Fraunhofer ILT

FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

ANNUAL REPORT 2020

ANNUAL REPORT

2020

Fraunhofer-Institut für Lasertechnik ILT

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Dear Readers,

A special year under the sign of the pandemic lies behind us: Indeed, 2020 demanded a great deal from people and their families. We responded to the changed conditions at breath-taking speed; we adapted processes and workflows and found creative solutions. At Fraunhofer ILT, we were able to convert many processes immediately to digital processes and, thus, maintain working at the level before the pandemic despite far-reaching cuts. My thanks go to our employees, who have absorbed the effects of the crisis with tireless dedication and a special commitment, and who have continuously driven our work forward.

Even before the COVID pandemic, 2020 was shaping up to be a more difficult year for the laser industry: Declining public funding for laser technology and photonics, market shifts to the Far East, changing business models and a reduction in the vertical value-creation chain are just some of the factors that are creating competitive and, at the same time, innovative pressure. However, change offers new opportunities. As the laser is »the« tool of high-tech manufacturing, digital photonic production can fully exploit its great potential in megatrends such as green hydrogen, e-mobility or even quantum technology.

The innovative capacity of Fraunhofer ILT is also reflected in a number of successes in 2020. In the European joint project ADIR, a laser-based, efficient recycling method was demonstrated in which cell phones and printed circuit boards can automatically be dismantled and substances such as tantalum, neodymium or cobalt can be detected and recovered with laser-induced breakdown spectroscopy (LIBS). In the Fraunhofer lighthouse project »futureAM - Next Generation Additive Manufacturing«, which we completed together with six partner institutes, we succeeded in accelerating the additive manufacturing of metal components by a factor of ten. In addition to increasing performance and cost-effectiveness along the entire process chain, we achieved this acceleration through innovations in system technology, materials and process control, as well as consistent end-to-end digitalization.

Another highlight last year was the award of the Science Prize of the Stifterverband für Verbundforschung (a donors' association for joint research) for the outstanding work on the development of the multi-beam laser process. In collaboration with innovative industrial partners, the ILT team has set new milestones in parallelized processing and especially in high-quality engraving of printing rollers using ultrashort pulse (USP) lasers. Yet even more powerful USP lasers are needed here, which we are also developing up to the multi-kW range. Industrial partners can now develop and test their USP applications in an application laboratory opened at Fraunhofer ILT specifically for this purpose.

Last but not least, we are vigorously advancing the industrial applications of quantum technology in cutting-edge international research together with our partners. This includes advancing low-noise, high-precision or high-power lasers, fabricating microstructures for photonic coupling of semiconductor-based qubits in quantum computers, or developing frequency converters so that large-scale quantum networks can be realized based on existing classical fiber infrastructure. In this annual report you will find further process developments, system and software solutions that contribute to increasing the competitiveness of our industrial clients. I look forward to stimulating discussions with you.

Cordially,

Constantin Häfner

Prof. Dr. rer. nat. Constantin Häfner

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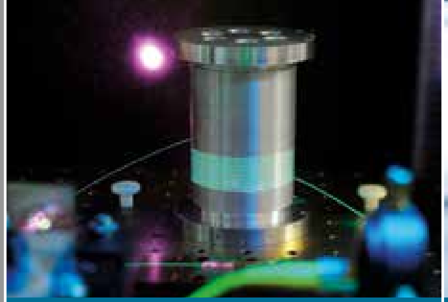

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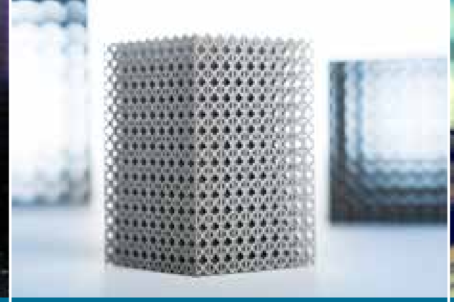

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EVENTS AND PUBLICATIONS

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

FACTS AND FIGURES

2020

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

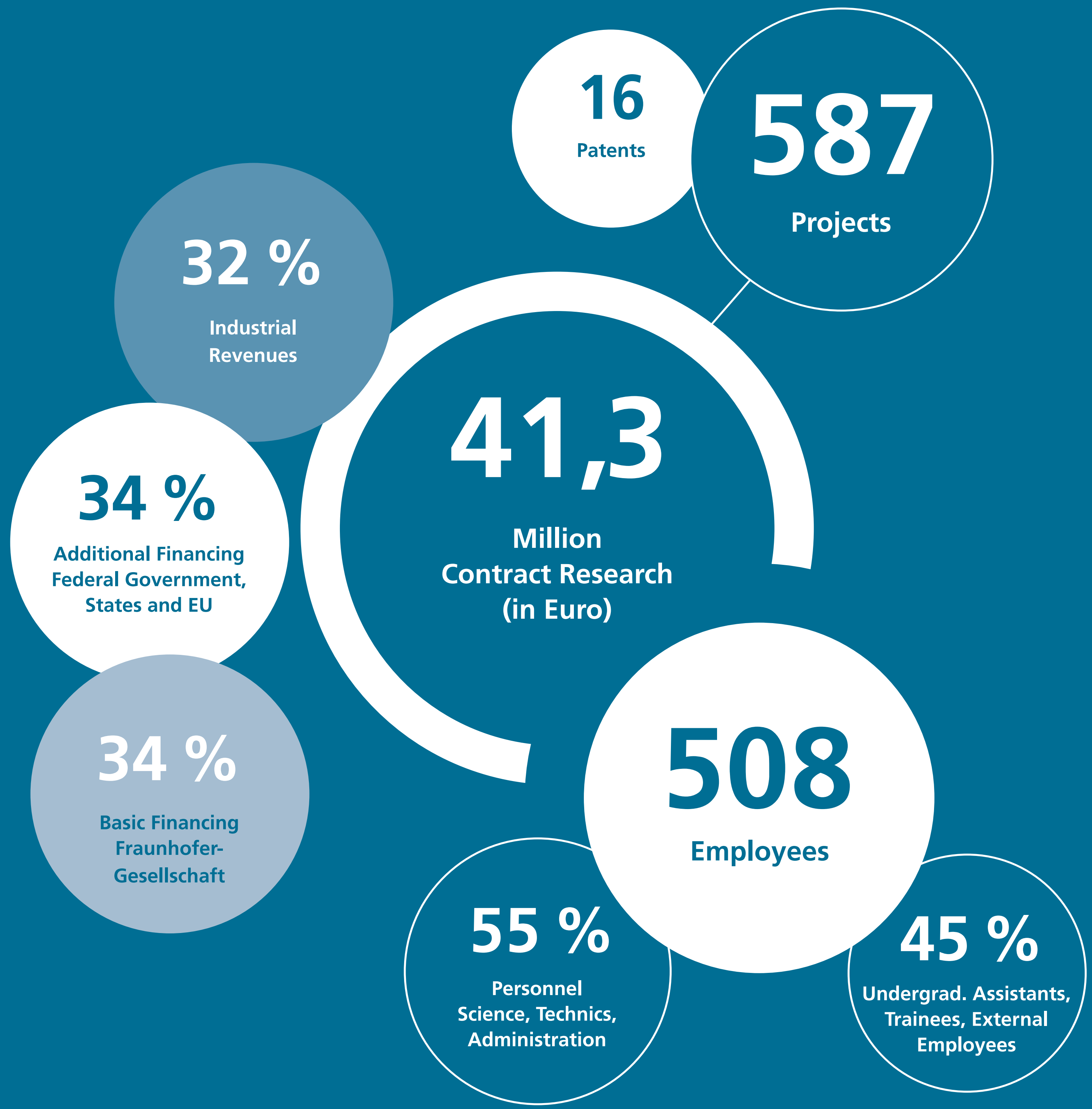
Our broad spectrum of resources enables us to offer one-stop solutions. We deliver innovative and cost-effective solutions and offer you R&D, consulting and integration. We solve our customers' tasks in multi-disciplinary teams using diverse and innovative facilities.

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 500 employees and more than 19,500 m^2 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 six 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 focus »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. In the technology focus »Quantum Technology« Fraunhofer ILT offers a broad portfolio of solutions in the field of photonic beam sources and components. These include parametric photon sources and frequency converters, integrated optical components, packaging processes and application-specific system technologies. The technology focus »Digitalization« is closely linked to the activities of the other technology focuses and combines competencies in digital production around laser technologies such as design-to-production, digital twins, smart simulation, fog and edge computing and AI.

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.

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

RANGE OF SERVICES

Services of Fraunhofer ILT

- 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
- Solutions for digital production
- Model and test series
- Development, set-up and testing of pilot plants
- Development of X-ray, EUV and plasma systems
- Photonic components and systems for quantum technology

COOPERATIONS

Cooperations of Fraunhofer ILT with R&D-partners

- 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

ALUMNI NETWORK AIX-LASER-PEOPLE

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 2020 alone, 94 students completed their bachelor's or master's theses at Fraunhofer ILT and 14 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 alumni have founded more than 40 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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STRUCTURE OF THE INSTITUTE

Board of Trustees 2020 at Fraunhofer ILT.

BOARD OF DIRECTORS

Prof. Constantin Häfner
Director

Prof. Peter Loosen
Vice Director

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IT Management

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

Dr. Arnold Gillner
Ablation and Joining

Dr. Jochen Stollenwerk
Additive Manufacturing and Functional Layers (temporary since 1.10.2020)

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:

MEMBERS

- Carl F. Baasel (Chairman)
- Dr. Reinhold E. Achatz, thyssenkrupp Transrapid GmbH
- Dr. Norbert Arndt, Precision Castparts Corp.
- Dipl.-Ing. Frank C. Herzog, HZG Group
- Dipl.-Ing. Volker Krause, Laserline GmbH
- Dipl.-Ing. Michael Lebrecht, Mercedes-Benz AG
- Prof. Gerd Marowsky, Advanced Microfluidic Systems GmbH
- Manfred Nettekoven, Kanzler der RWTH Aachen University
- Dr. Joseph Pankert, TRUMPF Photonic Components GmbH
- Dr. Silke Pflueger
- Dr. Stefan Ruppik, Coherent Hamburg
- Dr. Torsten Scheller, JENOPTIK Automatisierungstechnik GmbH
- Susanne Schneider-Salomon, Ministerium für Kultur und Wissenschaft des Landes NRW
- Dr. Ulrich Steegmüller, Microsoft Development Center Denmark
- Dr. Klaus Wallmeroth, TRUMPF Laser GmbH + Co. KG

The 35th Board of Trustees meeting was held on September 15 and 16, 2020 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. C. Häfner, Prof. P. Loosen, Dr. V. Alagic-Keller, P. Abels, A. Bauer, T. Biermann, G. Bongard (since 1.9.2020), Dr. A. Drenker, D. Esser, Prof. A. Gillner, H.-D. Hoffmann, Prof. R. Noll, Dr. D. Petring, Prof. J. H. Schleifenbaum (until 30.9.2020), Prof. W. Schulz, Dr. J. Stollenwerk, Dr. B. Weikl (until 31.8.2020).

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. C. Häfner, Prof. P. Loosen, Dr. V. Alagic-Keller, A. Bauer, M. Brankers, B. Erben, W. Fiedler, R. Frömbgen, F. Fuchs, M. Giesberts, A. Hajdarovic, M. Hesker, J. Jorzig, S. Jung, T. Kaster, K. Kohnen, D. Kreutzer, D. Maischner, V. Nazery Goneghany, B. Quilitzsch, M. F. Steiner, F. Voigt, T. Westphalen, T. Yildirim, Dr. R. Keul (Works doctor B.A.D), J. Pohl (B.A.D), S. Schönen (B.A.D).

SCIENCE AND TECHNOLOGY COUNCIL WTR

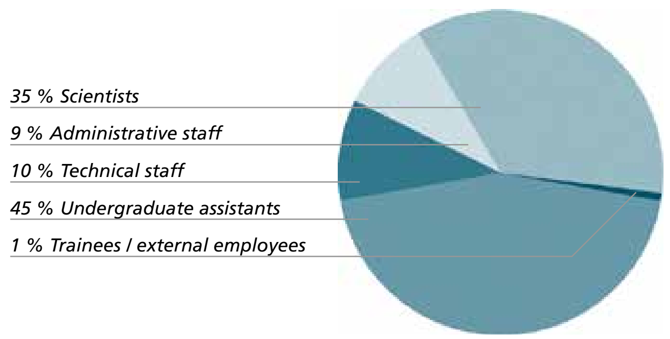
The Fraunhofer-Gesellschaft's Science & Technology Council supports and advises the various bodies of the Fraunhofer-Gesellschaft on scientific and technical issues. The members are the institutes'directors and one representative elected from the science/technology staff per institute. Members of the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

WORKERS' COUNCIL

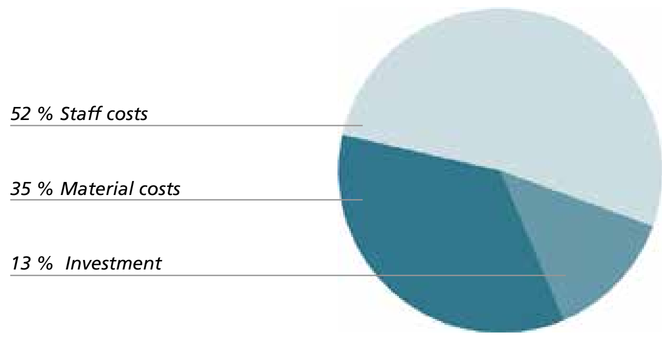
Since March 2003 there is a workers' council at Fraunhofer ILT.

THE INSTITUTE IN FIGURES

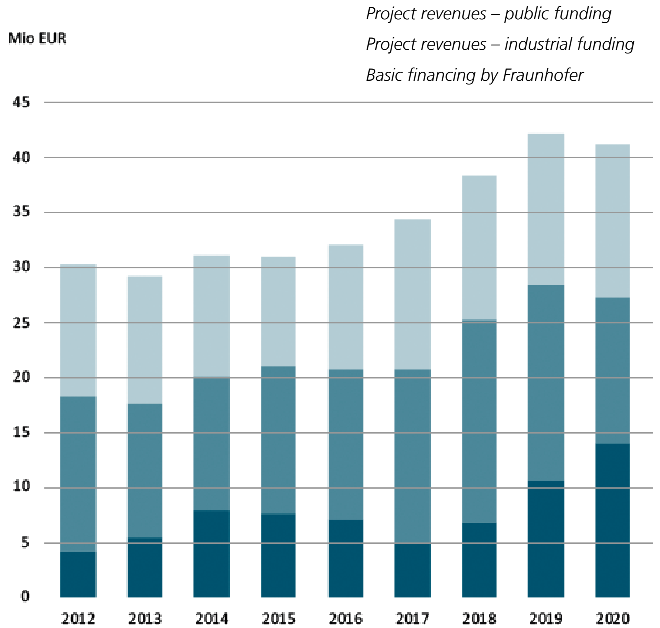
EMPLOYEES 2020	number
Personnel	**278**
- Scientists and engineers	180
- Technical staff	51
- Administrative staff	47
Other employees	**230**
- Undergraduate assistants	226
- External employees	2
- Trainees	2
Total number of employees at Fraunhofer ILT	**508**



EXPENSES 2020	Mill €
- Staff costs	24,7
- Material costs	16,6
Expenses operating budget	**41,3**
Investments	**6,2**



REVENUES 2020	Mill €
- Industrial revenues	13,2
- Additional financing from Federal Government, States and the EU	14,0
- Basic financing from the Fraunhofer-Gesellschaft	14,1
Revenues operating budget	**41,3**
Investment revenues from industry	**0,4**
Fraunhofer industry ρ_{Ind}	**32,8 %**



FACILITIES

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. The net floor area at Fraunhofer ILT amounts to 19,500 m².

