership:

- Fraunhofer Institute for Additive Production Technologies IAPT, Hamburg
- Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Bremen
- Fraunhofer Institute for Computer Graphics Research IGD, Darmstadt
- Fraunhofer Institute for Laser Technology ILT, Aachen
- Fraunhofer Institute for Material and Beam Technology IWS, Dresden
- Fraunhofer Institute for Machine Tools and Forming Technology IWU, Chemnitz

Strategic goals of the project partnership

1. Development of a comprehensive cooperation platform for the highly integrated cooperation and use of the distributed resources of the Fraunhofer-Gesellschaft in the field of Additive Manufacturing (AM)
2. Creation of the technological prerequisites that will increase scalability, productivity and quality of AM processes for the production of individualized metal components

Fields of activity

To ensure technological leadership, additive manufacturing will be systematically developed in four fields of activity coordinated by one institute each:

- Industry 4.0 and digital process chain
- Scalable and robust AM processes
- Materials
- System engineering and automation

There are many examples of the ambitious project goals in the four fields: novel software for automated AM component identification and optimization, a scalable SLM system design with productivity increase (factor > 10), a method and system technology for generating spatially resolved, customized multi-material properties and an autonomous manufacturing cell for the post-treatment of AM components.

Not only will the institutes cooperate intensively on the four fields of activity, they will also establish a »Virtual Lab«, which digitally maps the competences and resources of the project partners. Using this, all of the project partners will participate in developing technology demonstrators.

Contact and overall coordinator

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Further information at:
www.futuream.fraunhofer.de/en.html

FRAUNHOFER LIGHTHOUSE PROJECT »QUILT«

The second quantum revolution

Quantum mechanics provides access to the world of molecules, atoms and subatomic building blocks. In the first half of the 20th century the knowledge of quantum mechanics resulted in the development of modern electronics and communication. Billions of electronic transistors penetrate living and working worlds, whether as computers, smartphones, but also as control systems of modern cars and inconspicuous kitchen appliances. Photons and optical systems network our world to the last corner of the globe. Quantum physics is the basis of many modern technologies. Thus, semiconductor and laser technology are a result of the first generation of quantum technologies

A radically new paradigm is increasingly moving into the focus of quantum physics: While previously properties of collective quantum systems were exploited, now individual quantum states can be prepared, controlled and used. To take advantage of this research, the Fraunhofer-Gesellschaft is excellently positioned in the field of quantum imaging along with its institutes and partners from science and industry.

Quantum optical application research

The Fraunhofer lighthouse project »QUILT« (Quantum Methods for Advanced Imaging Solutions) bundles outstanding scientific expertise, technology platforms and great market knowledge of six Fraunhofer institutes, including Fraunhofer ILT, with the scientific excellence of the world's leading quantum technology institutions such as the Institute of Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences, and the Max Planck Institute for the Physics of Light (MPG MPL).

Mission of the QUILT project

1. To provide original scientific contributions to three research domains of quantum imaging and to conduct five excellent lighthouse experiments.
2. To network and adapt the outstanding technology platforms of its partners to achieve technology leadership in four key quantum technologies.
3. To establish quantum technology as an interdisciplinary field of excellence in the Fraunhofer-Gesellschaft and to anchor it in an open and lively research school.
4. Make the Fraunhofer-Gesellschaft the most important player in quantum optical application research, secure a strong presence in all important funding initiatives, open up new fields of application and develop innovative solutions with quanta for global industries.

The lighthouse project QUILT started in October 2017. The participating institutes are Fraunhofer IOF (Coordinator), Fraunhofer ILT, IMS, IOSB, IPM and Fraunhofer ITWM.

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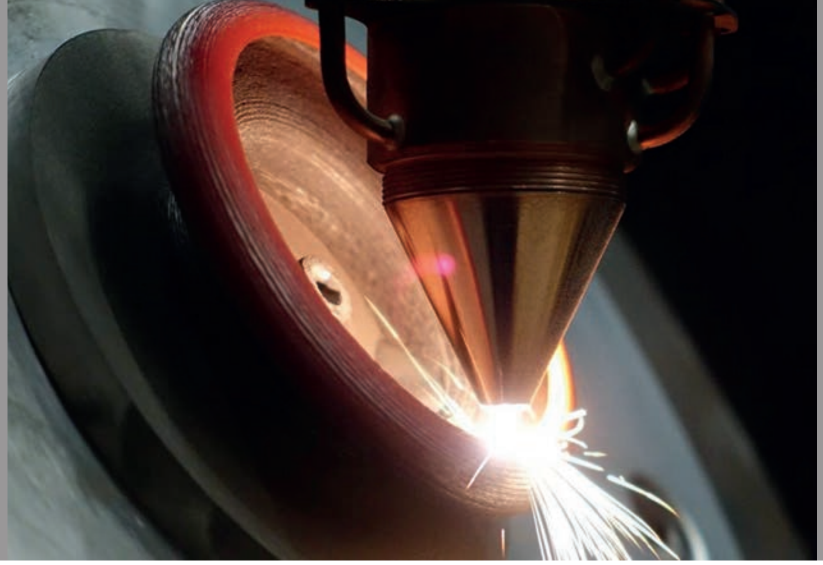
Source and further information on the Internet at: www.iof.fraunhofer.de/quilt

FRAUNHOFER ALLIANCES AND CENTERS OF EXCELLENCE



Robot-based Additive Manufacturing with Laser Material Deposition.

FRAUNHOFER ALLIANCES

Institutes or departments of institutes with different competences cooperate in Fraunhofer alliances in order to jointly process and market an industrially relevant business field. Fraunhofer ILT is involved in the following seven Fraunhofer alliances:

- Batteries
- Generative production
- Lightweight construction
- Nanotechnology
- Numerical simulation of products, processes
- Space
- SysWater

CENTERS OF EXCELLENCE

Centers of excellence help close the ranks between university and non-university research with the industry. Moreover, they are characterized by the participating partners following binding, continuous roadmaps in the areas of research and teaching, promotion of young researchers, infrastructure, innovation and transfer. They are an offer to politics to prioritize scientific excellence with social benefits. Fraunhofer ILT is involved in the Center of Excellence »Networked Adaptive Production«, which is coordinated by Fraunhofer IPT in Aachen and is one of 15 centers of excellence of the Fraunhofer-Gesellschaft in Germany.

Fraunhofer Center of Excellence for »Networked Adaptive Production« in Aachen

This center focuses on developing, systematically introducing and using modern digitization technologies for sustainable, industrial production systems and value chains in the context of »Industry 4.0«. As part of an overarching R&D module »Digitization and Networking«, the Center of Excellence develops the concept of fully networked, adaptive production in the fields of »Smart Manufacturing Platforms«, »Big Data«, »Adaptive Process Chains« and »Process Simulation and Modeling«. All of the developments are validated and demonstrated in six pilot lines in the fields of energy, mobility and health using representative process chains. The connection to the Fraunhofer Cloud System »Virtual Fort Knox« represents a neutral and secure platform for the storage of production data and execution of web services to analyze and optimize process chains. The close cooperation with well-known industrial companies ensures that the results can be transferred to an industrial environment.

The task of the center of excellence is to design an open research platform and test environment for the industry within a period of three years, one in which new concepts of digitalized production can be researched and tested in practice. Fraunhofer ILT is covering the following areas:

- Digital process chains for the laser-based repair of turbomachinery components
- Networking of conventional and laser-based processes in tool construction
- Model-based process development and evaluation of flexible interconnection concepts for battery module production using laser beam welding

»ICNAP« – International Community for the Development of Applications and Technologies for Industry 4.0

The work within the community of the International Center for Networked, Adaptive Production (ICNAP) aims to make demanding value chains for the production of complex and individualized products much more flexible and efficient.

The ICNAP represents a continuation of the research work in the center of excellence with the active participation of the industry. High-performance partners from IT system providers, plant manufacturers and manufacturing companies have already agreed to continue their cooperation.

The challenge is not merely the continued development of manufacturing processes. Rather, the community will demonstrate and validate the possibilities of digitization and networking for the most diverse technical products, processes and corporate networks.

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Further information at:
www.vernetzte-adaptive-produktion.de/en.html

ICTM AACHEN

ICTM – International Center for Turbomachinery Manufacturing

The Fraunhofer Institutes for Production Technology IPT and Laser Technology ILT as well as the Machine Tool Laboratory WZL and the Chair for Digital Additive Production DAP of RWTH Aachen University started the »International Center for Turbomachinery Manufacturing – ICTM« on October 28, 2015 in Aachen with 19 renowned industrial partners.

At present, the network’s 32 industrial partners are big and medium-sized companies in the fields of turbomachinery building, mechanical and automation engineering, machining as well as additive manufacturing. The center focuses on research and development around the production and repair of turbomachinery components which are covered by the partners in all areas. The research center was founded without any state funding and is thus one of the few independent networks that emerged from the Fraunhofer innovation clusters »TurPro« and »ADAM«. The ten-member steering committee comprises representatives of the participating industrial companies and research institutes.

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Further information at: www.ictm-aachen.com

FRAUNHOFER CLUSTER OF EXCELLENCE

The coordinators: cluster leaders Prof. Reinhart Poprawe, Fraunhofer ILT (front, 2nd from ri.), and Prof. Andreas Tünnermann, Fraunhofer IOF (front, 2nd from le.).

CLUSTER OF ADVANCED PHOTON SOURCES CAPS

With the Fraunhofer Cluster of Excellence »Advanced Photon Sources CAPS«, the Fraunhofer-Gesellschaft launched an ambitious project in May 2018. Its aim is to achieve international technological leadership in laser systems that achieve the highest performance with ultrafast pulses (UKP) and to research their potential applications in collaboration with Fraunhofer partners. The new systems will exceed all existing UKP lasers by one order of magnitude in average laser power. At the same time, the partners are working on the necessary system technology and possible applications in industry and research.

CAPS – a strong Fraunhofer network

The kick-off event on May 2, 2018 in Aachen marked the beginning of an extraordinary project. Prof. Reinhart Poprawe, Director of the Fraunhofer Institute for Laser Technology ILT, and Prof. Andreas Tünnermann, Director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, announced the launch of the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS.