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 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
- Disk lasers up to 12 kW
- Disk lasers with green wavelength up to 2 kW CW and QCW
- Fiber lasers with 1.5 µm and 2 µm wavelength up to 200 W CW
- Experimental lasers with 2 µm / 3 µm wavelength (ns, ps)
- Experimental LIDAR lasers with pulse energies up to 500 mJ
- Single- and multimode fiber lasers up to 6 kW
- Diode laser systems up to 12 kW
- Ultrashort pulse lasers up to 1 kW (ns, ps, fs)
- Frequency-multiplied laser in visible spectral range
- Excimer lasers amongst others with optical line systems
- Broadband tunable lasers
- MIR lasers (ps, ns) with average power > 10 W
- Laser platform for satellite-based LIDAR systems

PLANTS AND PROCESSING SYSTEMS

- Three-axis processing stations
- Five-axis gantry systems
- Robot systems including six-axis articulated 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

- ISO 5 and ISO 7 clean rooms for assembly and characterization of lasers and laser optics
- Life science laboratory with S1 classification
- Laboratory for battery technology
- Application laboratories for USP applications (e. g. CAPS laboratory)

MEASUREMENT AND SENSOR TECHNOLOGY

- Devices for process diagnostics
- 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 USP lasers
- Equipment for vibration tests
- Climate chambers for thermal tests with continual monitoring of the optical properties
- Single photon detector (APD) for NIR lasers
- Systems to characterize powder materials
- Measurement systems for single quantum detection

AWARDS AND PRIZES

HUGO GEIGER AWARD

Dr. Hendrik Sändker receives the Hugo Geiger Prize for outstanding doctoral achievements

Three young researchers from the Fraunhofer-Gesellschaft were honored with the prestigious Hugo Geiger Award for their doctoral theses. Their excellent research results help secure the economic strength of Germany and Europe with application-oriented research and future-oriented innovations. The prizes, endowed with 5000, 3000 and 2000 euros, were awarded by the Fraunhofer-Gesellschaft together with the Free State of Bavaria. They were presented at the Fraunhofer Symposium »Netzwert« on February 18, 2020 in Munich.

Award of the Hugo Geiger Prize to Dr. Hendrik Sändker (Laserline GmbH), © Fraunhofer / Marc Müller.

One of the award winners was Dr. Hendrik Sändker, who developed novel methods for producing functional coatings from particulate polyetheretherketone (PEEK) using laser technology within the scope of his doctorate at Fraunhofer ILT. The high-performance plastic PEEK is even more suitable than magnesium or other metals for coating metallic components when high resistance to temperature and corrosion is required, in addition to protection against abrasion. Such requirements are needed in many industries – from mechanical and automotive engineering to renewable energy production plants. Dr. Sändker made a significant contribution to developing needs-specific laser-based manufacturing processes as part of funded projects with industrial partners – including, above all, a dual-beam process with significantly increased energy efficiency as a key technology. Together with partners such as Schaeffler, Evonik, Mahle and Eloxalwerk Ludwigsburg ELB, Fraunhofer ILT is working on transferring the processes to industry. ELB has already received the ThinKing Community Award 2019 from the network Leichtbau BW for the process developed jointly with Fraunhofer ILT.

Sophia Schröder wins Carl Zeiss Student Paper Award 2020

Sophia Schröder received the 1st prize of the »Carl Zeiss Student Paper Award« at the online conference »SPIE Photomask Technology and EUV Lithography 2020« from September 21 to 25, 2020.

At the industry conference with over 1,500 participants, Sophia Schröder presented EUV spectrometry. Scientists from the Chair for Technology of Optical Systems TOS at RWTH Aachen University and Fraunhofer ILT developed this process in a compact laboratory setup and analyzed its measurement accuracy. Using extreme ultraviolet radiation, the process can be applied, among other things, to characterize novel absorber materials for mask production in industrial semiconductor technology.

Stifterverband award for efficient surface structuring with the multi-beam laser process.

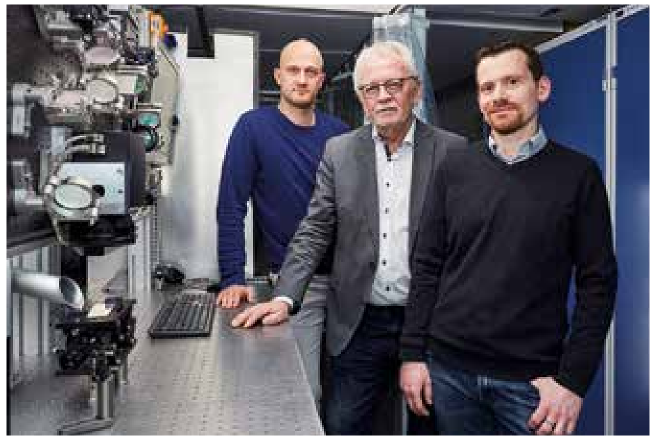
Stifterverband award for multi-beam laser process

On the evening of October 9, 2020, the Stifterverband Award was presented at the annual conference of the Fraunhofer-Gesellschaft in Berlin. Prof. Arnold Gillner from Fraunhofer ILT accepted the €50,000 science prize from the Stifterverband für Verbundforschung (a donors' association for joint research) on behalf of the partners in the collaborative project »High-power ultrashort pulse laser technology for functional micro- and nanostructures on large components - MultiSurf«. The collaborative partners include Dr. Stephan Brüning of Schepers GmbH & Co. KG, Dr. Gerald Jenke of Matthews International GmbH, Dr. Keming Du of EdgeWave GmbH and Dr. Manfred Jarczynski of LIMO GmbH, as well as Martin Reininghaus and Dr. Johannes Finger of Fraunhofer ILT. The MultiSurf joint project was funded by the German Federal Ministry of Education and Research (BMBF) as part of the funding initiative »The Basis of Photonics: Functional Surfaces and Coatings«.

In the MultiSurf joint project, an interdisciplinary team including businesses, specialists and institutes developed a solution for efficient surface structuring with the laser. The technical heart of the project is a new ultrashort pulse laser that has an average power of 500 W and whose light is distributed over up to 16 partial beams in a special optical system. In the meantime, the technology has even been expanded to 64 beams, which are individually controlled with special crystals. The beam matrix is guided over the surfaces to be structured, with all beams being switched on and off quickly and individually as required. The exact parameters for optimum material removal have been simulated and matched with process knowledge acquired over many years at Fraunhofer ILT.

The individual components are integrated into a new machine system based on the Schepers Digilas machine. This machine outperforms all current systems for roll structuring thanks to its combination of processing quality and speed.

The technology can be used in a wide range of applications: Tools for other roll-to-roll processes are also under discussion, as are special work steps in battery and hydrogen technology. Systems with considerably more parallel beams have also already been developed at Fraunhofer ILT, although they cannot be controlled individually. This is all part of a new generation of technology for the production of functional surfaces. With further power scaling, even larger surfaces can be processed in the future. For example, the wind resistance of wind turbines or aircraft wings could be reduced with suitable surface processing.



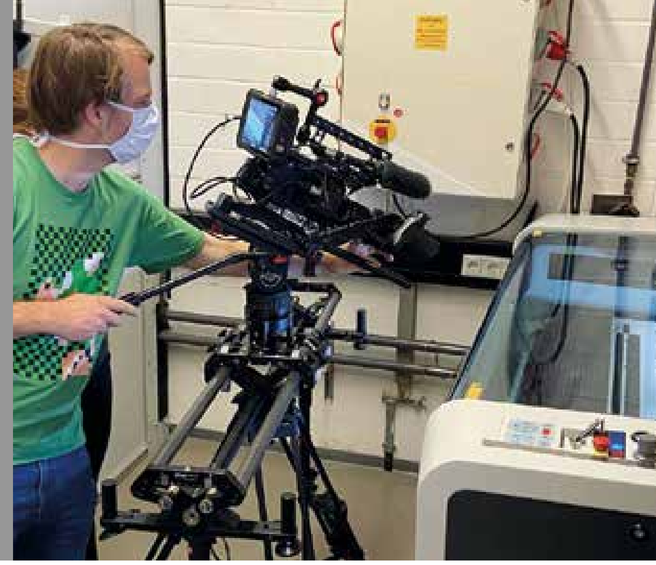
Fraunhofer ILT team (from left to right): Martin Reininghaus, Prof. Arnold Gillner and Dr. Johannes Finger, © Fraunhofer / Banczerowski.

Jasmin Saewe wins Fraunhofer TALENTA funding program

Jasmin Saewe, Group Leader of LPBF Process Development at Fraunhofer ILT, successfully applied for the TALENTA funding program. The TALENTA support program is a career and development program of Fraunhofer for female scientists and female managers and offers them the opportunity for personal and strategic development through tailored qualification and networking.

TRAINING THE NEXT GENERATION

Bus of the Aachen Fraunhofer lines with the newly designed banners, © Roland Schulteis.



Shooting of the RWTH mechanical engineering film by »Media for Teaching«.

Student University of Mechanical Engineering from July 27–31, 2020

In 2020, the Student University of Mechanical Engineering took place again along with the Cluster of Excellence Internet of Production IoP. Due to the corona pandemic, the Student University was held online for the first time. Seventeen students spent a total of five days in a virtual format at RWTH Aachen University to get a first impression of the Mechanical Engineering course of studies and its diverse possibilities. The participants gained insights into the fields of production engineering, process engineering, plastics, textile and automotive engineering, as well as optics and laser technology. Then, on July 31, 2020, they discovered the world of photonics. This day was organized by Fraunhofer ILT and the cooperating RWTH chairs LLT and TOS. There was a lecture by Martin Walochnik from the Chair LLT with a live demonstration of the construction of a laser as well as an interactive lecture by Jörg Hofmann from the Chair TOS on »Optics in Everyday Life«. In addition, the students participated in a group work on the topic »Lasers for the Environment«.

Aachen Fraunhofer bus lines in a new design

After more than ten years in the Aachen cityscape, the Fraunhofer (bus) lines received a completely new banner design in September 2020. The redesign of the bus banners combines emotionally charged employer branding messages with the technological focus of the Fraunhofer institutes at the innovation location Aachen. With Fraunhofer you can go from being a dreamer* or an amazer* to a pioneer* or a visionary* – a message that is symbolically visualized with a spectacular natural phenomenon transformed into a technological innovation. With this campaign, the three Aachen Fraunhofer Institutes ILT, IPT and IME want to draw attention to themselves as a modern and attractive employer and, above all, appeal to students and graduates of the Aachen universities.

Fraunhofer Student Assistant Days@Home in October 2020

On October 9 and 10, 2020, the Fraunhofer Student Assistant Days for students took place along with the participation of Fraunhofer ILT, this time in the form of an online event due to the corona pandemic. The event highlighted career options at Fraunhofer for entry after graduation. Any student assistant employed by Fraunhofer could register. The program included presentations by scientific staff, advice and workshops on career orientation, and the »Fraunhofer Escape Game@Home«.

Virtual student visit on October 15, 2020 as part of the Fraunhofer-Gesellschaft's »Talent Take Off« study choice orientation program

In cooperation with Femtec GmbH at the Technical University of Berlin, the Fraunhofer-Gesellschaft offered the following courses as part of its "FraunhoferTalents!" study courses for students in grades 10 to 13. For just under a week, these online courses explored various topics that are important for students when they choose a course of study: for example, in technology workshops, during a virtual visit to a Fraunhofer institute and in discussions with students from various subjects or with scientists. Fraunhofer ILT participated in this and welcomed a group of students to a virtual visit to the institute with live demonstrations on October 15, 2020.

RWTH children's supervision on October 15, 2020

RWTH Aachen University offers supervision during school break for the children of students and employees during the Easter, summer and fall vacations, which always have a specific theme. For example, the first week of the 2020 fall vacation was devoted to the theme of »The World of Machines«. Fraunhofer ILT also participated in this event. On October 15, 2020, 30 children between the ages of 8 and 13 visited the Fraunhofer ILT virtually. Live demonstrations from the laboratories provided them with practical insight.

Digital STEM-EC Camp Production Engineering from November 17 to 19, 2020 for students from STEM-EC schools

Every year, RWTH Aachen University offers all students from grade 10 upwards from schools in the STEM-EC network the opportunity to take part in four-day camps on STEM subjects. In 2020, the Cluster of Excellence Internet of Production, or IoP for short, once again gave STEM students from all over Germany exciting insight into a wide range of production technology topics. Whether the Fourth Industrial Revolution, automation, human-machine interaction or logistics, the spectrum of production engineering topics being researched in the Cluster of Excellence at RWTH Aachen University is very broad. The workshops on offer looked at questions relating to the future of production in Germany. The special feature of the cluster is the interdisciplinary cooperation of 35 institutes and research facilities. In this context, a lecture on photonics and a »livestream lab tour« by Tim Biermann and Maximilian Brosda from the Chair for Laser Technology LLT also took place on November 18, 2020.

Talk Teaching 2020 on November 12, 2020 – Digitalization of Teaching

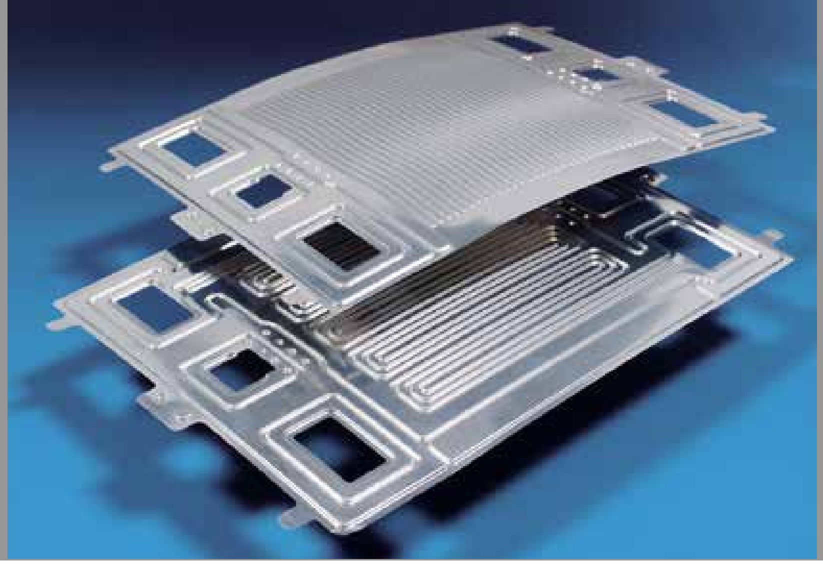
The main topic of the virtual conference »Talk Teaching 2020« on November 12, 2020 was the digitalization of teaching in the wake of the corona pandemic. A total of 340 people registered for the event. In a variety of talks and live demonstrations, teachers and students presented projects, concepts and best-practice examples from their faculties and departments that show how good teaching works in these digital times. The Chair for Laser Technology LLT also took up the challenge of continuing to provide students with elementary practical experience as part of their teaching. With a specially designed mobile live streaming setup, LLT has succeeded in continuing to maintain this link to praxis in the courses offered by means of digital laboratory tours directly from the laser laboratories. During the presentation, the mobile live streaming setup was introduced and the application demonstrated live.

2nd bonding Virtual Career Fair on December 9, 2020

For the first time, Fraunhofer ILT presented itself at the largest student-organized virtual company contact fair – the bonding Virtual Career Fair. Alongside 51 other exhibitors, Fraunhofer ILT informed students and graduates from the engineering, business and natural sciences in particular about entry-level and career opportunities at the institute in personal discussions.

MOBILITY

LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY



PRODUCTION »ELECTRIFIES« THE MOBILITY OF TOMORROW

2020 was a fateful year for vehicle manufacturers: The corona pandemic slowed down the production of classic vehicles with combustion engines in particular, while at the same time electromobility slowly picked up speed. Another reason for this are the new CO_2 fleet limits imposed by the EU. Since then, not only has the importance of methods to efficiently produce electric cars and batteries grown, but demand has increased for processes to reliably manufacture bipolar plates (BPP) for fuel cell vehicles.

Fraunhofer ILT reacted to these trends and pursued a multi-pronged strategy: In 2020, in addition to the second Laser Symposium Electromobility LSE, it now also organized the Laser Colloquium Hydrogen LKH_2 for the first time. This year's research activities for the mobility of tomorrow were correspondingly diverse.

Technical coexistence of fuel cell and battery

One message of 2020 is clear: The future is electromobile. However, two trends are now emerging here: Fuel cells are suitable for longer distances and above all for larger e-vehicles, while battery electric vehicles are better suited for short distances, for example, in the city. There is a great deal of motivation to make hydrogen technologies more efficient and their manufacturing processes more productive and, thus, more cost-effective.

By 2030, annual global production of fuel cell vehicles is expected to increase by a factor of 160 to almost four million. However, around 800 million bipolar plates and membrane electrode assemblies (MEAs), the core of the fuel cell, will also be needed. To achieve this, large-scale production must first be established and the higher costs significantly reduced. Around 30 percent of the total cost of a fuel cell is accounted for by the bipolar plates, which use metal and, more recently, highly conductive carbon compounds.

The manufacturing processes used play an important role not only in terms of cost, but also in terms of quality. For example, two formed half-shells are welded together to form a bipolar plate and arranged alternately with the MEA in a stacked composite. The entire composite must prevent cooling water from escaping and meet the high requirements for hydrogen tightness.

Welding bipolar plates with green laser light

Fraunhofer ILT is working on making the demanding laser welding process for bipolar plates faster and, at the same time, more reliable. This is being done, for example, as part of the joint project CoBiP, in collaboration with the Fraunhofer Institute for Production Technology IPT, among others. In this project, a continuous roll-to-roll production of metallic BPPs is being created.

Previously, laser welding of uncoated stainless steel foils just 100 micrometers thick under argon gas resulted in the so-called humping effect, which severely jeopardized the tightness of the seam due to deposits of the melt on the material surface. A significant improvement was achieved by switching from the near infrared range to visible green laser light, which generates a very good, tight weld seam – even at a feed rate of one meter per second.

Since manufacturers are increasingly using polymer-based compound bipolar plates, Fraunhofer ILT has developed a two-stage process for building stacks: A CO_2 laser cuts and a diode laser welds. In addition, the institute developed a process to selectively remove the plastic film on the compound BPP surface that arises during production using an ultrashort pulse laser. The USP laser is a good alternative to the grinding process commonly used today because it significantly reduces the electrical resistance between BPP and MEA compared with the conventional mechanical process, thus increasing the efficiency of the fuel cell.

Start of the Battery Lab

Due to the growing importance of battery technology, Fraunhofer ILT is particularly intensifying its research into laser processes in battery production. In 2020, the Battery Lab began operations for this purpose, providing a wide variety of facilities for the laser-based production of current lithium-ion batteries and future solid-state accumulators.

Here, for example, researchers are working on integrating laser-based processes (drying and structuring) into the continuously running process of a roll-to-roll system. The integrated, laser-based drying and structuring of active materials (anode and cathode foils) can be used to optimize important properties of lithium-ion cells such as capacity, fast-charging capability and service life. At the end of 2020, Fraunhofer ILT commissioned a facility that now rounds off the Aachen Battery Lab.

Blue laser with ring optics shortens welding process

Copper and aluminum perform an important task in batteries: Welded-on conductors made of these materials connect cells to form modules; several modules ultimately form battery packs. However, infrared lasers are often not ideal for welding aluminum and copper contacts because of their typically low absorption rates.

Instead, green and blue lasers are now being used. For blue lasers, Fraunhofer ILT scientists have developed a ring optical system for a wide range of cell diameters: This system can be continuously adjusted so that the annular laser beam can be precisely adapted to different cell types. A special feature of this system is that the complete laser weld is achieved in a single »shot«, so to speak, and thus in much less time than is possible with conventional methods.

The demands on the R&D activities for electromobility of Fraunhofer ILT and its partners will certainly continue to increase. This was also evident at the virtual premiere of the Laser Colloquium Hydrogen LKH_2 with 55 participants and 10 renowned speakers from industry and research. Thanks to its recent investments, Fraunhofer ILT is already well equipped to meet the new challenges.

Selected research results
Mobility: pages 51, 52, 60, 63 to 65 and 67.

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

PRODUCTION
LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY

ADDITIVE MANUFACTURING FOR CREATIVE FREEDOM IN PRODUCTION

Innovation in production succeeds when there is a balanced interplay between excellent research and application-oriented development. This is the competence of the Fraunhofer-Gesellschaft that ensures added value for its industrial partners; numerous project results with integrated solutions for the production of tomorrow prove this. For example, the Fraunhofer ILT's projects in additive manufacturing (AM) inspire SMEs and corporate strategists to take completely new paths in production.

Laser material deposition – a promising process

Metallic 3D printing plays a major role in the innovative city of Aachen. Fraunhofer ILT has been working for many years on various AM methods, their automation and the associated digital processes, including, for example, laser material deposition (LMD), which many industrial companies use for coating and repairing or servicing components. The process uses resources efficiently as feeds material to the laser both precisely and selectively. At the same time, very large components can be processed with suitable system technology. From the point of view of production experts, however, the promising process has often been insufficiently user-friendly and required cost-intensive system technology.

In ProLMD, a research project funded by the BMBF, Fraunhofer ILT and consortium partners together developed new hybrid processes that combine conventional manufacturing processes with laser material deposition to form an innovative manufacturing approach. This enables manufacturers to produce quickly and cost-effectively and can also be seamlessly integrated into existing process chains. An economical and robust system technology based on articulated robots was developed for the LMD process. The project partners researched various technologies necessary for robot-based hybrid additive manufacturing. They covered key aspects along the entire process chain – from machining heads, robotic and inert gas systems to welding processes, quality assurance and software.

Partnership development of hybrid additive manufacturing

The requirements of the ProLMD project partners for hybrid additive manufacturing were very different: MTU Aero Engines AG worked toward building up functional elements on an engine component. Component reinforcement by 3D ribbing was the objective for Airbus Defence and Space GmbH, and Mercedes-Benz AG wanted to optimize a press tool in car body production. The project focused on the local reinforcement or modification of conventionally manufactured large components. The tasks were clearly defined within the consortium: The Lasertec division of KUKA Industries GmbH & Co. KG in Würselen was responsible for project management and cell integration of the robot, while Laserline GmbH from Mülheim-Kärlich took care of the design and development of the beam source and optics. M.Braun Inertgas-Systeme GmbH in Garching was responsible for the construction of an inert gas cell, while BCT Steuerungs- und DV-Systeme GmbH in Dortmund developed the software and system-integrated measurement technology. The common goal was to develop a highly efficient, modular LMD cell that could be integrated into an existing process chain with little effort.

The completed research project was a great success since all the partners involved cooperated very closely. While project leader KUKA in Würselen had the robot weld oxidation-sensitive materials such as titanium in a flexible shielding gas cell safely, Fraunhofer ILT scientists worked with two other robot systems without a shielding gas cell. The findings from the respective approaches provided valuable impetus for the overall process and system development.

In addition to the robot systems for large components set up in the project, the partners were able to design a more compact ProLMD robot system with support from the German Federal Ministry of Education and Research BMBF and put it into operation at Fraunhofer ILT. It is intended for small and medium-sized enterprises (SMEs) and costs significantly less than a standard machining center. The robot cells with ProLMD technology will thereby also be available for applied research at Fraunhofer ILT in the future.

Next generation additive manufacturing – Collaboration in the Fraunhofer Group

Robot-assisted laser cladding of large metallic components in the joint project ProLMD is just one aspect of the Fraunhofer ILT's application-oriented work.

In the Fraunhofer lighthouse project »futureAM – Next Generation Additive Manufacturing«, which has also been completed, Fraunhofer ILT and five other Fraunhofer institutes demonstrated that the additive manufacturing of metal components can be accelerated by a factor of at least ten. Together, the Fraunhofer Institutes IWS, IWU, IAPT, IGD and IFAM, under the leadership of Fraunhofer ILT, increased the performance and economic efficiency of metal additive manufacturing along the entire process chain, from order entry to the finished metal 3D printed component. The Virtual Lab, in which competencies are digitally bundled, played a relevant role. The entire AM process can thus be made transparent for all partners involved.

High speed metallic 3D printing

A demonstrator component for the aircraft industry showed how advanced additive manufacturing development has become; this component was created on a system developed by Fraunhofer ILT as part of the futureAM lighthouse project. A new machine system with mobile optics uses laser powder bed fusion (LPBF) to produce a large demonstrator component for future generations of Rolls-Royce engines in an XXL build space (1000 mm x 800 mm x 400 mm).

The researchers at Fraunhofer ILT take an integrated approach to all their AM projects. In the field of metal AM, a number of cornerstones were laid at Fraunhofer ILT over 30 years ago which, thanks to systematic further development, have now grown to industrial maturity.

Selected research results
Production: pages 37, 48–69, 74–76, 83, 84, 86, 90–94 and 100.
Additive Manufacturing: pages 48–57, 74–76 and 92.

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

DIGITALIZATION
LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY

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UNLEASHING POTENTIAL IN PRODUCTION WITH DIGITALIZATION

We can learn how to deal with catastrophes by looking at the Chinese character for crisis: It is made up of the symbols for danger and opportunity. The current corona pandemic, for example, provides us with the opportunity to implement digitalization strategies at an accelerated pace. For manufacturing companies, digital innovations open the way to greater efficiency. Despite declining quantities and a lack of skilled workers, components can be processed at a high standard.

The reliability and predictability of many manufacturing processes, as well as their speed or resource efficiency, can be optimized by using suitable digitalization tools. Scientists at Fraunhofer ILT have been using digital technologies for years and conducted multifaceted research in this field. The institute has invested in developing new IT infrastructure and can advise and support companies in their digital transformation with state-of-the-art equipment.

Optimizing processes with digital twins

The experts from the technology focus Digitalization start with assessing processes at the customer's site: Together with the company, they analyze the task as part of a self-developed startup package in order to then tackle implementing it along the entire process chain – from design to construction and production to delivery.

This digital transformation requires a very precise analysis of the data in order to proactively manage plants and machines. The introduction of digital twins, which help to reduce costs and optimize processes, has proven its worth.

Sights set on the digital future: »Digital Light Factory«

The strategic thread running through Fraunhofer ILT's work is to provide a self-developed infrastructure: Its »Digital Light Factory« encompasses the manufacturing technology with all necessary control and automation interfaces. From integration to start-up testing, it offers companies an infrastructure that largely maps subsequent production conditions. Numerous Fraunhofer ILT building blocks from automation, simulation to sensor technology allow the institute and its partners to integrate additional solutions. The spectrum ranges from establishing process chains to evaluating how existing system solutions can be transferred to new fields of application.

A relevant, but still rarely used tool of digitalization is artificial intelligence, and yet a survey conducted by the German Economic Institute in 2019 revealed that only one in ten companies uses AI. The pioneers use AI systems primarily in quality assurance and predictive maintenance: for example, to predict an expected process deviation. The technology has proven itself, among others, for laser welding in automotive manufacturing or laser-based microjoining. In combination with image-based monitoring, AI systems can analyze weld seams in real time and reliably classify the seam quality using adapted algorithms.

»Learning by doing« in the AI Lab

Small and medium-sized enterprises (SMEs), in particular, find it difficult to get started because the effort required to develop and adapt AI processes is often high. Scientists at Fraunhofer ILT understand this barrier and have been working on AI for years. For this reason, an AI lab was created in which users can experiment with their own data on the basis of prepared modules: Through »learning by doing«, they receive an explanation of the results that is understandable even to AI laypersons, which helps them make well-founded decisions. They also learn in the AI lab how the behavior of production systems can be reliably predicted.

The Fraunhofer ILT's Process Sensors and Systems Engineering group is also active in this field, using machine learning to investigate how AI-based quality predictions can be achieved with high confidence in order to reliably detect defects in laser welding. An example from consulting practice: A company had 50,000 measurement signals from laser welds interpreted by machine learning. Although the signals showed hardly any perceptible differences when viewed manually, a hit rate of 70 to 80 percent in detecting process deviations based on the individual measurement signals was achieved. This occurred since the system took several signal characteristics into account when making its decisions. The decisive factor in this solution was the choice of the right AI tool and the appropriate algorithm.

Layer by layer: AI system checks 3D printing

AI methods are also helpful in optimizing manufacturing processes in the field of additive manufacturing: Fraunhofer ILT recently developed a process monitoring system for metallic 3D printing in which AI methods are also applied in image processing. It is designed to evaluate the quality of each individual layer based on irregularities in typical surface parameters such as roughness or impermissible shape deviations. This is followed by automated evaluation of the signals. To this end, the system will be enabled to warn the 3D printer in good time of impending deviations and to suggest suitable corrective measures in the form of adjusted process parameters.

These two practical examples show how much preliminary work and thought is required when AI systems are applied. In the AI Lab, potential users can experiment in joint projects with Fraunhofer ILT in this area and deepen their understanding of processes. They learn where the limits of AI lie and that there is always a residual risk, which can, however, be mathematically evaluated and taken into account. This knowledge can constitute a significant competitive advantage.

Selected research results

Digitalization: pages 36, 54, 67–69, 80, 81, 83–85 and 90–95

Further information on the Internet at:

www.ilt.fraunhofer.de/en.html

HEALTH

LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY

TRANSPORTING CELLS AUTOMATICALLY WITH THE LASER

The corona pandemic has shaped the year 2020, making the rapid development of tests and vaccines an issue of global importance. A crucial factor here is the automation of test procedures to ensure that a large number of samples can be analyzed in the shortest possible time. Laser-based methods offer great potential for automation in the laboratory: They can stimulate the emission of a spectroscopic »fingerprint« or even transport the living cell without contacting it.

In this area, the Fraunhofer-Gesellschaft is specifically promoting market-oriented preliminary research in the OptisCell project. In addition to Fraunhofer ILT, two other Fraunhofer institutes – for Applied Information Technology FIT in Sankt Augustin and for Interfacial Engineering and Biotechnology IGB in Stuttgart – are also involved. Biologists, computer scientists and laser experts from the three institutes have jointly developed a process that can detect, analyze and sort living cells and biomaterials automatically. They are focusing on an automated process chain in which the cells can be analyzed using optical methods such as microscopy and Raman spectroscopy and be transported without contact with a laser.