In the coming years, 13 Fraunhofer Institutes will jointly develop a new generation of extremely high-power ultrafast lasers, new approaches to systems technology and their application for industry and research. New fields of application are to be opened up, ultra-precise manufacturing processes in the industrial environment scaled and new pulse duration and wavelength ranges made available for research.

UKP lasers for high-precision applications

UKP lasers generate extremely high intensities in the focus even at comparatively low pulse energies. For a long time, however, they were only used in basic research. The development of highly efficient, powerful pump diodes has made it possible to use new laser media, especially ytterbium-doped fibers and crystals. In recent years, UKP lasers based on this technology have achieved average laser powers and a robustness that can also be used for industrial applications.

UKP lasers have two major advantages for micro material processing applications: On the one hand, they can process practically all materials; on the other, the ablation is particularly precise and therefore gentle, as the ultrafast interaction means that hardly any heat remains in the adjacent material. This is why these lasers were interesting for medical technology at an early stage, for example for eye operations using the Femto-LASIK process.

Advanced Photon Sources – UKP lasers with beam powers in the kW range

The power of current UKP lasers in the 100 W class is often insufficient with regard to economically justifiable processing speeds when ultra-hard ceramic materials and fiber-reinforced plastics are cut. Driven by the application potential in industry and the need for basic research, the partners in the cluster have set themselves the goal of increasing the average output of the UKP sources at the Fraunhofer Institutes ILT and IOF up to the 10 kW range.

Application laboratories for industry and science

In 2018 the two Fraunhofer Institutes ILT and IOF already set up application laboratories in order to start early developing system technology and innovative applications. The Fraunhofer Cluster of Excellence CAPS, founded in 2018, is open to all Fraunhofer institutes. Application development is aimed at investigating new processes and helping known processes to achieve industrially relevant throughputs. Examples range from microstructuring and surface functionalization of solar cells, ultra-hard ceramics and battery components all the way to cutting of glass and lightweight materials.

In addition to breakthroughs in ultra-precise production with high productivity, the new laser sources will also generate coherent radiation in the soft X-ray range. The targeted photon fluxes are two to three orders of magnitude higher than those achieved to date. The partners aim to establish applications such as the generation and investigation of novel materials in the materials sciences. In addition, new possibilities are opening up for the semiconductor sector, lithography and imaging of biological samples.

The scaling of the laser power is also interesting for basic research. In the future, laser particle accelerators will become much more compact and can even be integrated into existing laboratories. In addition, these so-called »secondary sources« can also significantly boost areas such as materials research and medical technology.

The synergies between the Fraunhofer institutes make it possible for them to develop both the beam sources and the process technology and many applications at the highest international level. Partners from industry and research have access to their work. As such high-power ultrafast lasers become available, research has the unique chance to systematically advance the innovation process in the laser industry.

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www.caps.fraunhofer.de

LASER TECHNOLOGY AT RWTH AACHEN UNIVERSITY

JOINTLY SHAPING THE FUTURE

The RWTH Aachen University Chairs for Laser Technology LLT, the Technology of Optical Systems TOS and Digital Additive Production DAP as well as Nonlinear Dynamics of Laser Processing NLD and Experimental Physics of Extreme Ultraviolett EUV represent an outstanding cluster of expertise in the field of optical technologies. This permits supercritical treatment of basic and application-related research topics. The close cooperation with the Fraunhofer Institute for Laser Technology ILT not only permits industrial contract research on the basis of sound fundamental knowledge, but also provides new stimuli for the advanced development of optical methods, components and systems. The synergy of infrastructure and know-how is put to active use under a single roof.

This structure particularly benefits up-and-coming young scientists and engineers. Knowledge of current industrial and scientific requirements in the optical technologies flows directly into the planning of the curriculum. Furthermore, undergraduates and postgraduate students can put their theoretical knowledge into practice through project work at the three chairs and at Fraunhofer ILT. University courses are drawn up jointly as well. Teaching, research and innovation – those are the bricks with which the five university departments and Fraunhofer ILT are building the future.

Chair for Laser Technology LLT

The RWTH Aachen University Chair for Laser Technology has been engaged in basic and application-oriented research and development in the fields of laser measurement technology, development of beam sources, joining and cutting processes as well as digital photonics since 1985.

A great part of the research activities is carried out in the framework of some big projects as e.g. the Cluster of Excellence »Integrative Production Technology for High-Wage Countries«, the BMBF Digital Photonic Production Research Campus and the Collaborative Research Center SFB 1120 »Precision Melt Engineering«. Furthermore, the Chair for Laser Technology is coordinator of the currently built »Research Center for Digital Photonic Production«.

Present topics of research:
- Interaction of ultra-short pulsed laser radiation with the material in ablation, modification, drilling or melting
- Future concepts for beam sources such as direct diode-pumped Alexandrite laser or EUV radiation by means of ultrashort pulses
- Integration of optical measuring processes for quality control in Additive Manufacturing
- New concepts for innovative laser-based processing and strategies

Prof. Reinhart Poprawe (Director of the chair)
www.llt.rwth-aachen.de

Chair for Technology of Optical Systems TOS

By establishing the Chair for Technology of Optical Systems in 2004, RWTH Aachen accorded recognition to the increasingly central role of highly developed optical systems in manufacturing, the IT industries and the life sciences. Research activities focus on the development and integration of optical components and systems for laser beam sources and laser devices.

Highly corrected focusing systems for a high laser output, beam homogenization facilities and innovative beam shaping systems are all key components of laser systems used in production engineering. The performance of fiber lasers and diode-pumped solid state lasers, for instance, is determined by optical coupling and pump light homogenizers. Free-form optics for innovative laser beam shaping are yet another topic of research. In the area of high-power diode lasers, micro- and macro-optical components are developed and combined to form complete systems. In addition, assembly techniques are optimized.

Prof. Peter Loosen (Director of the chair)
www.tos.rwth-aachen.de

Chair for Digital Additive Production DAP

The Chair for Digital Additive Production DAP together with industrial and scientific partners, researches the fundamental interrelationships of Additive Manufacturing (AM) from construction design to supply chains, production and component handling all the way to the operational properties of additively manufactured components. In addition, they focus their developments on accompanying processes such as design, quality management, mapping of the entire digital process chain and factory planning. Within the framework of basic, composite and industrial projects from a variety of industries such as automotive, aerospace, turbomachinery, life sciences, electronics, tool and mold making, as well as close cooperation with non-university research institutes, DAP has extensive expertise both in terms of software and hardware.

In addition to developing existing AM processes as well as existing machine and system technology, DAP focuses an essential part of its work on software-driven end-to-end processes. This way it can harness the advantages of additive processes, for constructing bionic lightweight components, optimizing functions for AM, designing »digital materials« all the way to validating in the real process.

Prof. Johannes Henrich Schleifenbaum (Director of the chair)
www.dap.rwth-aachen.de

Chair for Nonlinear Dynamics of Laser Processing NLD

Founded in 2005, the chair for Nonlinear Dynamics of Laser Processing NLD explores the basic principles of optical technology, with emphasis on modeling and simulation in the fields of application macro welding and cutting, precision processing with ultrafast lasers and PDT in dentistry and dermatology.

Mathematical, physical and experimental methods are being applied and enhanced to investigate technical systems. The application of mathematical models is helping to achieve a better understanding of dynamic interrelationships and to create new process engineering concepts. The results of these analyses are made available to industrial partners in the form of practical applications in collaboration with the Fraunhofer Institute for Laser Technology ILT.

The main educational objective is to teach a scientific, methodological approach to modeling on the basis of practical examples. Models are derived from the experimental diagnosis of laser manufacturing processes and the numerical calculation of selected model tasks.

Prof. Wolfgang Schulz (Director of the chair)
www.nld.rwth-aachen.de

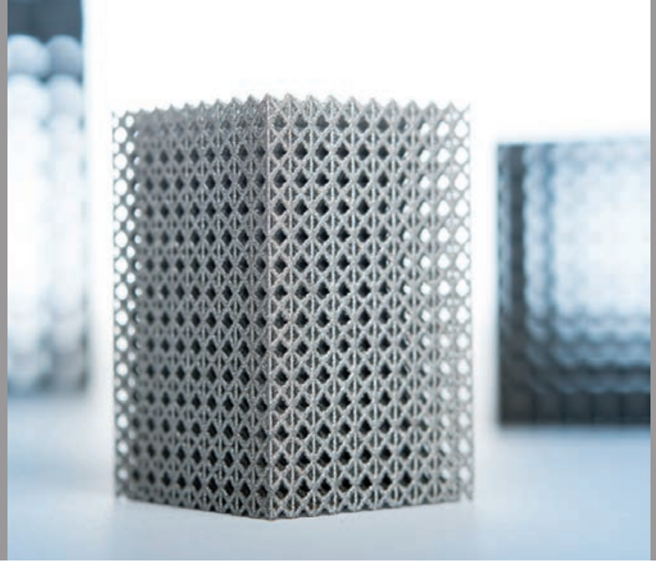
Chair for the Experimental Physics of Extreme Ultraviolet EUV

The spectral range of extreme ultraviolet radiation (extreme ultraviolet, EUV or XUV, 1 - 50 nm) offers the advantages of short wavelengths and strong interactions between light and material with atomic resonances. This allows both lateral and depth resolutions in the nanometer region with element-specific contrasts.

The Chair for the Experimental Physics of Extreme Ultraviolet EUV, founded in 2012 in RWTH Aachen University's Physics department, conducts research into various aspects of EUV radiation. These range from beam production and characterization, through wave propagation and interactions with materials, to specific applications and development of relevant methods. Two areas are of particular interest in all this: high-brilliance sources and interference lithography.

The research activities are embedded in the JARA-FIT section of the Jülich Aachen Research Alliance and are carried out in cooperation with the Peter Grünberg Insitute for Semiconductor Nanoelectronics at Forschungszentrum Jülich, with Fraunhofer ILT and the Chair for the Technology of Optical Systems TOS.

Prof. Larissa Juschkin (Director of the chair)
www.euv.rwth-aachen.de



DIGITAL PHOTONIC PRODUCTION DPP

Digital Photonic Production – the Future of Production

By taking up the topic of digital photonic production, Fraunhofer ILT is dedicating itself to a field that is central to tomorrow's production techniques. Digital photonic production permits the direct production of practically any component or product on the basis of digital data. Techniques that were developed over ten years ago for rapid prototyping are evolving into rapid manufacturing techniques for the direct production of functional components. Rapid manufacturing techniques have already been used in an initial batch of facilities for industrial production in the automotive construction and aviation industries. In the process, lasers are taking on a central role as the tool of choice thanks to their unique properties. No other tool can be applied and controlled with comparable precision.

Mass Customization

Digital photonic production goes far beyond laser-based additive manufacturing processes. New high-output ultrafast lasers, for example, can achieve very fast ablation almost regardless of material – allowing the finest of functional 3D structures to be produced down to the nanometer region. This new technology is seen by some as heralding a new industrial revolution. And the potential of this revolutionary technology lies above all in the way it fundamentally changes costing parameters in laser-based manufacturing techniques. In contrast to conventional techniques, using lasers makes manufacturing cost-effective both for small batch sizes and for the tiniest of complex products, using a wide variety of materials and featuring the most complex of geometries.

If they are to make full use of the potential of digital photonic production, industrial process chains must be considered in their entirety. These chains must be thoroughly redesigned, taking into account upstream and downstream manufacturing steps, component design, and accompanied by completely new business models such as mass customization or open innovation.

Digital Photonic Production Research Campus

The BMBF Digital Photonic Production Research Campus in Aachen enables just such a holistic view. As part of the German Federal Ministry of Education and Research BMBF's »Research Campus – Public-Private Partnerships for Innovation« funding initiative, the Aachen campus will receive lasting support in the form of up to 2 million euros in annual funding over the next 15 years.

The Chair for Laser Technology LLT at RWTH Aachen University emerged from the national competition as one of nine winners, having coordinated a proposals consortium. This new initiative sees more than 30 companies and scientific institutes working together under one roof on questions of fundamental research, with new partners joining all the time. The Digital Photonic Production Research Campus in Aachen offers local industry and science a skilled and responsive instrument with which to shape the future of production technology.

RWTH AACHEN CAMPUS

RWTH AACHEN CAMPUS

Taking its lead from the Stanford University and Silicon Valley model, the RWTH Aachen University is creating one of Europe's largest technology-oriented campuses over a total area of approximately 2.5 km², making it one of the leading national and international knowledge and research centers. It is located at the former university extension site in Aachen Melaten along with part of the Aachen Westbahnhof (Aachen West Train Station). For the first time, the core areas of the RWTH Aachen University will be connected – in the city center, in the Hörn district and in Melaten – to create an integrated campus.

Research catalyst and innovation generator

The RWTH Aachen Campus offers a groundbreaking symbiosis between industry and university education in the form of »university enrolment« for staff at locally based companies – an unrivalled combination in Germany. This enables companies to actively participate in centers which demonstrate the operative units of the cluster to cooperate in their areas of interest in an interdisciplinary and consortial way. At the same time, it ensures access to qualified young staff and facilitates accelerated and praxis-based PhD programs.

Interested companies can relocate to the RWTH Aachen Campus by leasing or building their own space. This proximity generates a unique, more intensive form of collaboration between university and business; no other university in Europe currently boasts a greater number of major application-oriented institutes than the RWTH Aachen University. An integrated concept underpins the entire project: research, learning, development, living.

The RWTH Aachen Campus creates an ideal, prestigious working environment for more than 10,000 employees, with research institutions, offices and training centers. The campus also offers a superb quality of life, through hotel and living accommodations, top-class restaurants, shopping facilities, childcare facilities and a range of service and relocation organizations.

Development and timetable

The RWTH Aachen Campus will be created in several stages. The first stage was started in 2010 with the development and construction of Campus Melaten with its six clusters – one is the Photonics Cluster coordinated by Fraunhofer ILT. In detail the clusters are:

- Bio-Medical Engineering Cluster
- Sustainable Energy Cluster
- Photonics Cluster
- Production Technologies Cluster
- Heavy Duty & Off-Highway Powertrain Cluster
- Smart Logistics Cluster

At the moment, the university is concentrating on the next thematic cluster, which will see the development of Campus Westbahnhof with four clusters and focus on the growth of 16 clusters in Melaten and the Westbahnhof. The infrastructure, for example, will be upgraded by the construction of a congress hall, library and hotels. The relevant future topics for industry and society will be tackled in all 16 clusters. More than 360 companies are already involved in the RWTH Aachen Campus.

Further information can be found at: www.rwth-campus.com/en

PHOTONICS CLUSTER

The Photonics Cluster, one of six initial research clusters on the RWTH Aachen Campus, researches and develops methods to produce, shape and use light, in particular as a tool for industrial production. In comparison to other tools, the laser beam can be more precisely modulated and controlled. The Photonics Cluster is coordinated by Prof. Poprawe, Director of Fraunhofer ILT and the RWTH Chair for Laser Technology LLT. The cluster's large premises offers sufficient space for, on the one hand, scientific institutions to cooperate in an interdisciplinary manner and, on the other, for companies to strategically collaborate with Fraunhofer ILT and the associated chairs of the RWTH Aachen University. In this respect, the Photonics Cluster is the consequent development of the Fraunhofer ILT User Center, which has existed since 1988; in it around 10 companies, as guests, work in close collaboration with Fraunhofer ILT in their own offices and laboratories.

The first building in the Photonics Cluster – the Industry Building Digital Photonic Production – was ceremoniously inaugurated during the International Laser Technology Congress AKL'16 on April 28, 2016, with more than 500 experts from laser technology and 100 guests from science, business and politics. The keys were handed over between the private-sector investor Landmarken AG with the KPF architects team and Fraunhofer ILT. The guests were able to visit the new DPP building with about 7,000 square meters of research and office space. The building had already been occupied by more than 20 companies as well as R&D teams of Fraunhofer ILT and the Chair for Laser Technology at RWTH Aachen University.

2019 will see a further infrastructure project open: the Research Center Digital Photonic Production DPP, funded by the federal government and the state of NRW for interdisciplinary cooperation in the field of digital photonic production. The topping-out ceremony of the new building took place on May 24, 2016 in the presence of Thomas Rachel, congressman and state secretary of the Federal Ministry of Education and Research (BMBF) and Prof. Ernst Schmachtenberg, the former rector of RWTH Aachen University. On an area of 4,300 square meters, 16 institutes of the RWTH Aachen University from 6 faculties will tackle the interdisciplinary and integrated research of digital photonic production chains.

The two buildings, the Research Center Digital Photonic Production and the Industry Building Digital Photonic Production, form the basis for the BMBF funded Research Campus DPP. At the moment more than 20 partners from industry can do research under one roof at the Research Campus DPP. These include large corporations such as Philips, MTU or Siemens as well as medium-sized companies and spin-offs of Fraunhofer ILT. The Photonics Cluster is thus the ideal spring board for research and development, education and training, innovation and networking in the field of optical technologies.

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1 3D sketch of the Photonics Cluster building (source: KPF, New York).

PHOTONICS CLUSTER

RESEARCH CENTER DPP

Research Center Digital Photonic Production

Inter- and transdisciplinary networking of different research areas is key to shortening innovation cycles. Here, the Excellence Cluster »Integrative Production Technology for High-Wage Countries« was already a major step forward. Scientists from various institutes and professorships at RWTH Aachen University research different topics for a common goal over a relatively long period of time. The scientists and infrastructure are located at the respective institutes and chairs, and at present, they exchange information and results in temporary intervals. However, in order to allow an even more effective networking of the different research disciplines and the scientists involved, they should be located in a common place for a longer period of time.

In 2014, institutes and chairs from six faculties at RWTH Aachen University, headed by the Chair for Laser Technology LLT, received funding for the construction of the »Research Center Digital Photonic Production RCDPP«. Construction, first-time installation and large-scale equipment with a total volume of approx. 55 million euros have been financed by the federal government and state of North-Rhine Westphalia, each covering 50 percent.

In the building of the Research Center DPP up to 100 scientists will be able to conduct basic research in the field of photonics on about 4,300 square meters of usable floor area, including 2,800 square meters of laboratory, clean room and hall areas.

The institutes and chairs currently involved are from six faculties at RWTH Aachen University: Engineering, Mathematics, Computer Science and Natural Sciences, Electrical Engineering and Information Technology, Geo Resources and Materials Engineering, as well as Medicine and Economics. This way, project-related interdisciplinary working groups can form and research, for example, new materials for 3D printing. Material scientists, together with experts for laser processes, beam sources or plant engineering, can coordinate the relevant building blocks in joint experiments and shorten innovation cycles.

Other key areas include, among others, adaptive manufacturing of complex optical systems, direct photonic ablation with high ablation rates, ultra-precision processing, EUV beam sources, high-performance ultra-short pulse lasers, medical technology, biotechnology and quantum technology.

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INDUSTRY BUILDING DPP

Industry Building Digital Photonic Production

In the immediate vicinity of the Fraunhofer Institute for Laser Technology ILT and the associated chairs – LLT, TOS, DAP and NLD – at the RWTH Aachen University, companies in the Industry Building Digital Photonic Production can set up strategic partnerships to develop new components, systems, process chains or business models in the field of optical technologies, especially for production technology. Joint research and development forms the basis for these long-term cooperations. Here, it does not matter whether a company as a legal person, a specifically selected R&D team or several doctoral students from within its own ranks set up shop on this location. Facilities such as laboratories and offices can be rented by private operators, who benefit from this cooperation due to the proximity to the experts of Fraunhofer ILT and the associated RWTH Aachen University chairs, which also have their own premises on site. In open-space structures and shared labs, mixed teams from industry and science can interact and inspire each other. The »enrollment of companies« at the RWTH Aachen University is also a very efficient way of providing initial and further education as well as access to on-site scientific events.

In addition to individual companies, major initiatives such as the Research Campus DPP, funded by the Federal Ministry of Education and Research (BMBF) or centers of the Photonics Cluster such as ACAM – Aachen Center for Additive Manufacturing – are located in the Industry Building DPP with approx. 7,000 square meters of usable floor space. For example, in the Research Campus DPP, companies can develop new processes for additive manufacturing or nanostructuring of smart products, in close coordination with the players involved, or carry out process optimization for 3D printing technologies, which they test in pilot plants.