Marker-free analysis with artificial intelligence

With the laser, samples can be analyzed without the addition of dyes – in other words, free of markers. This is made possible by Raman spectroscopy, in which a biological sample is irradiated with laser light. The spectrum of the light scattered by the sample forms an optical fingerprint that contains a great deal of information about the sample's composition. The method also allows individual cells to be examined microscopically. The data thus obtained is further processed on the digital platform. With machine learning and artificial intelligence, completely new ways of analysis will then be possible.

LIFT: Laser-induced transfer of living cells

In the laser-induced transfer plant, the sample is first analyzed optically. For example, cells that produce a specific protein can be identified in this way. In a second step, these cells are transferred by laser to a commercially available microtiter plate. Laser-induced forward transfer (LIFT) is the name of the process in which a thin absorber layer, mainly of water, is vaporized on the carrier with a laser pulse. The small vapor bubble generates a jet that transfers a small amount of liquid together with the selected cell to a microtiter plate on the opposite side. A laser in the mid-infrared range is used for this purpose so that metal layers are no longer necessary for laser absorption.

Developing drugs cost-effectively and efficiently

The automated OptisCell process shortens cell line development time by identifying, isolating and selecting cells directly in one facility. The simple integration of LIFTSYS® into almost any biological workbench provides the health industry with a fast and efficient alternative to conventional methods for precise, cell-preserving and contact-free cell sorting. The cells can subsequently be used for the production of monoclonal cell lines.

Another important aspect is the resource-saving handling of the samples: Unlike in titration systems, there is no dead volume, and the LIFT process can be adjusted with extreme precision.

Automation for pharmaceutical research

One area where LIFT can be applied is medical and pharmaceutical research. For the production of active pharmaceutical ingredients, the process promises a significantly shortened process chain for manufacturing biologics – i.e., proteins made by cells – which are becoming increasingly important in drug production. At Fraunhofer ILT, the LIFTSYS® technology is being continuously developed. Our main focus is on customer orientation: How can the system be optimally adapted to existing processes or best integrated into existing process chains?

Printing test organs in the future

A look into the future opens up a number of other possibilities: Via laser-induced cell transport, tissue-like structures can be built from living cells with the long-term goal of printing perfused organ structures and eventually entire organs.

Selected research results
Medical technology: pages 39 and 72–76.

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

ENVIRONMENT

LASER TECHNOLOGY SOLUTIONS FOR INDUSTRY AND SOCIETY

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CLEAN WATER THROUGH HIGH-TECH FILTERS

Three of the United Nations' Sustainable Development Goals assume there is an adequate supply of clean water. But even in highly developed industrial nations, water is threatened by microplastics because conventional filters in use today cannot retain all plastic particles. In the SimConDrill project, a technology has now been developed that can efficiently filter out – with tiny laser-drilled holes – even the smallest particles from the wastewater of our major cities.

Microplastics: these are plastic particles smaller than five millimeters. Often they are much smaller and barely visible to the naked eye. Microscopic particles from peelings, toothpaste or hand washing products are just as much a part of this as is the abrasion from car tires. The latter already counts as secondary microplastics, since it is first formed from larger particles. Secondary microplastics are also produced during washing – up to 2,000 synthetic fibers from fleece garments, says the German Federal Environment Agency, enter the marine environment via flowing waters per wash cycle. Normal sewage treatment plants cannot retain them.

Breaking new ground in wastewater treatment

The German Federal Ministry of Education and Research BMBF has been funding the SimConDrill research project since 2019, in which five project partners from industry and research are jointly developing a water filter for microplastics. Klaas-Filter GmbH, in particular, has a great deal of experience with wastewater treatment; this project partner has been developing special cyclone filters for years, even for large volumes of liquid. In such a system, the contaminated liquid is separated by a cyclically applied pressure differential profile at the filter surface, which is generated by means of a revolving rotor. Solid components are retained and discharged. At the front of the rotor, contaminated water is forced against the filter surface and, after passing through the rotor, retained particles are lifted from the filter by suction caused by the rotor. How fine the filter works depends on the size of the holes drilled.

This is where the Fraunhofer Institute for Laser Technology ILT and LaserJob GmbH come in. Together, they have developed a technology for using a laser to efficiently drilling holes into the metal foils in the cyclone filters. In order to efficiently remove even small particles, holes with a diameter of less than 10 micrometers are drilled in large numbers into the metal foils, which are almost 10 to 20 times thicker. The challenges here are considerable: For a lot of water to flow through the filters, the number and density of the holes must be as large as possible.

Award winning technology

Laser systems with ultrashort pulses in the femtosecond range are particularly suitable for such drilling tasks as they can remove material very precisely down into the micrometer range. In addition, the laser source should have the highest possible maximum pulse energy so that the actual processing speed is as high as possible. Another key innovation developed at Fraunhofer ILT helps to increase the processing speed: the multi-beam process. In this process, a laser beam is split into many similar partial beams by means of special optics, making it possible to drill more than 100 holes simultaneously in parallel, which significantly increases the processing speed. In October 2020, the ILT researchers and the four industrial partners in the MultiSurf joint project received the Science Award of the Stifterverband für Verbundforschung (a donors' association for collaborative research) for the development of a technology that also allows the partial beams to be controlled separately.

Multibeam technology, however, requires that more than one beam matrix move across the material surface. The hundredfold energy input in such a small space would melt the metal foil. In order to coordinate all process parameters as well as possible and select suitable processing strategies, the researchers in the SimConDrill project are combining a process simulation developed at Fraunhofer ILT and optimization software from OptiY GmbH. In addition, a measurement system developed jointly with Lunovu GmbH finally guarantees quality assurance of the laser drilling process to ensure that all holes are drilled through and that the water throughput is not reduced.

Series production for various applications

The SimConDrill research project is initially scheduled to run until June 2021. Holes with a diameter of 10 micrometers can already be drilled in metal foils 200 micrometers thick. In a next step, the final prototype is to be manufactured and its function validated using test fluids.

In the future, there will be a number of different possible applications. Although the filter module is being developed and tested for wastewater treatment plants, mobile applications for industrial wastewater or in private households are also conceivable. The purification of ballast water also offers great potential. A rotor ensures that the SimConDrill filter does not become clogged and is, therefore, not disposable. The separated microplastics can be fed out of the cyclone filter and then recycled or disposed of properly. The SimConDrill project, thus, provides society with a new and sustainable solution to the microplastic pollution in our wastewater

Selected research results
Environment: pages 40, 45, 58, 80 and 81.
Science Award of the Donors' Association: page 15.

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

QUANTUM TECHNOLOGY

LASER TECHNOLOGY SOLUTIONS
FOR INDUSTRY AND SOCIETY

PHOTON SOURCES AND OPTICAL COMPONENTS FOR NEW QUANTUM TECHNOLOGIES

Photonics is a key for novel applications based on quantum technology, for example, in quantum computers, quantum internet or quantum metrology. Together with top German and international researchers, Fraunhofer ILT scientists are developing a broad portfolio of solutions for new quantum technologies, which – in addition to lasers and fiber technology – include parametric photon sources and frequency converters as well as integrated optical components and packaging processes.

Within the so-called second quantum revolution, new technologies are being developed that exploit fundamental properties of quantum physics. The requirements for precision, complexity, individuality or compactness of system components are very high, and solutions are needed that can later be implemented on an industrial scale.

In this context, Fraunhofer ILT scientists are researching quantum physical effects and how they can be used for novel applications. They are developing not only lasers, laser-based processes and process technology as a basis for producing quantum materials and components, but also the configuration and hardware for quantum systems. This includes waveguides, couplers and filters as well as single photon and photon pair sources with high signal-to-noise ratios and frequency converters that preserve quantum properties. Close cooperation with, among others, the chairs for Laser Technology LLT and for Technology of Optical Systems TOS at RWTH Aachen University provides a fundamental understanding of the underlying interaction effects, which is necessary for precise control of quantum states. In addition, there are long-term collaborations, for instance, with the Forschungszentrum Jülich or the Dutch research center QuTech.

Quantum Imaging

Imaging with previously unused wavelengths is interesting, e.g., for biology, medicine or metrology: In quantum imaging, non-classical photon states are used to overcome the limits of current sensor technology. Among others, wavelengths in the mid-infrared (MIR) - the so-called »fingerprint region« – are of interest, where many substances exhibit characteristic absorption lines, but suitable detectors are technically complex and limited by low sensitivity. The use of entangled photon pairs now enables the separation of interaction and detection wavelengths. One photon of the pair interacts with a sample, while the other is detected but reveals information about the interaction of its partner. In this way, highly sensitive silicon detectors can be used to evaluate the image information.

Fraunhofer ILT develops parametric photon sources for imaging applications in the MIR range. These sources use periodically poled crystals pumped with semiconductor disk lasers at 532 nm, for example, which already generate measurement wavelengths in the range of 1.5 to 4.5 µm and about 100,000,000 entangled photon pairs per second. These photon sources can be used as an imaging system in an interferometer setup. The next step is to develop methods for image acquisition with optimized imaging quality.

Fraunhofer ILT is also working on new solutions for production metrology. Here, optical coherence tomography (OCT) is combined with quantum imaging – of particular interest to researchers looking for imaging solutions in production technology. In the process, the OCT method can be integrated into a quantum interferometer, e.g., for the detection of internal defects and volume properties.

Quantum computing and quantum internet

Quantum computers make it possible for us to perform highly complex calculations in the shortest possible time and also to revolutionize information technology. In the future, several quantum computers can be securely connected in a quantum internet, enabling users to exploit new technologies such as distributed quantum computing.

In the DFG-funded Cluster of Excellence »Matter and Light for Quantum Computing« (ML4Q), Fraunhofer ILT is working together with other research institutions from the German state of North Rhine-Westphalia on technologies for quantum computers. Their long-term goal is to create architectures in which fault-tolerant quantum computers are implemented in a modular fashion and photonically coupled. Intrinsically, the qubits used in this process emit and absorb photons with different wavelengths. Among other things, quantum frequency converters (QFC) are needed for the connection, which transfer the wavelengths of different qubits into each other.

Fraunhofer ILT is also focusing on the development of efficient and low-noise QFCs to connect qubits to the optical telecom band, which will allow quantum computers to be connected in long-range fiber optic networks in the future. The target wavelengths for low-loss transmission are in the range between 1500 and 1600 nm.

Fraunhofer ILT is developing such converters as part of the Fraunhofer ICON project »QFC-4-1QID«. These are key components for the demonstration of the first quantum internet, for which qubits will be connected by optical fibers in Delft, Leiden, The Hague and Amsterdam in 2022.

Integrated quantum photonics

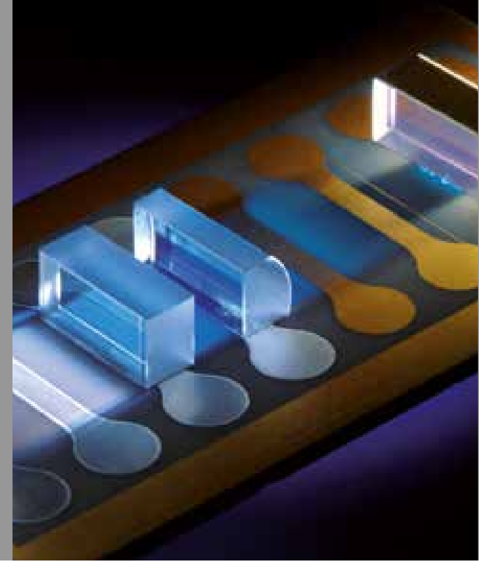
Laser-based processing methods – including micro- and nanostructuring with ultrashort pulse lasers (USP lasers) or selective laser-induced etching (SLE) – are used at Fraunhofer ILT to create structures and components for the field of integrated quantum photonics. The surfaces or material volumes of materials such as diamond, silicon carbide, gallium arsenide or lithium niobate can be selectively processed by laser at a high spatial precision of less than one micrometer.

Surface structures or integrated structures based on lithium niobate, for example, are produced for corresponding circuits. For optimized guiding properties, the surface roughness must be minimized so that scattering effects play a negligible role in guiding visible or infrared light. Communication between qubits can be achieved via microscopically dimensioned waveguide structures, which are written in semiconductor material using USP lasers via local refractive index changes.

Selected research results
Quantum Technology: pages 41, 42 and 98–100.

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, quantum technlology 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.

TECHNOLOGY FOCUS

DIGITALIZATION

The technology focus Digitalization is closely linked to the activities of the technology focuses Laser and Optics, Laser Material Processing, Medical Technology and Biophotonics as well as Laser Measurement and EUV Technology. It combines competencies in digital production around laser technologies: from design-to-production, digital twin and smart simulation to fog and edge computing. The comprehensive view of processes and procedures – from modeling to data integration – is a core component of the technology focus of digitalization.

The services offered in »Design to Production« include closed workflows, which are recorded completely digitally. This ensures transparent, secure and versioned documentation and handling of data. The services offered under »Digital Twin« comprise virtual models of processes with which the real data of the processes can be systematically collected and analyzed. Influencing factors can be easily identified and cause-effect relationships demonstrated without intervening in the real process.

The »Artificial Intelligence (AI) Lab« provides space for experimenting with machine learning and neural networks. The results are presented to users in a comprehensible way via visualization environments. The »Digital Light Factory« provides them with an individual and isolated development and production environment. At its core, it comprises the production technology with all desired control and automation interfaces.

QUANTUM TECHNOLOGY

Modern communication and the internet would not be possible without the first generation of quantum technologies. Now a paradigm shift is imminent, one that will enable further development towards quantum computers and the quantum internet. Whereas collective particle phenomena were in the foreground of quantum developments, researchers are currently able to manipulate and control individual photons and quantum states in a selective manner.

Together with top international researchers, scientists at Fraunhofer ILT are developing photonic solutions for quantum technology tasks. In particular, beam sources with tailored properties and precise assembly technologies for optical components and systems are of great interest for quantum technology. For example, the Aachen engineers are optimizing single photon sources with very high signal-to-noise ratios and realizing waveguides, couplers and filters in glasses and crystals for quantum imaging and fingerprint spectroscopy. They are also focusing their research on quantum frequency converters for connecting qubits to fiber optic networks, which will allow quantum computers to be connected in networks in the future.

At the Aachen location, the proximity between Fraunhofer ILT, RWTH Aachen University and Forschungszentrum Jülich ensures there is a fruitful exchange of know-how and technology. Regional and international collaborations are paving the way for research to technically implement Quantum Technologies 2.0.

FUNDING BODIES

Some joint projects presented in this annual report have been supported with public funding. We would like to express our gratitude to the public donors for their support at this point.