Partners from Industry

- 4JET Technologies GmbH
- Access e.V.
- AixPath GmbH
- Aixtooling GmbH
- AMPHOS GmbH
- BMW AG
- EdgeWave GmbH
- Exapt Systemtechnik GmbH
- EOS GmbH
- Fionec GmbH
- Innolite GmbH
- KEX Knowledge Exchange AG
- LighFab GmbH
- ModuleWorks GmbH
- MTU Aero Engines AG
- PHILIPS
- Pulsar Photonic GmbH
- Siemens AG
- SLM Solutions GmbH
- TRUMPF Laser- und Systemtechnik GmbH
- WBA Aachener Werkzeugbau Akademie GmbH

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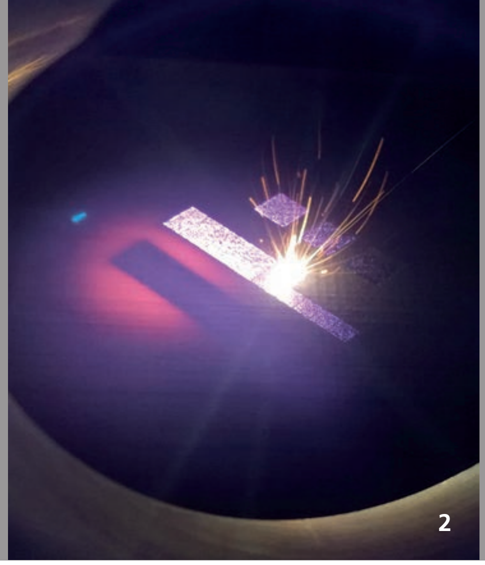
1 Industry Building DPP in the Photonics Cluster on the RWTH Aachen Campus.

2 Research under one roof: Research Center Digital Photonic Production RCDPP, sketch: Carpus+Partner.

RESEARCH CAMPUS DPP

1



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RESEARCH CAMPUS DIGITAL PHOTONIC PRODUCTION DPP

Goals and tasks

The Research Campus »Digital Photonic Production DPP« in Aachen is a location where scientists can explore new methods and basic physical effects in order to use light as a tool in the production of the future. Thanks to the BMBF funded Research Campus DPP, RWTH Aachen University, the Fraunhofer-Gesellschaft and industry can establish a new form of long-term and systematic cooperation that aims to concentrate the various resources under one roof for joint, complementary application-oriented basic research. This is made possible by a new building on the RWTH Aachen Campus: the Industry Building DPP. Here the partners from business and science can research together on about 7,000 square meters of office and laboratory space under one roof as part of the Research Campus DPP.

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Road mapping process

The collaboration of the two Fraunhofer Institutes ILT and IPT and the around 20 industrial companies is defined in jointly agreed technology roadmaps. Alongside the technology roadmaps, the partners are exploring basic aspects of light generation (e.g. modeling of ultra-short pulse resonators), new possibilities of light guiding and shaping (e.g. modeling of free-form optics) and physical models for the interaction of light, material and functionality (e.g. modeling of load-optimized additively manufactured structures).

Joint working groups

The cooperation at the Research Campus DPP is organized along the technology roadmaps in joint working groups with scientists from the scientific community and the industry. The following five working groups have been established:

- DPP Direct
- DPP Femto
- DPP Nano
- DPP MaGeoOptics
- DPP Digital Photonic Process Chain

DPP Direct

The additive manufacturing process Laser Powder Bed Fusion (LPBF) allows the direct, tool-free production of functional components with serial-identical properties. In addition to the high resource efficiency, the tool-less production of complex components is particularly noteworthy. They can be produced quickly and comparatively inexpensively in small numbers. Likewise, functionally and weight-optimized components for new products with improved properties can be built cost-effectively. The LPBF process is increasingly used in industries such as dental technology, toolmaking, power engineering, automotive engineering and aircraft construction.

DPP Femto

With the relatively new ultra-short pulse lasers (UKP lasers), new functionalities can be created on components made out of different materials. However, the fundamental connections between the interaction between UKP laser light and modern functional materials of the digital world have not yet been sufficiently researched. The partners in the network project DPP Femto aim to analyze these complex relationships in detail and, thus, open up new horizons for this laser technology in the processing of electronic components, such as in display making or the production of modern LEDs.

DPP Nano

In order to carry out localized, timed, precisely applied heat treatment, researchers have been developing and testing new laser beam sources (such as, for example, VCEL lasers), optical systems and algorithms. Their aim is to produce tailor-made, material-matched light distributions. These new applications are being developed in the industry (e.g. by the functionalization of surfaces based on nanoparticulate materials), which increases the productivity of heat treatment processes (e.g. laser hardening) as well as the application spectrum (e.g. the production of complex components from composites).

DPP MaGeoOptics

The aim of the research project »MaGeoOptics« is to significantly increase the performance of current beam guidance systems by using high-quality optics, novel materials and more complex geometries. For this purpose, research is designing and qualifying new pressing processes for quartz glass, developing software and processes with innovative machining kinematics for diamond optics and using suitable metrological methods of non-contact optical inspection. As a result, complex geometries – for example, array structures with aspherical individual geometries – can be produced in quartz glass cost effectively.

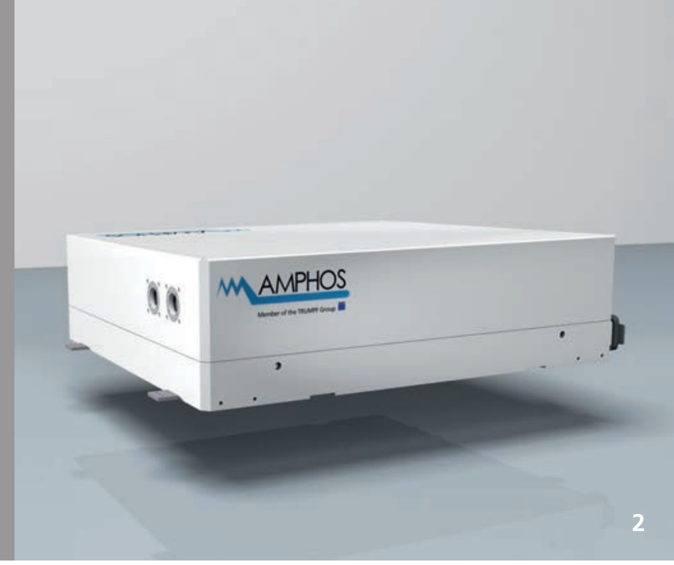
DPP Digital Photonic Process Chain

The high energy density in the laser focus can be used to either selectively ablate or melt material. Thus, the smallest structures can be inserted into the surface of components for technical functions or design purposes. Modeling the sophisticated structures is very complex, thus costly, with common CAD/CAM systems. Therefore, a digital infrastructure has been created to utilize procedurally described structures for photonic manufacturing processes. The results are implemented in CAx libraries for path calculation and then integrated into conventional CAM software products.

1 Meeting space in the light-flooded atrium of the Industry Building DPP.

2 DPP Nano: Selective preheating by means of VCSEL in Laser Powder Bed Fusion (LPBF).

SPIN-OFFS



Networks and infrastructure

Together with the Digital Photonic Production Research Campus, funded by the Federal Ministry of Education and Research (BMBF), and the RWTH Aachen Campus, Fraunhofer ILT offers an ideal environment for setting up a company in the field of photonic production. Fraunhofer ILT acts as a know-how partner, who is more or less – depending on the cooperation agreement – involved in the development of new technologies. Through appropriate license agreements, the spin-offs also have access to those patents that, for example, the founders have themselves obtained while at Fraunhofer ILT.

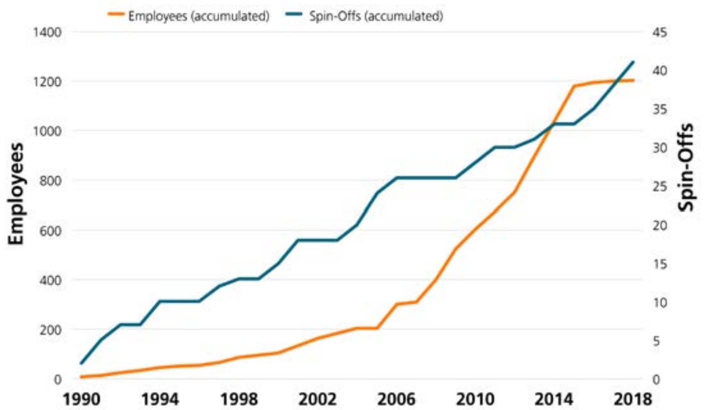
The DPP Research Campus forms the platform for intensive exchange with companies, institutes and consultants involved in the field of photonic production. Co-creation areas and open innovation concepts are also used at the research campus when required. In the DPP Industry Building on the RWTH Aachen Campus site, founders can rent their own offices and laboratories on 7,000 square meters of floor space. Thirty companies have already established themselves here, including research groups from major corporations such as Siemens, TRUMPF, Philips and MTU. The entire environment of the campus acts as an incubator for successful business spin-offs.

Supporting services

In addition to the publicly funded programs, spin-offs have direct access to regional counseling services such as from AGIT, a regional business development company, or IHK Aachen, the city's chamber of commerce and trade. The latter also coordinates the approximately 200-member volunteer AC^2 advisory network.

Alongside the regional players, the Fraunhofer Venture, a division of the Fraunhofer-Gesellschaft, supports scientists in developing and implementing their ideas all the way to market readiness. The diverse range of services extends from advising and optimizing a business plan, to supporting legal and organizational design, to arranging investors and preparing for possible participation by the Fraunhofer-Gesellschaft.

Spin-offs since 1990



SPIN-OFFS OF FRAUNHOFER ILT

Intensive spin-off culture at Fraunhofer ILT

The Fraunhofer Institute for Laser Technology ILT has maintained an intensive spin-off culture since the early 1990s. This is essentially the case because it recognized that an efficient way of introducing a new technology into the market is the entrepreneurial activity of the relevant promoters of the respective technology. Founders are deeply convinced of their idea and are rarely slowed down by skeptics or administrative hurdles. At the same time, they have to be flexible enough to constantly adapt their business model to the needs of the market, but without abandoning their core idea. Innovative founders, thus, generate impulses in the industry for new technological solutions and perspectives, but there are also classic entrepreneurs who need to keep an eye on sustainable business development.