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Energie

Die Landesregierung Nordrhein-Westfalen

EUROPÄISCHE UNION

EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds für regionale Entwicklung

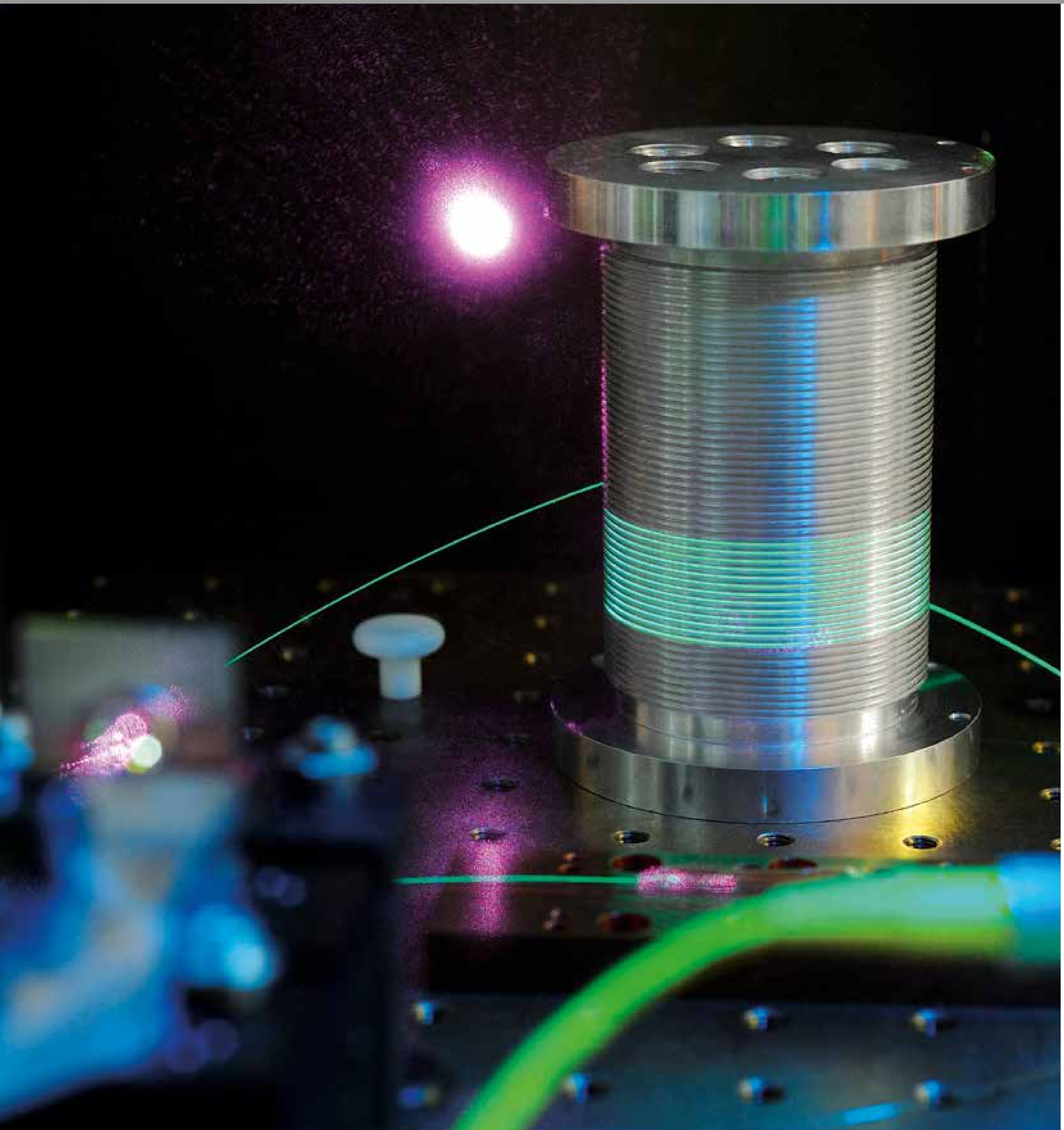
DFG Deutsche Forschungsgemeinschaft

EFRE.NRW Investitionen in Wachstum und Beschäftigung

eit RawMaterials Connecting matters

esa European Space Agency

LASERS AND OPTICS



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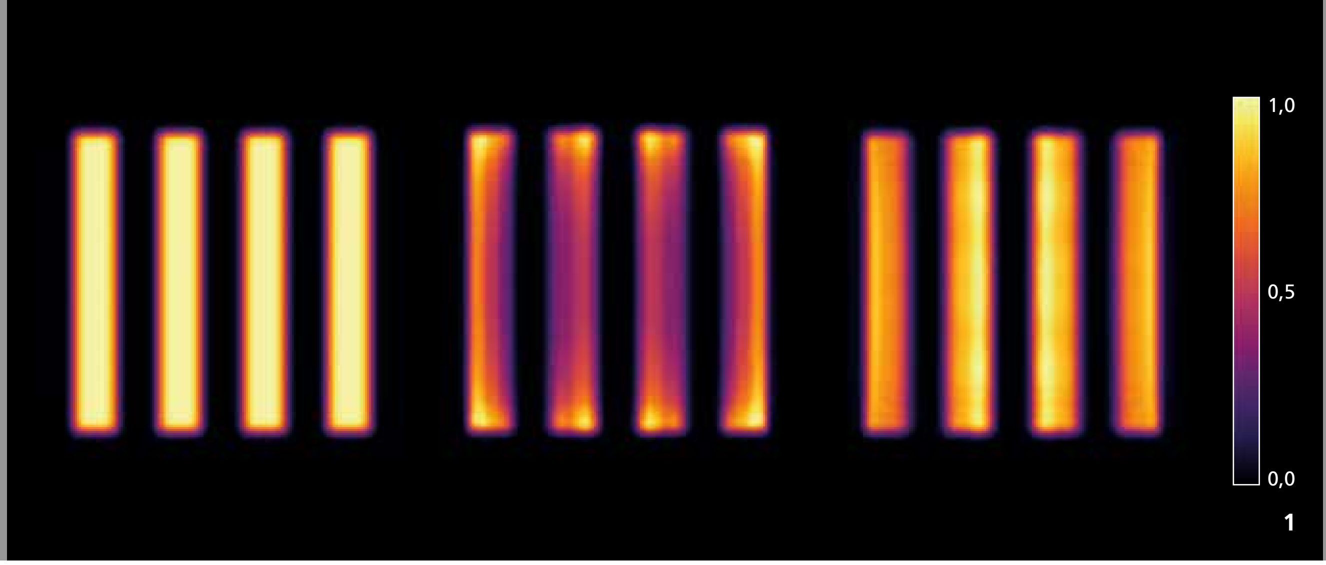

PROCESS-ADAPTED POWER-DENSITY DISTRIBUTIONS THROUGH DYNAMIC LASER-BEAM SHAPING AND AMPLIFICATION

Task

As an essential process parameter, the power density distribution (PDD) of the laser beam significantly influences the machining results of laser-based processes. In particular, process-adapted PDDs enable a distinct increase in machining speed and quality. However, changes in the process parameters or in the local geometry of the workpiece often require a dynamic adaptation of the PDD, e.g. in order to achieve constant machining results.

Method

In dynamic laser-beam shaping for laser materials processing, there is a trade-off between the required laser power and the required number of degrees of freedom. Dynamic beam-shaping elements such as Liquid Crystal on Silicon (LCoS) and Digital Micromirror Devices (DMD), each with a sufficiently high number of degrees of freedom (>> 100), have been limited to laser powers less than 200 W so far. To circumvent this trade-off, a laser beam can first be shaped at low laser powers and then amplified to the target power. However, nonlinear effects in optical amplifiers usually lead to a significant change of the PDD in the amplifier and in the target plane. By simulatively and/or metrologically accounting for these changes, Fraunhofer ILT – in cooperation with the Chair for Technology of Optical Systems (TOS) at RWTH Aachen University – has been able to iteratively adjust the PDD in the target plane until the target PPD is achieved. Moreover, influence of any number of other optical elements can also be taken into account and compensated for.

Results

The approach that scientists at ILT and TOS have developed accounts for nonlinear effects, thus enabling the industry to use modern, highly dynamic beam shaping elements for applications whose required laser power is far above the damage thresholds of these beam-shaping elements. The approach and the software tools it has developed can be applied to almost any amplifier geometry and optical system.

Applications

Now that highly dynamic laser-beam shaping is possible even at high laser powers (> 200 W), the institute has created the foundation for increasing productivity and/or quality of a variety of laser-based processes.

The work has been funded by the German Research Foundation (DFG).

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1 Examples of target PDD (left) and the PDD after passing through an ideal amplifier without (center) and with (right) compensation of nonlinear effects. All PDDs are normalized.

BEAM GUIDANCE SYSTEM FOR HIGH-POWER ULTRASHORT-PULSE LASERS IN THE CAPS USER FACILITY

Task

In the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS, researchers are investigating applications that require an economical use of ultrashort laser pulses (UKP) with a high peak power and at the same time a high average power. Such laser systems can be used in material processing and for the generation of coherent radiation in the XUV range. In the CAPS User Facility, the laser radiation is to be switched and routed from two laser sources to three user laboratories. For reasons of laser safety and to protect the optical systems at extreme laser powers, this is only possible in a sealed beam path. Both heating and ablation processes from scattered radiation must be suppressed as far as possible.

Method

The CAPS User Facility provides users with a commercially available 1 kW ultrashort-pulse (UKP) source and an experimental UKP source with up to 10 kW average power at pulse powers up to several 100 GW. The beam distribution system currently directs laser radiation from these sources to two user laboratories. Both on the beam source side and on the user side, changes can be made at short notice within the scope of the experimental task. Moving mirrors can be used to switch between the beam sources on the input side and the exit port on the user side. The beam guidance takes place inside a sealed mirror system, which ensures that the laser operates safely and the beam quality is not disturbed by air fluctuations. To prevent ablations caused by stray light, an inner lining made of glass is used, which is surrounded by an outer metal encasing. Since the laser radiation has to cross escape routes, the corresponding parts of the encasing can be detached; if the encasing system is opened, the beam source is automatically switched off.

Results

In the CAPS User Facilities, UKP processes can be evaluated with two different beam sources. The facility makes available average powers in the kW range and a maximum pulse energy of about 10 mJ.

Applications

The developed beam distribution system can be used wherever a switchable beam routing between separated beam sources and applications is required or desired.

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2 Partially opened pipework of the beam guide.

1 *Detailed view of the amplifier platform.*

YTTERBIUM-INNOSLAB-ULTRA-SHORT-PULSE AMPLIFIER PLATFORM FOR MULTI-KW-OUTPUT POWERS

Task

Ultrashort-pulse (UKP) laser sources based on Yb:YAG as active medium currently achieve output powers of around 1 kW. Scaling the output power by up to one order of magnitude promises to open up new applications.

Method

The existing Ytterbium-INNOSLAB amplifier platform developed by Fraunhofer ILT is designed for approx. 500 W extracted power per amplifier stage and achieves output powers greater than 1 kW by cascading two stages. The institute is developing a completely new amplifier platform designed for greater than 1500 W of extracted power per amplifier stage. By cascading these amplifier stages, Fraunhofer ILT intends to achieve output powers of up to 5 kW.

Results

Essential core components of the INNOSLAB amplifier architecture have been fundamentally redesigned or refined:

- A new modular pumping arrangement developed and patented by Fraunhofer ILT was used, in which the radiation from up to six modules is geometrically superimposed in the crystal.
- The slab crystal package was adapted for the increased output power, and the soldering technology required for thermal contacting was successfully refined.
- Arrangements for high-gain operation of the amplifier modules, enabling output powers greater than 1.5 kW at seed powers less than 50 W, have been designed, simulated, and are undergoing experimental testing.

Applications

The scaled UKP laser parameters show great promise for applications in high-throughput microstructuring, for example in the field of electromobility, as well as in laser-driven generation of secondary radiation.

The R&D project underlying this report has been funded within the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS. The laser source is made available to partners from industry and research in the CAPS application infrastructure for them to run application studies and experiments.

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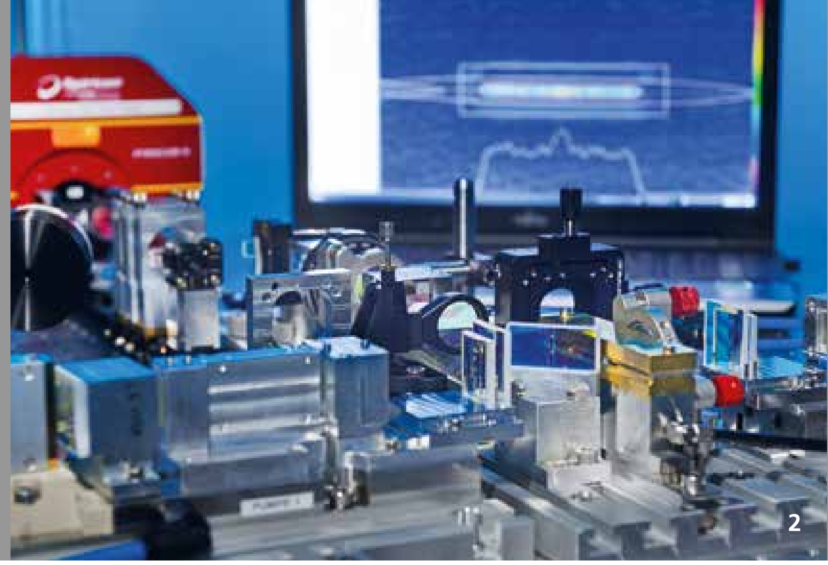

2 *Q-switched 1.9 µm INNOSLAB oscillator.*

Q-SWITCHED INNOSLAB LASER OSCILLATOR AT 1.9 µM EMISSION WAVELENGTH

Task

Within the Fraunhofer Max Planck cooperation project DIVESPOT, the partners are developing pulsed laser beam sources, among others, that emit in the near infrared (IR-B) at wavelengths from 1.9 to 2.9 µm. Short high-energy laser pulses at 1.9 µm are used for efficient optical pumping of the Cr:ZnSe gain medium. These are necessary because the luminescence lifetime of Cr:ZnSe at room temperature is only a few µs.

Method

The pulsed pump light radiation with a wavelength of 1.9 µm is generated with a Q-switched solid-state laser. Here, an INNOSLAB laser oscillator with Tm:YLF is used as the gain medium. For this purpose, an adapted oscillator design with resonator-internal lens was developed, a design that allows the use of an acousto-optic modulator as a Q-switch. The slab-shaped laser crystal was installed into an optimized heat sink by means of a soldering process to achieve very good and homogeneous heat dissipation. The Tm:YLF laser medium is pumped on both sides with high-brilliance laser stacks at 793 nm.

Results

Fraunhofer ILT built a Q-switched INNOSLAB oscillator, emitting at a wavelength of 1.9 µm. A pulse energy of more than 30 mJ was achieved at a pulse repetition rate of 1 kHz. At a repetition rate of 3 kHz, 22 mJ was generated, corresponding to an average optical output power of 66 W. The optical-optical efficiency was up to 20 percent. The pulse length was just under 600 ns. The beam profile had a top hat distribution ($M^2 \sim 200$) in one beam axis and a Gaussian distribution ($M^2 \sim 1.3$) in the beam axis orthogonal to the first beam.

Applications

This laser-beam source is suitable for optical pumping the Cr:ZnSe amplification medium thanks to its beam distribution, especially for slab-shaped amplifiers. Due to the high absorption of laser radiation at 1.9 µm in water, the laser beam source lends itself to processing hard and soft tissue in medical technology. After the beam profile is symmetrized, low-loss transport fibers can be used for beam transport and, thus, can easily be integrated into processing systems.

The DIVESPOT project was funded by the Fraunhofer-Max Planck Cooperation Program.