These characteristics are shared by the founders with the namesake of the Fraunhofer-Gesellschaft: Joseph von Fraunhofer emerged as a researcher, inventor and entrepreneur at the beginning of the 19th century. His activities ranged from discovering the Fraunhofer lines, later named after him, in the solar spectrum to developing new processing methods for the lens production all the way to managing a glassworks. In this respect, Fraunhofer ILT continues this entrepreneurial tradition by supporting employees willing to start a spin-off. And that since the institute was founded.

Spin-offs generate added value for the laser industry

In retrospect, one to two companies have been created per year over the past 25 years. Thus, the spin-off frequency of the institute is above the average of the Fraunhofer-Gesellschaft. Around 40 so-called spin-offs operate in laser technology and not only generate new sales, but also expand the market potential of the industry. They contribute directly to economic growth.

In addition to this financial aspect, the spin-offs are attractive employers as they move in an industry that has been experiencing outstanding growth for years. Laser technology is growing exceedingly fast, even in comparison to the entire machine and plant engineering industry. Of course, the spin-offs also provide added value for large established groups, which rely on the new technologies when needed. Whether it is about new cleaning methods, custom-made additively manufactured implants, new high-power diode lasers or high-performance ultrashort pulse lasers, the roughly 40 spin-offs of Fraunhofer ILT cover a broad spectrum. In 2018 three companies were founded: HPL Technologies GmbH, Aixway 3D GmbH and DAP Aachen GmbH.

1 Domicile of the spin-off AMPHOS GmbH at the Technologiepark Herzogenrath.
2 »AMPHOS2000« laser system.

INITIATIVES

ACAM

ACAM Aachen Center for Additive Manufacturing

Together with partners from science, the Fraunhofer Institutes for Production Technology IPT and for Laser Technology ILT founded the ACAM Aachen Center for Additive Manufacturing GmbH in 2015. The aim of ACAM is to help manufacturing companies implement additive manufacturing in their production processes. The Center for Additive Manufacturing is run by Kristian Arntz, Fraunhofer IPT, and Prof. Johannes Henrich Schleifenbaum, Fraunhofer ILT.

The ACAM GmbH operates a center on the RWTH Aachen Campus Melaten and bundles the competencies of different research institutes in their services. ACAM brings together an expert community that deals with additive manufacturing and continues to systematically develop its know-how in this area. The existing expertise is made directly accessible to the users.

ACAM community meeting on March 21, 2018 at GKN Sinter Metals in Radevormwald.

In terms of training, ACAM GmbH offers tailor-made seminars. Interested companies can participate in the ACAM community for a fee. If required, the partner companies can also establish their own resources directly on the campus. The employees of these companies can also take part in training and further education programs offered by RWTH Aachen University and are involved in the university environment.

Strategic partners of ACAM

- Fraunhofer Institute for Laser Technology ILT
- Fraunhofer Institute for Production Technology IPT
- Access Technology GmbH
- KEX Knowledge Exchange AG
- Institute for Tool-free Production IwF, an institute associated to the FH Aachen University of Applied Sciences

RWTH Aachen University:

- Chair for Laser Technology LLT
- Chair for Digital Additive Production DAP
- Chair of Production Engineering of E-Mobility Components PEM
- Chair for Nonlinear Dynamics of Laser Processing NLD
- Chair and Institute of General Design Engineering of Mechanical Engineering ICT
- Machine Tool Laboratory WZL
- Institute for Automotive Engineering IKA
- Institute of Plastics Processing IKV
- Institute for Material Applications in Mechanical Engineering IWM

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Further information at: www.acam.rwth-campus.com

AACHENER CENTER FOR 3D PRINTING

The Aachen Center for 3D Printing is a joint research group of Fraunhofer ILT and the FH Aachen University of Applied Sciences, and aims to give small and medium-sized companies access to the entire process chain in the field of additive manufacturing (AM). This way, they can exploit the economic and technological opportunities offered by this innovative technology.

As small and medium-sized businesses screen their own applications, they increasingly see the economic and technological opportunities of AM in their production environments. Often, however, they shy away from investment risks; most of all, they seldom have qualified 3D printing specialists and skilled workers. This is where the closely cooperating team of experts from Fraunhofer ILT and FH Aachen comes in.

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gebhardt@fh-aachen.de

Further information at: www.ilt.fraunhofer.de/en.html and www.fh-aachen.de/en

MEDLIFE E.V.

MedLife is the network of life sciences in the Technology Region Aachen. Currently, more than 80 members are involved in this regional industry association. MedLife offers events and services for the medical technology, biotechnology, pharmaceutical and healthcare industries. The network is the contact for entrepreneurs and scientists who are looking for an exchange with other life science actors and competent advice and support for innovative projects and business ideas.

In addition to the MedLife e.V., the affiliated limited liability company (GmbH) deals with the management of clusters and funding projects and offers services such as business and innovation consulting. Fraunhofer ILT is actively involved in MedLife e.V. Since the general meeting on March 7, 2016, Dr. Arnold Gillner, the competence area manager of Ablation and Joining at Fraunhofer ILT, is the spokesman of the advisory board of the MedLife e.V.

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Additive-manufactured letters with integrated lightweight structures.

COOPERATIONS AND ASSOCIATIONS

The Fraunhofer Institute for Laser Technology ILT has partnerships with domestic and foreign research centers, universities, clusters and companies so that it can offer its customers solutions from a single source. Fraunhofer ILT also maintains close contacts to associations, chambers of commerce and trade, testing institutes and ministries.

REGIONAL NETWORKS

At the local level, Fraunhofer ILT cooperates with RWTH Aachen University, the FH Aachen University of Applied Sciences and Forschungszentrum Jülich in many fundamental issues. At the Aachen Center for 3D Printing – a cooperation between FH Aachen and Fraunhofer ILT – medium-sized companies, for example, can receive support in all aspects of additive manufacturing. In the life sciences too, Fraunhofer ILT is well networked via the MedLife e.V. The trade association IVAM e.V. allows ILT access to numerous experts in microtechnology. In the NanoMicroMaterialsPhotonic.NRW state cluster, Fraunhofer ILT is involved in the fields of nanotechnology, photonics and microsystem technology.

NATIONAL COOPERATIONS

Together with around 70 research institutes, Fraunhofer ILT is embedded in the Fraunhofer-Gesellschaft, the largest organization for application-oriented research in Europe. Our customers benefit from the combined expertise of the cooperating institutes.

The networking of laser users, manufacturers and researchers at the national level succeeds, among others, in the Arbeitskreis Lasertechnik e.V., in the Wissenschaftliche Gesellschaft Lasertechnik e.V. (Scientific Society of Laser Technology) and in various industry associations such as DVS, SPECTARIS or VDMA. The national initiatives such as the »go-cluster« of the Federal Ministry of Economic Affairs and Energy (BMWi) or the research campus of the Federal Ministry of Education and Research (BMBF) actively support Fraunhofer ILT. In all committees, ILT employees provide impetus to further develop the field of laser technology as well as forms of cooperation between science and industry for the benefit of society.

NETWORKED INTERNATIONALLY

Fraunhofer ILT carries out bilateral projects as well as joint projects with foreign companies and branches of German companies abroad. In addition, the Fraunhofer-Gesellschaft maintains liaison offices in numerous countries. To support international developments of fields relevant to Fraunhofer ILT in a timely manner, employees are actively engaged in selected associations and networks such as the European Photonic Industry Consortium EPIC and the technology platform Photonics21 at the European level or the Laser Institute of America LIA at the transatlantic level. Numerous scientific lectures at international conferences complete the picture.

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ARBEITSKREIS LASERTECHNIK E.V.

The Arbeitskreis Lasertechnik AKL e.V. (AKL e.V. for short) was founded in 1990 in order to make the fascinating possibilities that the laser opens up – with regard to precision, speed and economy – useful for the industry by intensifying the level of information and education. While many laser-based applications are known today, new laser beam sources and laser processes are constantly being developed, which lead to innovative prospects in industrial production. In this rapidly changing discipline, a network of laser experts supports ongoing innovation processes and AKL e.V. serves exclusively and directly to promote scientific goals.

Tasks of the AKL e.V.

- Promoting scientific work in the field of laser technology by stimulating and supporting research projects carried out at research institutes as well as cooperating with other research associations and scientific institutions.
- Promoting the dissemination of laser technology in industry and supporting the scientific exchange of ideas with persons, companies, associations, authorities and offices of all kinds, in particular through funding and organizing research projects, lectures, conferences, meetings and symposiums. In this context, AKL e.V. also organizes the seminars and events of the alumni network »Aix-Laser-People«.

Currently, AKL e.V. has about 170 members. The personal communication between the members forms the backbone of the association.

Innovation Award Laser Technology

Every two years, the Arbeitskreis Lasertechnik e.V. and the European Laser Institute ELI e.V. bestow the Innovation Award Laser Technology, worth €10,000. This European prize for applied science is aimed at both individuals and project teams whose skills and commitment have led to an outstanding innovation in the field of laser technology. The eight-man international jury nominated three outstanding finalists in 2018:

- 1st place: Dr. Axel Luft, Laserline GmbH
  Topic: Multi Spot Modules to Improve Joining Processes due to Tailored Spot Geometries
- 2nd place: Dr. Gerald Jenke, SAUERESSIG GmbH + Co. KG
  Topic: Multi Parallel Ultrafast Laser Ablation for Large Scale Ultraprecision Manufacturing
- 3rd place: Alejandro Bárcena M.Sc.Eng,
  Talens Systems S.L. Etxe-Tar Group
  Topic: RAIO DSS – A High Flexibility Dynamic Beam Control System for Laser Heat Treatment and Related High Power Laser Applications

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EVENTS AND PUBLICATIONS

»Everything, great and small, rests on passing it further.«

Christian Morgenstern

PATENTS

PATENTS GERMANY

DE 102014206143.1 Laserauftragschweißen von hochwarmfesten Superlegierungen mittels oszillierender Strahlführung

DE 102015014060 B4 Verfahren zum Fügen von zwei Bauteilen im Bereich einer Fügezone mittels mindestens einem Laserstrahl sowie Verfahren zum Erzeugen einer durchgehenden Fügenaht

DE 10342239.0-54 Gasentladungsquelle für EUV-Strahlung

DE 102014208371B4 Verfahren zur Laserbearbeitung einer Oberfläche

DE 102006050466.6 Anordnung zur Verkleinerung der thermischen Effekte in Laser- und nichtlinearen Medien

DE 102013012730.0 Verfahren zur Strukturierung von Dünnschicht-Elektronik ohne Materialentfernung

DE 102014116567.5 Verfahren und Vorrichtung zur Identifikation und Sortierung von strömenden Mikropartikeln in einem Fluid

DE 102015202470.9 Verfahren und Vorrichtung zur hochpräzisen optischen Messung mit anhaftenden fluidischen Schichten

DE 102012021061.2 Verfahren zur Herstellung einer Beschichtung auf einer Substratoberfläche

PATENTS EUROPE

EP 3099446 Laserauftragschweißen von hochwarmfesten Superlegierungen mittels oszillierender Strahlführung

EP 15717453.3 Verfahren zur Laserbearbeitung einer Oberfläche

EP 2084794 B1 Anordnung zur Verkleinerung der thermischen Effekte in Laser- und nichtlinearen Medien

EP 15794534.6 Verfahren und Vorrichtung zur Identifikation und Sortierung von strömenden Mikropartikeln in einem Fluid

56
Bachelor theses in 2018

PATENTS
22 patents, 23 patent applications in 2018

108
Scientific lectures in 2018

67
Master theses in 2018

109 Publications

PATENTS

PATENTS USA

US 14/293,495 Method of manufacturing organic light-emitting display device by using laser beam irradiation apparatus

US 10,144,092 B2 Laserverfahren mit unterschiedlichem Lasterstrahlbereich innerhalb eines Strahls

PATENTS CHINA

CN 201410231251.0 Method of manufacturing organic light-emitting display device by using laser beam irradiation apparatus

CN 105228789 B Verfahren zum Abtragen von sprödhartem Material mittels Laserstrahlung

CN 201580014382.6 Bearbeitungsvorrichtung und -verfahren zur Laserbearbeitung einer Oberfläche

PATENTS TAIWAN

TW 102128219 Laser processing apparatus

TW 103118984 Method of manufacturing organic light-emitting display device by using laser beam irradiation apparatus

TW 102142186 Laser processing apparatus

PATENTS JAPAN

JP 6430523 Machining device and method for laser machining of a surface

PATENT APPLICATIONS GERMANY

102018132441.3 Verfahren zur Bearbeitung einer Oberfläche mit energetischer Strahlung

102018208752.0 Vorrichtung zur Laserbearbeitung schwer zugänglicher Werkstücke

102018103967.0 Laserbasiertes Verfahren zur Herstellung funktionaler Beschichtung aus partikulären Hochleistungspolymeren

102018210698.3 Vorrichtung und Verfahren zur Erzeugung von hoch-dynamischen Leistungsdichteverteilungen u. a. für Lasermaterialbearbeitungsprozesse

102018214715.9 Verfahren und Vorrichtung zum Abbau von Schadstoffen in Wasser

102018220342.3 Methode zur semantischen Segmentierung von mehrdimensionalen Prozessdaten in der Lasermaterialbearbeitung

102018216206.9 Verfahren zum Glätten der Oberfläche eines Kunststoffbauteils

102018128754.2 Vorrichtung und Verfahren zur Elementanalyse von Materialien

102018217774.0 Radar- und Lichtausstrahlungsanordnung für Fahrzeuge zum Ausstrahlen von Licht und Radarstrahlung sowie Verfahren und Verwendung

102018132660.2 Kompakte optische Abtastvorrichtung

PATENT APPLICATIONS EUROPE

EP18173136.5 Verfahren zur Verringerung der Reibung aneinander gleitender und/oder rollender Flächen

PCT/EP2018/051450 Verfahren zum Fügen von Bauteilen auf eine Trägerstruktur unter Einsatz von elektromagnetischer Strahlung

PCT/EP2018/058883 Verfahren und Vorrichtung zur Bereitstellung einer eine gewünschte Zielprotein-Expression aufweisenden Zelllinie

PCT/EP2018/058884 Veränderung der Leistung beim Wobbeln

PCT/EP2018/000419 Vorrichtung und Verfahren zur Materialbearbeitung

PCT/EP2018/079238 Verfahren zur Beschichtung einer metallischen Oberfläche mit einem metallischen Material

PCT/EP2018/067097 Vorrichtung zum Laserauftragsschweißen

PCT/EP2018/069520 Verfahren zur Bearbeitung einer Oberfläche und Laserscanvorrichtung

18191074.6 Monitoring of tissue coagulation by optical reflectance signals

PCT/EP2018/086895 Method of treating a layer of material with energetic radiation

18020564.3 Vorrichtung zum Beschichten eines Werkstücks mit mindestens einem Hochleistungspolymer; Beschichtungsverfahren

PCT/EP2018/058705 Verfahren und Anordnung zur kontinuierlichen oder quasikontinuierlichen generativen Fertigung von Bauteilen

PATENT APPLICATIONS USA

15/987,218 Laser beam irradiation apparatus and method of manufacturing organic light emitting display device by using the same

DISSERTATIONS

DISSERTATIONS

15.2.2018 – Torsten Hermanns (Dr. rer. nat.)
Interaktive Prozesssimulation für das industrielle Umfeld am Beispiel des Bohrens mit Laserstrahlung

15.6.2018 – Nelli Hambach, geb. Brandt (Dr.-Ing.)
Grenzen der Lochdichte beim Perkussionsbohren mit Ultrakurzpulslasern

15.6.2018 – Christian Hördemann (Dr.-Ing.)
Partikelfreier Abtrag von Schichtsystemen für Feststoffbatterien mittels Ultrakurzpuls-Laserbearbeitung

2.7.2018 – John Walter Flemmer (Dr.-Ing.)
CAM-NC-Datenkette für die Laserbearbeitung von Freiformflächen mit simultaner Bewegung mechanischer Achsen und galvanometrischem Laserscanner

10.7.2018 – Marie Jeanne Livrozet (Dr. rer. nat.)
Design und Charakteristik eines satellitentauglichen optisch-parametrischen Oszillators im nahen Infrarot

10.8.2018 – Stefan Janssen (Dr.-Ing.)
Laserstrahl-Bohren von CFK-Preforms

17.8.2018 – Maximilian Meixlsperger (Dr.-Ing.)
Anwendungsspezifische Prozessführung des Selective Laser Melting am Beispiel von AlSi-Legierungen im Automobilbau

20.9.2018 – Stefan Herbert (Dr. rer. nat.)
Bildgebung im kurzwelligen Spektralbereich zur Inspektion von Nanodefekten

8.10.2018 – Lisa Bürgermeister (Dr. rer. nat.)
Modellierung und Simulation der Degradation Mikrogel-funktionalisierter Fasern aus Polyester

11.10.2018 – Christian Rüdiger Hinke (Dr.-Ing.)
Digitale Photonische Produktion

8.11.2018 – Michael Ungers (Dr.-Ing.)
Bildgebende Prozessüberwachung und -steuerung zur Qualitätssicherung für das Laserstrahlhartlöten

19.11.2018 – Sascha Brose (Dr. rer. nat.)
Auslegung und Charakterisierung einer Nanostrukturierungs-anlage für den extrem ultravioletten Strahlungsbereich

30.11.2018 – Lucas Jauer (Dr.-Ing.)
Laser Powder Bed Fusion von Magnesiumlegierung

3.12.2018 – Hendrik Sändker (Dr.-Ing.)
Laserbasierte Herstellung funktionaler Beschichtungen aus partikulärem Polyetheretherketon

6.12.2018 – Alexander von Wezyk (Dr. rer. nat.)
Emissionscharakteristik von XUV-Strahlungsquellen bei Wellenlängen im Spektralbereich zwischen 2 und 10 nm

14.12.2018 – Ulrich Halm (Dr. rer. nat.)
Simulation hochdynamischer Vorgänge in der Schmelze beim Laserstrahlschneiden

You will find a list of Fraunhofer ILT's scientific publications and lectures as well as bachelor and master theses online in our media center on the Internet at:
www.ilt.fraunhofer.de/en/media-center.html

EVENTS

Very well attended: exhibition accompanying the conference at the AKL'18 – International Laser Technology Congress in Aachen.

AKL'18

AKL'18 – International Laser Technology Congress May 2–4, 2018 in Aachen

From May 2 to 4, 2018, the AKL took place for the twelfth time at Fraunhofer ILT in Aachen. Taking part in Europe's leading congress for applied laser technology in production were 661 experts from industry and science from 26 countries. In addition to numerous networking opportunities, visitors were treated to a varied program with 77 lectures, the presentation of the Innovation Award Laser Technology and a series of supporting events. The accompanying sponsor exhibition was booked out long in advance with 56 companies. The conference was complemented by two forums on process monitoring and additive manufacturing as well as the »Laser Technology Beginners' Seminar« and the »Technology Business Day«. The »Laser Technology Live« open-house event – at which the experts from Fraunhofer ILT demonstrated more than 100 processes and systems live in the laboratories – was again very well attended.

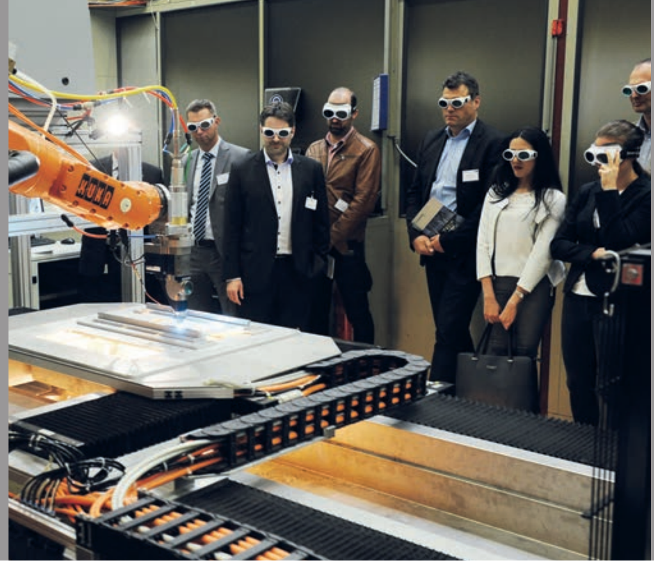
Technology symposium

The spectrum of topics of the technology symposium ranged from new laser beam sources to innovative process technologies and pioneering industrial applications. The trend towards higher productivity is leading to disruptive individual innovations and growing digitization in laser production. The topic of Digital Photonic Production was, therefore, also discussed in a separate session.