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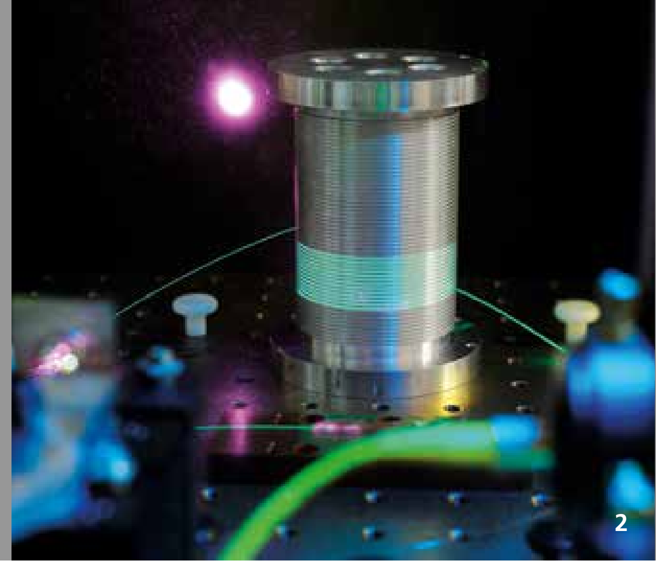

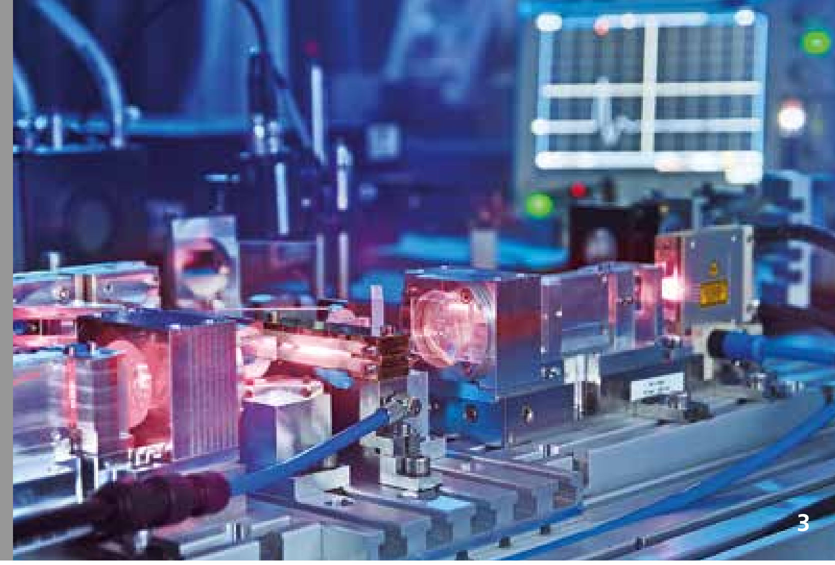

CAVITY LENGTH CONTROL FOR FREQUENCY STABILIZATION OF LASER OSCILLATORS

Task

Detection of gases by LIDAR processes generally requires laser-beam sources which have high demands placed on their spectral characteristics. For airborne and satellite-based LIDAR instruments, pulsed oscillator-amplifier arrays (MOPA) are often used, which emit narrowband light pulses with high frequency stability. For this application, the oscillator in particular must be stabilized since it essentially determines the spectral characteristics of the MOPA. This is done by means of coupling it to a highly stable, narrowband seed laser, which requires resonator length control with accuracies lower than 100 nm. Vibration loads during flight operations pose a particular challenge.

Method

In cooperation with the company Beratron GmbH, Fraunhofer ILT developed electronic circuits for several control processes:

- Classic Ramp Fire.
- Spectral and temporal stabilization of two spatially superimposed MOPAs with fixed temporal pulse spacing using ramp fire.
- Ramp-Delay-Fire for time synchronization of the stabilized oscillator to an external signal.
- Cavity Dither for piezo-protective control of a satellite-based oscillator.

Depending on the environmental conditions and requirements, the institute has successfully employed the Pulse Build-Up Time process and the Pound-Drever-Hall process in other applications.

Results

Lasers stabilized with the Ramp-Fire process have been successfully used in aircraft and helicopter flight operations. The Ramp-Delay-Fire process has been implemented on a laboratory scale under experimentally simulated flight conditions, as has the Cavity-Dither process, and is ready for use. Depending on the requirements, the most suitable process or a combination of several processes is used.

Applications

Fraunhofer ILT achieved and implemented the results presented here in a large number of publicly funded projects as well as bilateral industrial projects. Examples of applications include the detection of leaks in pipelines, the measurement of wind speeds, and the detection of greenhouse gases and water vapor in the atmosphere.

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1 Electronics for the various control processes.

400 W INNOSLAB AMPLIFIER FOR ULTRA-STABLE SINGLE FREQUENCY LASERS

Task

Ultrastable laser sources are used in precision interferometry. They currently achieve their highest precision in length measurement in gravitational wave detectors. One way to further improve the sensitivity of these detectors is to scale the power fed into the enhancement cavity of the interferometer.

The low-noise and narrow-bandwidth high-power beam sources currently used consist of a non-planar ring oscillator (NPRO) as seed source and a downstream multistage amplifier chain based on Nd:YVO_4 rod lasers. A four-stage amplifier chain and four more amplifier modules constitute the state of the art: The latter are optionally arranged as a linear amplifier or ring oscillator and reach an output power of up to 220 W.

The aim of the work presented here is to investigate if a single-stage INNOSLAB amplifier developed at Fraunhofer ILT is principally suitable, and to achieve power values in the range of several hundred watts with an input signal in the watt range. This is intended to demonstrate a simple and highly efficient alternative to the multi-rod systems currently in use and also to fiber laser systems.

Method

The output power of a narrowband, low-noise NPRO laser oscillator has been amplified to a power of several watts by a stabilized fiber laser amplifier developed at Fraunhofer ILT, providing the ultra-stable input signal. The power is amplified with a highly efficient in-band pumped Nd:YVO_4-INNOSLAB amplifier. The radiation propagates in seven optimized single passes through the bilaterally pumped Nd:YVO_4 crystal.

Results

With input powers between 1 W and 3 W, the INNOSLAB amplifier achieved an output power of more than 400 W with a high optical-optical efficiency of more than 45 percent. In a subsequent step, the noise behavior of the amplifier system will be investigated using active control of the amplifier's pump diodes for noise suppression.

Applications

In addition to use in precision interferometry, the values achieved are attractive for applications such as the cooling of atoms in atom traps or as a beam source for subsequent nonlinear frequency conversion as well as the coherent superposition of multiple beam sources.

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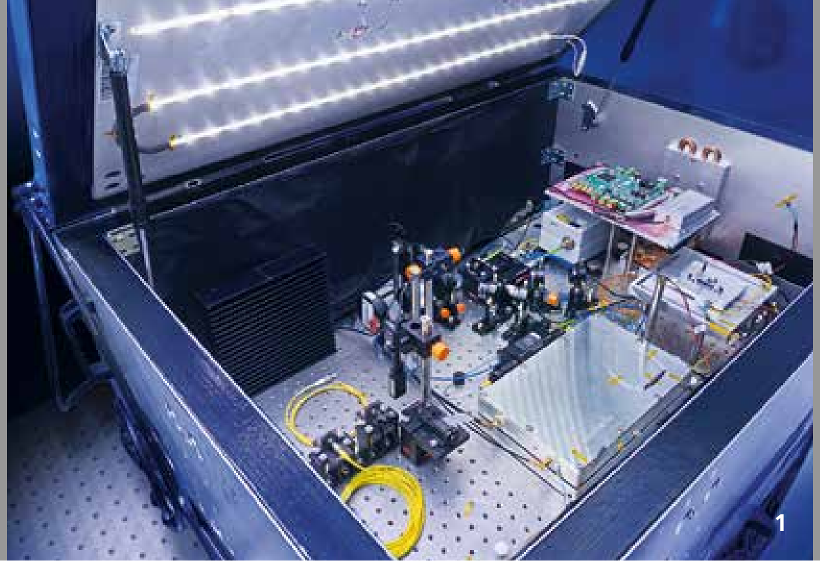
2 Highly stable single-frequency fiber amplifier with active fiber.

3 Single stage 400 W NdYVO_4 laser amplifier.



LISA – HIGHLY STABLE FIBER AMPLIFIER FOR GRAVITATIONAL WAVE DETECTION

Task

The future space-based gravitational wave detector LISA (Laser Interferometer Space Antenna) requires a narrow-band, linearly polarized and highly stable single-mode laser with an output power of greater than 2 W and phase modulation at ± 2.4 GHz around the central wavelength of 1064 nm. Within a project for the European Space Agency ESA as a study for the LISA mission, Fraunhofer ILT and its partners have initially developed and built a power-stabilized fiber amplifier with an output power greater than 2 W. Currently, the amplifier is to be revised and optimized with regard to power stability in the low frequency range, and the components installed are to be tested and qualified for use in a satellite.

Method

To minimize the amplified spontaneous emission (ASE) and its influence on the power stability of the system, Fraunhofer ILT redesigned the laser and built a two-stage fiber amplifier. Furthermore, it investigated in detail the laser's relative intensity noise (RIN) in the frequency range from 10^{-5} Hz to 10^{5} Hz and the necessary modulation of the sidebands. Due to the extremely high stability requirements, all thermal influences had to be minimized as far as possible during setup in the laboratory, making the thermal enclosure of both the laser itself and the measurement setup necessary.

Results

The highly stable fiber amplifier built at Fraunhofer ILT with a spectral linewidth below 10 kHz at 1064 nm generates an output power of more than 2 W. The power fraction based on nonlinear effects, especially stimulated Brillouin scattering (SBS) and ASE, has been minimized. In addition, a polarization extinction ratio of 25 dB and a very good beam quality M^2 of 1.1 have been achieved. In the entire frequency range, the amplifier fulfills the RIN requirement so that all required specifications could be demonstrated except for the phase sideband fidelity, which is still to be demonstrated in current investigations.

Applications

The highly stable and narrow-band fiber amplifier can be used for satellite-based gravitational field measurement, atom cooling and trapping, and communications applications, in addition to its use in space-based and earth-based gravitational wave detectors.

The work has been funded by the European Space Agency (ESA) under the reference number 4000119715/17/NL/BW.

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1 Thermal enclosure of the fiber amplifier and the measurement setup for stabilization.

DEVELOPMENT OF AN ULTRASONIC VACUUM SOLDERING FURNACE

Task

When optomechanical components are assembled – those that must satisfy strict requirements on thermal conductivity, robustness, long-term stability and freedom from outgassing – soldering technologies have advantages over adhesive bonding processes. Soldering technology can be used to great advantage in high-power lasers and laser systems for aerospace applications. Here, soldering of the components is currently carried out with previously applied intermediary layers under vacuum or inert gas atmosphere.

With ultrasonic soldering, the industry applies solder to materials that are difficult to wet without needing intermediary layers. To reduce the effort with intermediary layers, Fraunhofer ILT is to develop a furnace for soldering under a vacuum or inert gas atmosphere and with simultaneous ultrasonic support.

Method

To this end, the institute is testing vacuum-compatible geometries and materials for the mechanical and electrical ultrasonic components. They should permanently withstand temperatures of up to 250 °C, but still exhibit a uniform frequency response over the entire temperature range from 25 °C to at least 250 °C. In addition, materials for the furnace's heating units are being investigated which exhibit high thermal conductivity, low heat capacity and efficient conduction of the ultrasound into the optomechanical components.

Results

With the developed furnace, optomechanical components of approx. 100 x 50 x 100 mm³ (LxWxH) can be soldered at a maximum temperature of 350 °C at an accuracy of ±1 °C. Pressures down to 5 x 10^{-6} mbar or various inert gas atmospheres can be generated. The ultrasonic power is a maximum of 30 W and has a frequency resonance of 34 kHz with a stability of ± 0.8 Hz over the temperature range of 25 °C to 350 °C. The furnace enables most soft solders to be used thanks to its many setting options for temperature, pressure, atmosphere and ultrasonic power.

Applications

Uncoated crystals and optical components for solid-state lasers can be soldered using the newly developed furnace. This is followed by a comparative study of conventional and ultrasound-assisted bonds.

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2 Ultrasonic soldering of an optic.

ACTIVE SOLDERING PROCESS FOR RETARDATION PLATES

Task

Soldering processes are already being used today to mount optical components, especially in space applications, such as in the MERLIN project. In this context, active soldering is developing into a technology that can ensure a resilient connection of special optical components, such as retardation plates. Fraunhofer ILT has established methods in the field of packaging with which adjustable, highly stable holders for retardation plates can be produced.

Method

The active soldering process is used here to fix λ/2 or λ/4 retardation plates directly to a metallic counterpart. The soldering process does not require any complex pretreatment of the optical substrates, such as the application of adhesion-promoting coatings. Process steps such as applying flux or creating an evacuated environment to increase wetting of the joining partners with solder are also eliminated. In addition, processing can be carried out quickly without the aid of complex soldering systems. Optimized mechanical interfaces ultimately lead to a single component that can be integrated into an existing laser system. If necessary, such a component can be adjusted or even replaced.

Results

The active soldering process was used in combination with optimized mechanical interfaces to assemble retardation plates. Fraunhofer ILT checked the quality of the assembled phase plates using thermal and mechanical alternating loads. The observed stress states in the optical substrate remained within the acceptance range. No damage or misalignment of the retardation plates was observed.

Applications

The assembly of optical components is often limited by their mechanical properties or special geometry. The process developed at Fraunhofer ILT makes it possible to mount particularly thin substrates with direction-dependent, thermal expansion coefficients. By eliminating expensive pretreatment processes of the optical substrates in this assembly technology, the institute is helping to develop economical industrial applications that require individual and robust components stable for the long-term and over a large temperature range.

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1 Retardation plate in holder.

MERLIN – CRITICAL DESIGN REVIEW (CDR) COMPLETED

Task

Fraunhofer ILT is developing and building the Laser Optical Bench as the core element of a laser beam source for the German-French climate mission MERLIN (Methane Remote Sensing LIDAR Mission). This bench constitutes the laser transmitter along with the pressure housing developed by Airbus and the cooling, supply and control units.

The aim of the mission is to measure the greenhouse gas methane in the Earth's atmosphere from a satellite. The laser pulses backscattered from the Earth's surface will provide information about the methane concentration of the overlying atmospheric column. Generating the laser pulses with the required properties is not the only challenge here: The complex and compact laser system must also be insensitive to strong vibration and temperature fluctuations. Since the enclosed system must have a service life of more than three years, it is necessary to do without outgassing materials to avoid contamination.

Method

Fraunhofer has developed the final detailed design of the Laser Optical Bench and verified the resilience of the system to all environmental loads encountered with an extensive analysis campaign. Likewise, the laser performance was analyzed for all operating conditions and load scenarios occurring on the satellite. In parallel, the institute procured long-lead items.

Results

In addition to the optical elements, the design includes a passive cooling structure and an electrical harness for signal, high-current and high-voltage transmission for laser operation. Soldering techniques are used to contact electrical components and to mount the optics, ensuring robust, ultra-precise and contamination-free connections for a long service life. The institute has demonstrated that the system is able to resist environmental loads and that it performs as required. After the successful completion of the CDR, the client Airbus Defence and Space GmbH and DLR Space Management confirmed and approved the design. The procurement of components has been largely completed and the first laser baseplate prepared for the integration of the functional components.

Applications

The model philosophy and the assembly concept can be transferred to other laser beam sources. This applies to both aerospace and industrial applications, where high reliability and robustness are key factors.

The work is being funded by the German Federal Ministry for Economic Affairs and Energy BMWi under the reference number 50EP1601 and is being carried out on behalf of DLR Space Management by Airbus Defence and Space GmbH as a subcontractor.

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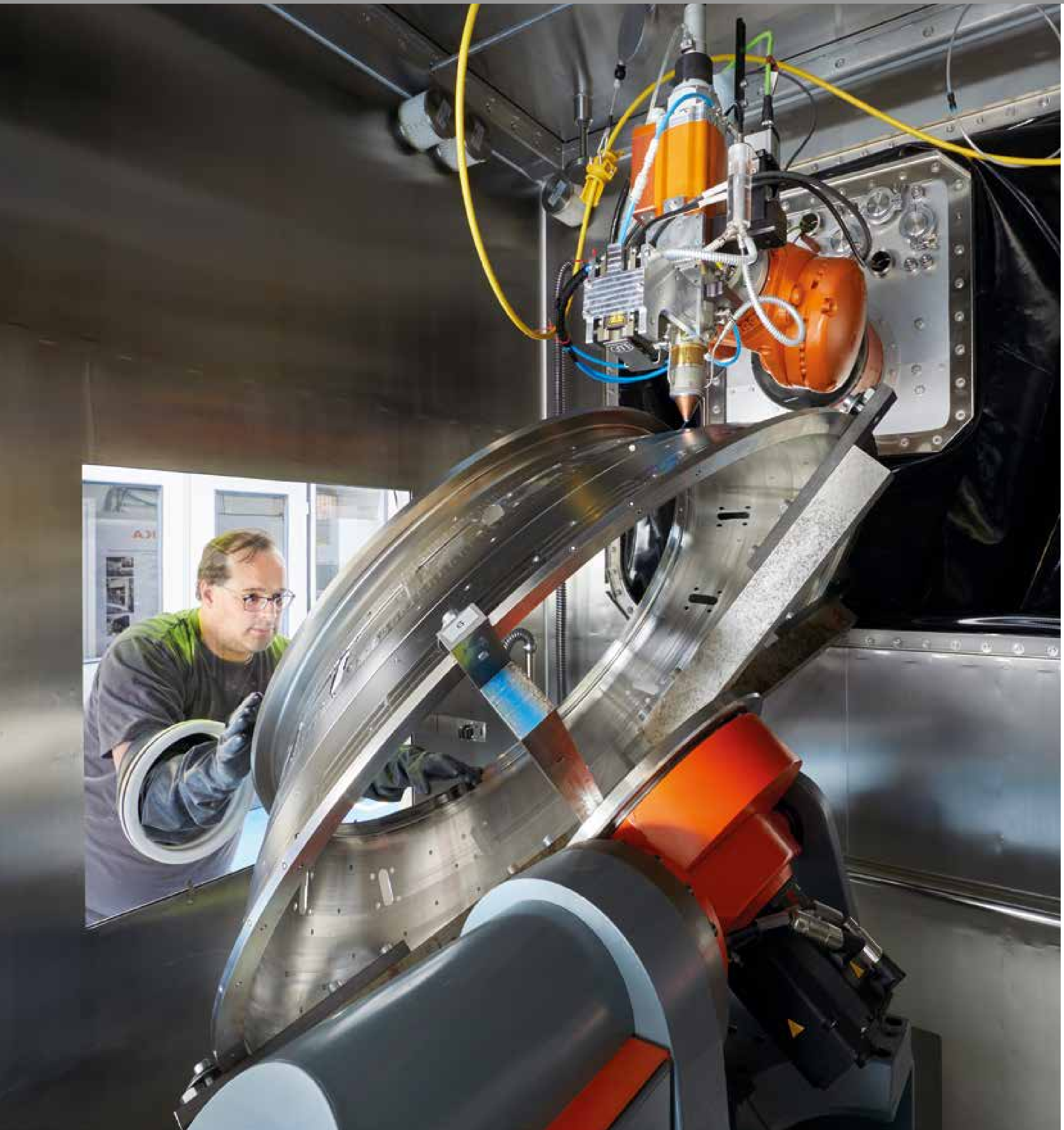
2 Prepared laser base plate.

LASER MATERIAL PROCESSING



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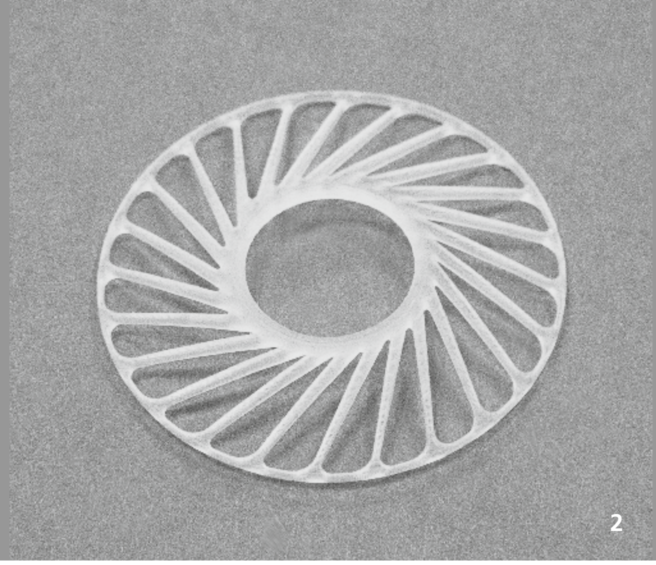

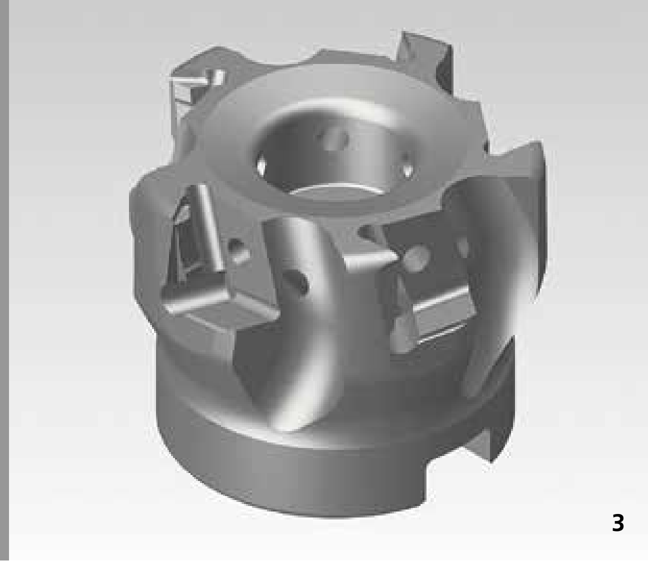

FULLY AUTOMATED 3D PRODUCTION WITHOUT SUPPORT STRUCTURES

Task

In 3D printing with vat-based photopolymerization (stereolithography and DLP), manual work steps are still a significant cost driver in manufacturing chains. Qualified personnel are required for the time consuming preparation of the data and the individual post-processing of the components (separating, washing, removing support structures, grinding, etc.), all of which cause many interruptions in the production chain. Approaches already exist for partial automation of the process, but full automation has so far failed because support structures, and the resulting connection to a build platform, are still necessary.

Method

To transfer the high resolution and surface qualities of vat-based photopolymerization to a fully automated process, researchers had to fundamentally modify the technology. With the TwoCure® process from Fraunhofer ILT, classic support structures can be replaced by custom tailored materials and a novel thermally controlled process. In the TwoCure® process, non-polymerized photo resin is thermally (reversibly) solidified within the printed layer, thus supporting the following layer. This process makes it possible to significantly increase volume efficiency, as more components can be produced in the same amount of time. Since the printed block is ejected automatically, the component can be post-processed without any manual steps at all.

Results

A prototype was used to demonstrate the operation principle for the first time in a larger format (build volume 130 x 80 x 100 mm³). Currently, Fraunhofer ILT is developing the first production-ready machine, with a build volume of 190 x 110 x 100 mm³, a system that can manufacture components fully automatically. In the future, two additional post-process modules will be developed, both of which will also allow the components to be washed and post-cured (thermally and photochemically).

Applications

With the TwoCure® process, users can produce small batches or large quantities of individual one-off products in a single step – from digital file to finished product – without any significant process knowledge or manual interrupts. An initial demonstration was given in the area of earmolds. Other fields of application include lost forms (e.g. jewelry), technical products (e.g. waveguides, connectors or housings) and dental applications. A variety of tailored materials are available for these applications.

The work was funded under the EXIST program by the German Federal Ministry for Economic Affairs and Energy BMWi under the number 03EFMNW212.

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1 Process chamber of the TwoCure® process.

2 High-resolution cross-strut braced wheel (outer diameter: 22 mm).

ADDITIVE MANUFACTURING OF MILLING CUTTER HEADS MADE OF BAINITIC STEEL

Task

Additive manufacturing with laser powder bed fusion (LPBF) unlocks great potential in tools for machining because it can be used not only to customize cooling channel guides and nozzle arrangement, but also to improve their fluid-mechanics. Since the process offers such a high geometric freedom, there is almost unlimited flexibility in developing and manufacturing components. However, the material requirements for milling cutter heads cannot be fulfilled as few steel materials have been qualified.

Method

In collaboration with the Fraunhofer Institute for Laser Technology ILT, the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University has been designing milling cutter heads with an improved cooling lubricant supply (fluid mechanics). Fraunhofer ILT additively manufactured them from bainitic steel, qualified them for LPBF and tested them. First, a process window was determined by systematically varying the process parameters so that components could be manufactured without defects (e.g. preventing pores and cracks) and with a high component density (> 99.5 percent). In addition, the process parameters were transferred to complex structures; moreover, the partners also investigated suitable post-processing methods for internal cooling channels and outlet nozzles. This enables adapted milling cutter heads to be manufactured in a high number of variants. The partners are focusing on deriving design guidelines to improve the design of additively manufactured milling tools from the collected findings.

Results

Promising results have already been achieved for bainitic steel: Components were manufactured crack-free with a density > 99.9 percent at a hardness of 400 HV.

Applications

The LPBF process enables tool weight to be reduced by adapting the geometry (e.g. integration of lattice structures) and integrating additional functions (e.g. complex cooling channels). The material under investigation could also be applied in the automotive industry as well as in mechanical and plant engineering.

The research project – as part of the program to promote joint industrial research (IGF No. 21049 N) – has been funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) via the German Federation of Industrial Research Associations (AiF) e. V.

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3 CAD of a milling cutter head (design: © Sumitomo).

4 Additively manufactured milling cutter head elements made of bainitic steel.

INCREASING THE QUALITY OF ADDITIVELY MANUFACTURED COMPONENTS THROUGH ADAPTIVE PROCESS CONTROL

Task

In laser powder bed fusion (LPBF), geometric shape deviations and, in particular, surface roughness occur since powder particles adhere to the component surface. The causes of these effects include melt pool movements and flows. For this reason, Fraunhofer ILT is investigating how adaptive process control can be applied to LPBF processes: Pulsed wave (pw) laser radiation is used to expose the contour and combined with continuous wave (cw) laser radiation to expose the volume.

Method

Fraunhofer ILT has developed specific process parameters for pw contour exposure experimentally for various component regions and geometric features, such as thin-walled structures and pointed contours. In addition, the institute determined the surface quality and geometric accuracy achievable in each case.

Results

By using pw contour exposure, Fraunhofer ILT was able to reduce both the geometric deviation from the target geometry and the surface roughness as compared to conventional cw contour exposure. This is particularly true for pointed component contours, which are susceptible to excess melting due to heat build-up. This occurs because individual melt baths solidify discretely and independently when the pw process is used, resulting in smaller melt pools compared to cw contour exposure.

Applications

The process control developed at Fraunhofer ILT is suitable for components that have to meet high demands on precision and surface quality. Since it has lower productivity compared to cw process control, selective use in component areas with high quality requirements is recommended. The investigations carried out to date with Inconel® 718 have been in turbomachinery construction. Future investigations will investigate how this process control can be transferred to other materials (e.g. 316L, Ti6AlV4, AlSi10Mg) and, thus, further industrial sectors.

The R&D project underlying this report was carried out on behalf of the German Federal Ministry of Education and Research (BMBF) under the funding code 13N15001.

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1 pw contour exposure.
2 cw contour exposure.

»SENSING« COMPONENTS MANUFACTURED WITH LASER-BASED ADDITIVE PROCESSES

Task

The collection of component condition data such as thermal and mechanical stress forms the basis for predictive maintenance, Big Data and AI approaches. For this purpose, components must be equipped with suitable sensors. Additive manufacturing methods such as laser powder bed fusion (LPBF) offer a wide range of possibilities for producing application-adapted components. Laser-based coating approaches can be used to additively manufacture sensors directly on component surfaces, e.g. through the wet-chemical deposition of electrically insulating and conductive materials; subsequently laser radiation is used for thermal post-treatment of the printed layers. Fraunhofer ILT combines these additive manufacturing methods to equip printed lightweight components with printed sensors.

Method

As early as the design stage, the topology can be optimized to save material and reduce component weight. In this way, even complex bionic structures can be made for lightweight applications. To additively attach the sensors, the researchers at Fraunhofer ILT print the necessary layers and structures made of different materials directly onto the component layer by layer and then functionalize them using laser radiation. In the case of strain gauges, the insulation layer, the measuring grid and the encapsulation are applied one after the other. The wireless telemetry system on a compact circuit board is finally attached to the component and connected to the electrical contact pads.

Results

By combining LPBF with digital printing and laser post-treatment processes in an innovative process chain, Fraunhofer ILT is paving the way for the production of »sensing« components from the printer. Conventional sensors no longer need to be applied manually. When installed, the fully digitally manufactured component enables users to permanently monitor the component, document component load and detect overload conditions.

Applications

Such components can be used in classic areas such as drive or gear technology, large machines, power generation, rail vehicles and aerospace, in which predictive maintenance is already being used. By producing component and sensor in one step, research will be able to open up new fields of application – such as automotive, consumer electronics and toolmaking – in which condition monitoring was previously too complex or too expensive.

The demonstration device was produced in cooperation with i4M technologies GmbH.

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3 Fully additively manufactured, sensor-integrated component with wireless telemetry.

LASER MATERIAL DEPOSITION OF ALUMINUM ALLOYS FOR LIGHTWEIGHT CONSTRUCTION

Task

Additive manufacturing (AM) is considered a key technology for the production of lightweight components and structures. Among AM processes, laser material deposition (LMD) stands out as it can be used to manufacture a wide variety of free-form surfaces. For this reason, LMD can be flexibly applied to repair and coat as well as to selectively individualize and functionalize prefabricated basic components (hybrid additive manufacturing). However, the processing of aluminum alloys with laser-based methods is challenging, especially because these alloys have a low degree of absorption and high thermal conductivity. This means that adapting the LMD process control to the specific material plays a decisive role in opening up lightweight construction applications with aluminum materials.

Method

Powder-based LMD was used to process aluminum alloys with silicon, magnesium and zinc – as the main alloying elements – in order to produce structural elements such as tracks, layers and solid bodies. Fraunhofer ILT is investigating process regimes that span orders of magnitude in terms of key process parameters, such as feed rate and deposition rate. For this purpose, the process control was adapted according to the desired requirements in terms of productivity, shape accuracy and material properties.