Disruptive innovations at the AKL'18 included powerful ultra-fast (UKP) lasers in the kW range and new diode laser systems with application-adapted wavelengths. While UKP lasers with about 50 W have established themselves well, systems with several hundred watts are now coming onto the market. They are expected to deliver significantly higher productivity, with the right process technology being a decisive factor alongside the beam sources. In the strategic Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS, UKP lasers in the multi kW range will be developed over the next two years thanks to the merger of several institutes. For diode lasers, innovative fiber-coupled cw beam sources in the blue wavelength range are suitable for demanding applications such as copper welding. Blue light also opens up new perspectives in underwater applications or water-guided laser systems.

Cutting and welding are the most important applications for industrial laser technology. The AKL'18 presented the development of a high-speed laser cutting system for up to 19,000 sheets per day, a system that could increase productivity tenfold compared to conventional punching systems.

The hot topic »Perspectives of Quantum Photonics« was also addressed for the first time at the AKL'18. Quantum sensor technology is the field in which most applications are expected in the short term. With the aid of extremely sensitive magnetometers, currents can already be measured in circuits or even in the brain.



»Laser Technology Live« at Fraunhofer ILT on May 3, 2018.

Expert Forum »Process Monitoring and Additive Manufacturing«

The three-day AKL´18 started with the expert forums »Process Monitoring« and »Additive Manufacturing«, which focused on measures for further automation and increasing productivity. The spectrum of sensors for process monitoring is now broad. For quality monitoring, the relevant parameters of the workpieces, processes and tools must be recorded before, during and after the machining process and compared with specified limits. With the documented data, productivity as well as the necessary maintenance can be monitored and planned as part of Industry 4.0.

Developed control systems are also suitable for process optimization, e.g. for welding applications. In a control loop, deviations from a nominal value are recorded and certain process parameters corrected until an optimum is reached. Since additive technologies grew by about 70 percent in 2017, process optimization is also one of the current tasks here.

»Laser Technology Live«

At the very well-attended »Laser Technology Live« event on May 3, 2018, the participants were able to exchange information about new technological developments with the Aachen researchers at over 100 live presentations at Fraunhofer ILT. The topics covered ranged from beam source and optics development to macro and micro material processing and laser measurement technology.

Launch of the »I^3-Research Center for Digital Photonic Production – RCDPP«

On the evening of May 3, 2018, Prof. Reinhart Poprawe gave the go-ahead for a new form of university cooperation within the »I^3-Research Center for Digital Photonic Production« (RCDPP). In this integrated interdisciplinary institute, I^3 for short, scientists from 16 institutes from 6 faculties of RWTH Aachen University will explore the use of the unique physical properties of photons for the production of the future. This complements the industrially established research work of the »Digital Photonic Production DPP Research Campus«, a BMBF-funded initiative, on the university side.

Innovation Award Laser Technology

The presentation of the Innovation Award Laser Technology on May 2, 2018 in the coronation hall of Aachen's city hall was a special highlight at AKL´18. Endowed with 10,000 euros, the prize is awarded by the Arbeitskreis Lasertechnik e. V. and the European Laser Institute (ELI) e. V.; it honors innovations in the field of applied laser technology. First prize went to the team led by Dr. Axel Luft (Laserline GmbH) for the development of a »multi-spot module for improving joining processes through tailor-made spot geometries«. The team from VW, Scansonic and Laserline developed a system for laser soldering that offers cost and quality advantages, e.g. in automotive manufacturing.

Further Information on the Internet at:
www.lasercongress.org | www.innovation-award-laser.org

Polymer Optics Days 2018 in Aachen.

Prof. Johannes Henrich Schleifenbaum at the 3D Valley Conference 2018.

EVENTS

April 10–11, 2018, Aachen
Aachen Polymer Optics Days 2018
Organized by Fraunhofer ILT, Fraunhofer IPT and the Institute for Plastics Processing IKV in Industry and Trade at the RWTH Aachen University. The event focused on topics such as:

- Injection-molded optics
- Continuous production of flat optics and foils
- New materials and applications for plastic optics
- Light sources and optical systems
- Digitization for optical production

During the event, the participants were able to visit the laboratories of Fraunhofer ILT.

September 12–13, 2018, Aachen
3rd Conference on Laser Polishing LaP 2018
Organized by Fraunhofer ILT the conference aims to present scientific and application-oriented results on laser polishing, to provide a platform for experts working on laser polishing worldwide, and to promote discussions and new scientific collaborations. A total of 84 participants from 14 countries attended the two-day conference at Fraunhofer ILT.

September 12–13, 2018, Frankfurt am Main
Discover 3D Printing at the Automechanika Frankfurt
Seminar for newcomers to 3D printing held by Max Fabian Steiner from Fraunhofer ILT and Christoph Zymla from ACAM Aachen Center for Additive Manufacturing.

Contents of the seminar were:

- What are 3D printing and additive manufacturing and how does it work?
- Can 3D printing make sense in my production?
- Can I earn money with it?
- Where can I find examples of obstacles, experience and successful implementation?
- What are the first/next steps to implementing 3D printing?

September 25–27, 2018, Aachen
3D Valley Conference 2018
Organized by TEMA Technologie Marketing AG and the ACAM Aachen Center for Additive Manufacturing. Topics covered were the use of additive manufacturing in industrial applications, new process developments, integrated process chains and innovative business models.

- Participation of Fraunhofer ILT in the accompanying industrial exhibition.
- Lectures and seminars by Dr. Sebastian Bremen, Prof. Johannes Henrich Schleifenbaum, Christoph Gayer and Anders Such from Fraunhofer ILT.

October 12, 2018, Bochum
LaserForum 2018
The LaserForum is organized by IVAM Microtechnology Network together with its partners Fraunhofer ILT, Laser Zentrum Hannover e.V. and the Chair for Laser Application Technology (LAT) of the Ruhr-University Bochum (RUB). Once a year, the forum participants present and discuss selected questions and trends regarding the use of laser technology along the entire value chain.

- Topic: 3D manufacturing of precision components.
- Lecture by Dr. Arnold Gillner on »Photonic Milling – 3D processing with high-power ultrafast lasers«.

November 22, 2018, Aachen
Foundations Seminar on Laser Material Deposition
As part of the ACAM Aachen Center for Additive Manufacturing seminar program, Max Fabian Steiner of Fraunhofer ILT conducted the foundations seminar on Laser Deposition Welding in the Photonics Cluster. The event was followed by a guided tour of Fraunhofer ILT laboratories.

December 8–10, 2018, Nanjing, China
Sino-German Cooperation Summit on Intelligent Manufacturing
The summit in Nanjing focused on the Internet of the future, intelligent manufacturing, innovation in science and technology and the central economy. Within the scope of the event, Fraunhofer ILT and Fraunhofer IPT opened an innovation and exhibition center in Nanjing Future Science and Technology City. As the basis for technology transfer between the two institutes, the center will continue to promote technical cooperation and industrial incubation initiatives between China and Germany in the field of intelligent manufacturing. Lectures were given by Prof. Reinhart Poprawe and Frank Zibner of Fraunhofer ILT.

December 11, 2018, Aachen
smartSHM Innovation Forum – Workshop 1
»Metal and hard components« was the topic of the first specialist workshop of the »smartSHM Innovation Forum« at Fraunhofer ILT. The focus of the workshop was on sensor solutions assembled from or attached to metal and hard, homogeneous structures.

The cross-sector network »smartSHM Innovation Forum« promotes the interdisciplinary networking of companies and research institutions with the aim of creating smart SHM solutions on the basis of »sensing«, self-diagnostic components along the entire product life cycle – from product development to integrated use in serial components and complex technical systems. The consortium currently consists of eleven institutes of RWTH Aachen University, three institutes of the Fraunhofer-Gesellschaft, including Fraunhofer ILT, and a growing circle of associated commercial companies.

COLLOQUIUM LASER TECHNOLOGY AT RWTH AACHEN

October 23, 2018 – Chair for Laser Technology LLT
Dr. Peter Thierolf, Fakultät für Physik der LMU München
»The elusive 229-Thorium isomer: On the road towards a nuclear clock«

November 8, 2018 – Chair for Laser Technology LLT
Dr. Falk Rühl
»Quanten existieren nicht! Eine alternative, logisch konsistente Beschreibung von Quantenexperimenten«

November 22, 2018 – Chair for Laser Technology LLT
Prof. Xinhua Wu, Monash Centre for Additive Manufacturing (MCAM) Monash University, Melbourne, Australia
»New light alloy and metallurgical issues for Selective Laser Melting (SLM)«

Fraunhofer ILT at the joint Fraunhofer booth at analytica 2018 in Munich.

Well attended: Fraunhofer ILT booth at the LASER World of PHOTONICS China in Shanghai.

TRADE FAIRS

January 27 – February 1, 2018, San Francisco, USA
SPIE Photonics West
International Trade Fair for Optics and Photonics
Fraunhofer ILT presented the following exhibits at the joint booth of the Federal Republic of Germany:
- Lasers for satellite-based LIDAR systems (FULAS)
- Thermomechanically robust OPO demonstrator for the climate mission MERLIN
- Fiber-coupled diode laser module with dense wavelength superposition (EU project »BRIDLE«)

A total of ten lectures were held by Fraunhofer ILT experts at the accompanying conference.

March 6–8, 2018, Paris, France
JEC World 2018
The Leading International Composites Show
Fraunhofer ILT presented laser-based technologies for the industrial processing of fiber-reinforced plastics at the joint stand of the Aachen Center for Integrative Lightweight Construction (AZL):
- Multi-material roof bows demonstrator (HyBriLight project)
- Cutting of GFRP-CFRP mixed components
- High-speed microstructuring of metals for plastic-metal hybrid connections

March 14–16, 2018, Shanghai, China
LASER World of PHOTONICS China
International Trade Fair for Optics and Photonics
Fraunhofer ILT presented new ideas for industrial laser applications at the LASER World of PHOTONICS China. These included self-adjusting helical optics for ultra-precise drilling and cutting. In addition, it presented solutions for laser-based micro and macro processing of various materials. The Laserfact combi-head, which allows high-precision cutting and welding without retooling, was also on display. The top topics at LASER China were:
- Material ablation using ultrashort pulsed lasers
- New helical drilling optics with smart sensor systems and automated adjustment
- Multi-beam laser processing
- Laserfact combi-head
- Laser material deposition and cladding

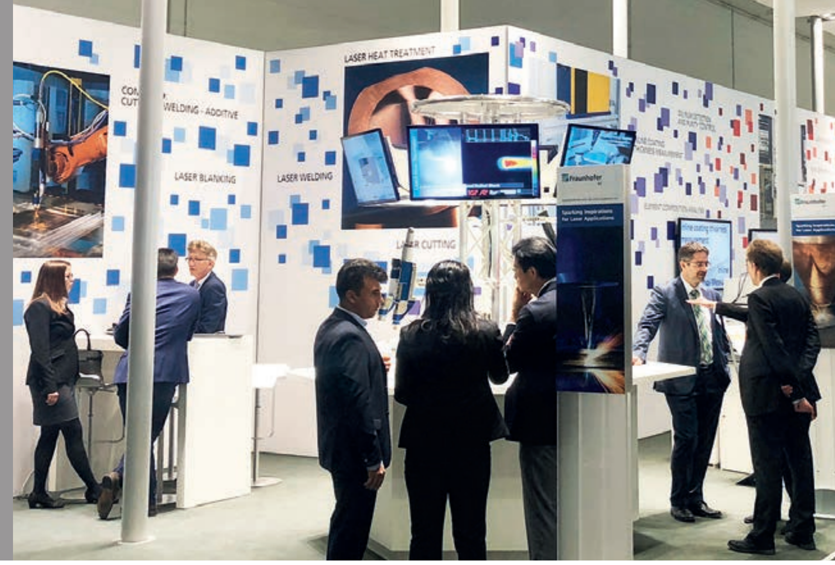
Co-exhibitor: Laserfact GmbH, ACunity GmbH.

The Fraunhofer ILT was also represented at the 13th International Laser Processing and Systems Conference (LPC 2018) in Shanghai, giving four presentations. Prof. Reinhart Poprawe also served as one of the two general chairs of the conference.

April 10–13, 2018, Munich, Germany
analytica 2018
26th International Leading Trade Fair for Laboratory Technology, Analytics, Biotechnology
Fraunhofer ILT was represented at the Fraunhofer joint booth with the following topics:
- OptisCell – process chain for automated cell isolation. Within the framework of the MAVO research project »OptisCell«, the three Fraunhofer Institutes ILT, IGB and FIT are developing an automated selection of individual cells in order to produce high-producer cell lines for the production of biologics.
- LIFTSYS Workbench – laser-based cell picker. Optical analysis of cells in closed and air-conditioned workspaces by Laser Induced Forward Transfer (LIFT) in microtiter plates.
- Thiol-ene-based photo resins for the production of optical components.

Laser-based technologies for the optical production of glass materials at Optatec 2018.


COMPAMED 2018: Fraunhofer ILT at the joint IVAM booth.


Future-oriented trends for sheet metal processing at EuroBLECH 2018.

Fraunhofer ILT is developing improved material systems and process technology for the individual manufacture of (micro-) optics by means of stereolithography. The basis for this is the use of thiol-ene click chemistry to polymerize special photo resins and thus produce optics with a high refractive index and low dispersion.

April 23–27, 2018, Hanover
Hannover Messe, 2018
The Fraunhofer Institutes IPT, ILT and IME in Aachen want to develop new production systems and value chains in the context of Industry 4.0 together with renowned industrial partners in the Center of Excellence »Networked, Adaptive Production«, thus setting the standards for the production of tomorrow. This center of excellence was ceremoniously opened at the Hannover Messe. At the Fraunhofer joint stand, Fraunhofer ILT had exhibits on the subject of »Battery Production and E-mobility« and also showed how a turbine blade can be produced and repaired using additive manufacturing and a digital twin.

April 24–27, 2018, Stuttgart
Control 2018
At the joint stand of the Fraunhofer VISION Alliance, Fraunhofer ILT presented a machine-integrated system with functions for process setup, powder gas jet measurement and process monitoring for laser material deposition. With this system, powder gas jet nozzles can be certified in the system and their powder gas jet can be fully characterized. In addition to the standardized and documented process equipment, the process is visualized and monitored.

April 25–29, 2018, Berlin
ILA Berlin Air Show 2018
Fraunhofer ILT was represented with exhibits from the areas of additive manufacturing and laser material deposition (LMD) at the booth of the Fraunhofer Traffic Alliance – Aviation Working Group. The institute presented blade clusters produced by laser powder bed fusion (LPBF) in a 3D printing process, as well as applications for an automated repair process chain of blade tips with LMD at the ILA Berlin Air Show.

May 15–17, 2018, Frankfurt am Main
Optatec 2018
International Trade Fair for Optical Technologies, Components and Systems
The Fraunhofer ILT presented itself at the joint Fraunhofer stand with laser-based technologies for the optical production of glass materials:
- Laser-based shaping
- Laser polishing
- Laser-beam figuring

June 5–7, 2018, Erfurt
Rapid.Tech 2018
International Hub for Additive Manufacturing
The Aachen Center for 3D Printing presented itself at the FH Aachen University of Applied Sciences stand. The Aachen Center for 3D Printing is a joint project between Fraunhofer ILT and the FH Aachen with the aim of giving small and medium-sized companies access to the integrated process chain in the field of additive manufacturing. Shown at the event were the first successfully manufactured demonstrators for an integrated additive process chain for the production of large-volume components using laser powder bed fusion (LPBF). Furthermore, the FH Aachen presented its mobile 3D printing laboratory, the FabBus of the GoetheLabs for AM.

July 16–22, 2018, Farnborough, UK
Farnborough International Airshow 2018
Additive manufacturing processes such as 3D printing stand out from other processes as they can be used to construct components in almost any complexity. In order to achieve a good surface quality for metallic components, it is often necessary to use milling or grinding processes for finishing. Especially when thin-walled components are milled, vibrations often occur, which worsen the accuracy and machining time. At the Farnborough International Airshow, the Fraunhofer Institutes ILT and IPT used the production of engine components as an example of how special support structures can be used to prevent such vibrations during the post-processing of additively manufactured components.

September 10–15, 2018, Chicago, USA
IMTS 2018
International Manufacturing Technology Show
At the joint Fraunhofer booth, Fraunhofer ILT presented the following:
- Brake discs coated using the EHLA process
- Components manufactured using µ-LPBF
- Thin film process – printed and laser functionalized sensors on components

October 1–5, 2018, Bremen
IAC 2018
International Astronautical Congress
Fraunhofer ILT presented the following topics at the Fraunhofer Alliance Space stand:
- Diode-pumped solid-state lasers for satellite-based free-space communication
- Laser powder bed fusion (LPBF)
- Key optical components for robust laser systems
- Space-based optical parametric oscillator (OPO)

October 9–12, 2018, Chania, Greece
ICSO 2018
International Conference on Space Optics
Fraunhofer ILT took part in the accompanying exhibition at the Fraunhofer Alliance Space stand with various exhibits from the field of laser technology suitable for use in space.

October 14–18, 2018, Orlando, USA
ICALEO 2018
International Congress on Applications of Lasers & Electro-Optics
- Five presentations by Fraunhofer ILT experts in various sessions, including »Surface Texturing«, »Laser Metal Deposition« and »Advanced High Power Microprocessing«
- Participation of Fraunhofer ILT in the accompanying Vendor's Exhibition

October 23–26, 2018, Hanover
EuroBLECH 2018
25th International Technology Fair for Sheet Metal Working
Fraunhofer ILT presented the following topics at the joint Fraunhofer stand:
- Laser heat treatment - free-form optics with armchair intensity distribution for local conditioning of high-strength steels at high feed rates
- High-speed laser beam cutting
- Laser-beam welding
- Laser processing of FRP and FRP-metal hybrid material

November 12–15, 2018, Düsseldorf
COMPAMED 2018
High-Tech Solutions for Medical Technology
At COMPAMED, Fraunhofer ILT was represented at the joint IVAM booth with the following topics:
- Laser polishing
- Plastics processing
- Compact application-specific µFACS systems
- High-throughput screening
- 3D microfluidics
- OptisCell – Process chain for automated cell isolation
- LIFTSYS® Workbench – laser-based cell picker


formnext 2018: Fraunhofer ILT with results on additive manufacturing.

In the Compamed High-Tech Forum by IVAM, Dr. Achim Lenenbach gave a lecture in his session »Laser and Photonics Applications I - Laser Surgery: Clinical Applications and Novel Developments«. Maximilian Brosda also gave a lecture in the session »Laser and Photonics Applications II – EPIC Tech Watch«.

November 13 – 16, 2018, Frankfurt am Main
formnext 2018
International Exhibition and Conference on the Next Generation of Manufacturing Technologies
At formnext 2018, Fraunhofer ILT presented innovative results at the joint Fraunhofer stand:
- New LPBF preheating concepts using Vertical Surface Emitting Lasers (VCSEL)
- »TwoCure«: resin-based 3D printing enables the automated production of plastic components without supporting structures and in large quantities
- Fraunhofer lighthouse project »futureAM«
- Material concepts for additive production – elemental powder blend
- Software for precise cost and construction time calculation for the LPBF process
- Laser material deposition with coaxial wire feeder

In addition, Ulrich Thombansen and Andreas Vogelpoth each gave a lecture at the »TCT Conference @ formnext« in the sector of New Research and Academia.

November 13 – 16, 2018, Munich
electronica 2018
The world's leading trade fair and conference for electronics
At electronica 2018, Fraunhofer ILT was represented at the joint booth of the Fraunhofer-Gesellschaft with the following topics:
- »Transport and Smart Mobility«,
  - Contacting of 18650 battery cells with printed copper connectors
  - Contacting prismatic battery cells with an aluminum connector
  - Contacting of pouch cells
- »Digital Industry«
  - Printed and laser functionalized sensors on metal components
  - Printed and laser-functionalized sensors on plastic foils
  - Selectively gold-plated contacts on industrial connectors
  - Wafer with laser crystallized silicon layers

You will find further information on our trade fairs and events on the Internet at:
www.ilt.fraunhofer.de/en/fairs-and-events.html

REFERENCES

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INFORMATION

For more information about Fraunhofer ILT please visit our website or follow the social media channels mentioned below.

→→ www.ilt.fraunhofer.de

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