Results

Demonstration models with adapted coating thickness and dilution can be manufactured with a density of over 99.8 percent through targeted design of the process control and powder pretreatment. The processes developed here allow solid bodies to be produced at high precision, with structure resolutions of less than 100 µm and at build-up rates greater than 0.5 kg/h. Laser beam sources with a maximum output power of 4 kW were used.

Applications

Since the process control has been fundamentally advanced, new types of lightweight construction applications with aluminum can be put into practice, e.g. in the aerospace, automotive and mechanical engineering sectors. Current investigations into the processing of metal-ceramic composites will further expand the available range of materials.

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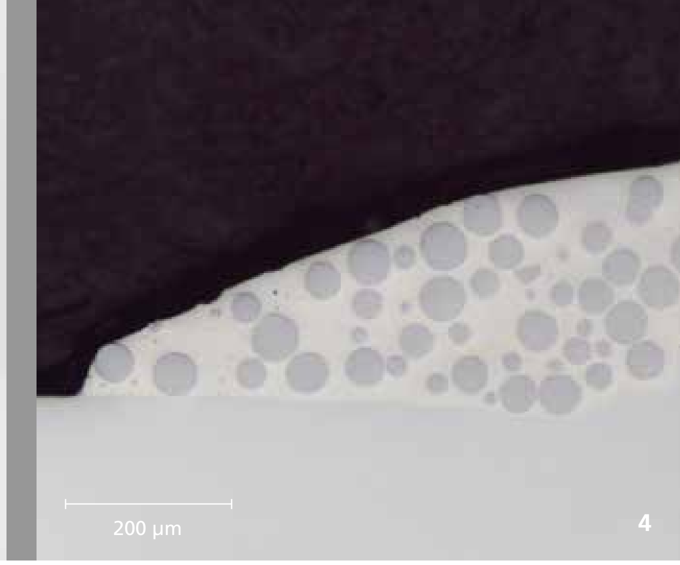
1 Solid body produced by EHLA (component height approx. 45 mm, build-up rate approx. 0.3 kg/h).

2 Solid body built with conventionally laser material deposition (component height approx. 90 mm, build-up rate approx. 12 g/h).



ARMOR PLATING AND REPAIR OF ALUMINUM DIE CASTING MOLDS WITH LASER MATERIAL DEPOSITION

Task

In aluminum die casting, liquid aluminum is pressed into a mold under high pressure. The mold, often made of steel, is the negative of the casting to be produced and exposed to high stresses due to corrosion and wear during its service life. Depending on the size and complexity of the mold, the molds can weigh up to several tons. Furthermore, the costs to manufacture them are in the range of several hundred thousand euros, making replacement and the associated loss of production time-consuming and, thus, costly.

To increase component life, Fraunhofer ILT is using laser material deposition (LMD) to armor plate the molds. This effectively protects the workpiece edge zone against corrosion and wear. Furthermore, if damaged, the mold can be repaired in a cost- and time-efficient manner by rebuilding defective component areas using LMD.

Method

Fraunhofer ILT investigates different process strategies to produce coatings that are as thin as possible, resistant to corrosion and wear, and that have adapted thermal conductivities. The coating is applied close to the final contour to minimize post-processing and speed up production of the mold. The coating material used was a metal matrix composite consisting of a ductile Ni-based matrix with embedded tungsten carbide hard materials, for which the institute investigated different mixing ratios of the two components in the coating.

Results

By developing suitable process strategies, Fraunhofer ILT has been able to apply coatings with layer thicknesses between 300–600 µm and a mixing ratio of up to 50 vol% tungsten carbide content in the Ni-base matrix to steel molds. After the armored molds were subsequent machined, field tests demonstrated that component service life increased significantly.

Applications

In addition to applications in the fields of forming and master molds, the process is suitable for numerous components and industries in which heavy-duty components have to be coated or repaired, e.g. in the fields of power generation, hydraulics, rolling or housing construction. The coating properties can be flexibly adapted to the specific application since a large number of materials can be processed.

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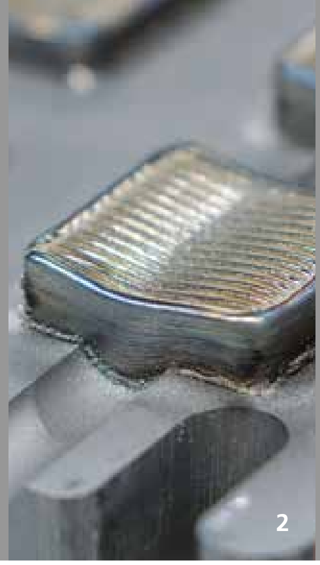
3 Steel mold coated by laser material deposition.

4 Cross-section of the applied coating on the steel mold.



LASER MATERIAL DEPOSITON WITH SELF-ADAPTING TOOL PATH PLANNING

Task

To produce high-quality metal solid bodies, Laser Material Deposition (LMD) has to be operated within a qualified process window. When the ideal distance between the processing head and the substrate deviates, geometric inaccuracies occur in the material volume applied, material quality suffers and the process becomes instable. Often, such differences result from deviations of the real substrate surface from that of the CAD model, the latter of which guides tool path planning. A particular challenge is posed by small deviations in the build-up height of individual tracks, inaccuracies that accumulate in multilayer welds.

Method

By integrating a laser line scanner (LLS) into the LMD system, Fraunhofer ILT is able to digitize the surface topology of the substrate directly in the machine. Based on the 3D scan, tool paths can then be planned using automated algorithms. To counteract small deviations in track height, geometry is recorded between the build-up of the individual layers and, based on this, the path planning is adapted to the real build-up height. In addition, special path planning algorithms allow local geometric deviations to be counteracted by adjustments to the process parameters.

Results

Fraunhofer ILT has implemented this approach in a software solution that combines machine-integrated geometry acquisition, automated web planning and program generation. The open-machine solution can be used on different industrial machine concepts.

Applications

The software solution developed here, the path generation and the process adaptation could be successfully tested for LMD on freeform surfaces within the ProLMD project (funding code: 02P15B115). In addition, it was successfully demonstrated for repair applications in both the aerospace as well as tool making sectors. In the EVEREST project (funding code: EFRE-0800732), the approach was also qualified for Extreme High-Speed Laser Material Deposition (EHLA) on rotationally symmetric components.

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1 Robot system during geometric acquisition of a welding layer.
2 Machining result with uncontrolled setup.
3 Machining result with controlled setup.

EHLA 3D – EXTREME HIGH-SPEED LASER MATERIAL DEPOSITION FOR ADDITIVE MANUFACTURING

Task

Economical build-up rates are mandatory for the industry to begin using additive manufacturing processes. Currently, increased build-up rates in Laser Material Deposition (LMD) are primarily achieved by increasing the dimensions of the manufactured weld beads (track width and height). This results in an inherent conflict of goals: between fast build-up rates, on the one hand, and precise, near-net-shape build-up, on the other hand. EHLA 3D solves this dilemma for the first time by applying precise, small weld beads with layer thicknesses in the micrometer range at speeds that are orders of magnitude higher than those of conventional LMD. This way, components can be produced in a shorter period of time and require less post-processing.

Method

Up to now, Extreme High-Speed Laser Material Deposition (EHLA) has been used primarily to apply wear and corrosion protection for rotationally symmetric components. To make this process usable for additive manufacturing at feed rates in the range of several 100 m/min, Fraunhofer ILT, in cooperation with Ponticon GmbH, developed and built a highly dynamic machine system. Based on the principle of a tripod type parallel manipulator, it allows either the build platform or the processing head to be moved very quickly and precisely.

Results

With a path and repeat accuracy of approx. 100 µm in all spatial directions, the system makes precise build-up possible. The maximum acceleration of 50 m/s² allows fast direction changes with low dead time. The institute has proven that the EHLA process principle can be transferred to additive manufacturing by demonstrating it for iron, nickel and aluminum-based materials at feed rates of up to 50 m/min. The material characteristics are on par with conventional laser material deposition. The tripod machine is currently used to explore the process regimes from 50–200 m/min. In the future, Fraunhofer ILT aims to further increase the degree of automation by process monitoring, capturing the component geometry and using path-planning software.

Applications

Since it can be used to process a wide range of material combinations, the EHLA 3D process finds broad application across the industrial sectors of surface coating and repair as well as in hybrid additive manufacturing.

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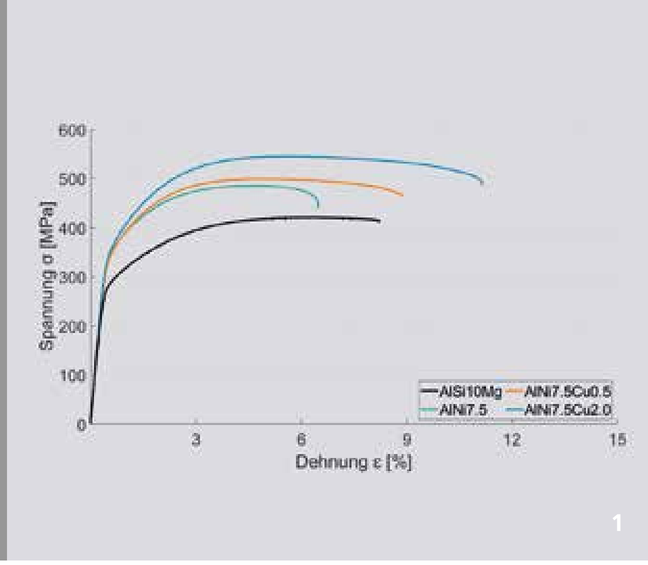
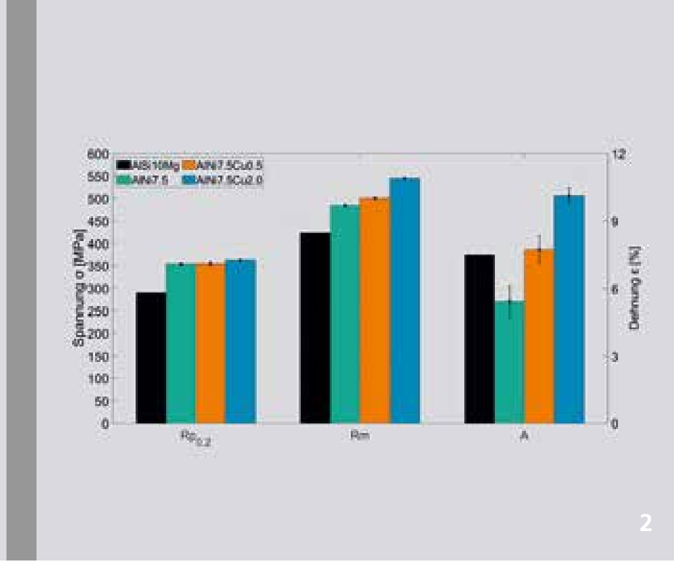
4 Construction of ILT characters out of several materials with EHLA 3D.





HIGH-STRENGTH AL-ALLOY FOR ADDITIVE MANUFACTURING

Task

The market for aluminum-based alloys for additive manufacturing is currently dominated by commercially available aluminum-silicon alloys (e.g. AlSi10Mg). These alloys, however, have insufficient mechanical properties for broader applications (e.g. in structural components). Other commercially available aluminum alloys that achieve the required mechanical properties either cannot be processed by additive manufacturing methods (e.g. 6XXX or 7XXX series) or contain expensive strengthening agents (e.g. Scalmalloy®). The work presented here aims, therefore, to develop an economical Al-based alloy that can be processed by additive manufacturing and has tensile strengths > 500 MPa and elongations at break > 10 percent.

Method

Eutectic Al-Ni alloys were identified as promising candidates for investigation with additive manufacturing processes. Al 7.5 wt. percent Ni (AlNi7.5) was selected as a binary base alloy to be studied with laser powder bed fusion (LPBF). Based on the binary composition, strengthening agents were added to enhance the mechanical properties through solid solution and precipitation hardening. The selection of the strengthening agents was based on simulated phase diagrams. Test specimens of the alloys under investigation were analyzed in terms of their mechanical properties and how well they could be processed (pores, cracks).

Results

Parameters were identified to build components that were crack-free and had part densities > 99.9 percent, thereby confirming that the binary Al-Ni alloy and the ternary Al-Ni-Cu alloys can be successfully processed. The addition of Cu to the binary alloy results in increased ultimate tensile strength and elongation at break up to 545 MPa, or 10.1 percent, respectively. Thus, the mechanical properties obtained in the processed state exceed those of the commonly used AlSi10Mg alloy. The addition of further strengthening agents is being investigated in ongoing work.

Applications

As emission and weight need to be reduced, automotive and aerospace sectors, in particular, could profit from a broad application of lightweight components. The project presented here is being carried out jointly with Fraunhofer Institutes IWM and IGCV as part of the Fraunhofer-Gesellschaft's strategic pre-market research.

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1 Stress-strain diagram of the investigated alloys.

2 Determined mechanical properties of the investigated alloys.

COBALT-FREE, HIGH-ENTROPY ALLOY FOR ADDITIVE MANUFACTURING

Task

High-entropy alloys (HEA) exhibit both high strength and ductility as well as good corrosion and wear resistance thanks to the large mixture entropy of multi-element compounds. These properties make HEA particularly suitable for producing components subject to complex stresses. As part of the NADEA joint project, Fraunhofer ILT has developed an HEA that can be processed with additive manufacturing (AM) and that surpasses the properties of conventional duplex steels. A key objective is to avoid the use of cobalt, a metal that is not only harmful to the environment and health, but that is also rare.

Method

Fraunhofer ILT is investigating how well $AlCrFe_2Ni_2$-based alloys can be processed with laser material deposition. With rapid screening by simulation (Access e. V.) and experiment (Fraunhofer ILT), both project partners selected a suitable material composition. One challenge they face, however, is reducing the material's susceptibility to cracking. Suitable build-up strategies were, therefore, developed focusing on local temperature management. The group aims to develop a stable process window for the geometrically variable, near-net-shape build-up of real component geometries such as pump impellers.

Results

The partners achieved crack-free processing of $AlCrFe_2Ni_2$ into a near-net-shape component with a density > 99.5 percent. Investigations at the project partner Access e. V. show that a superfine FCC-BCC duplex structure is obtained after solution annealing and ageing and has a yield strength $R_{p0.2}$ of 600 MPa. The tensile strength R_m is 1100 MPa with a total elongation of 27 percent. A comparable duplex steel achieves $R_m \approx 900$ MPa, $R_{p0.2} \approx 640$ MPa and A ≈ 20 percent in the tensile test.

Applications

The alloy developed can be broadly used for the oil and gas industry and mining, and is equally predestined for applications in the off-shore sector and the chemical industry.

The joint project NADEA is part of the M-era.Net network of the European Union and is funded by the German Federal Ministry of Education and Research (BMBF) under the grant number 03XP0163B.

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3 Pump impeller.

4 $AlCrFe_2Ni_2$ microstructure (© Access e. V.).

CLEANING COMPLEX 3D GEOMETRICAL SHAPES WITH LASER RADIATION

Task

Within the scope of regular turbine engine maintenance, combustion residues must be removed from compressor rotors (including blades). Up to now, these rotors have been cleaned with wet-chemical processes. Due to tightening legislation, such as REACH & RoHS (Restriction of Hazardous Substances), this cleaning method has come under increasing scrutiny and should soon be replaced by a laser-based process. As disassembling the compressor rotor into its individual parts is costly and should be avoided, the complex component should be cleaned in its assembled state.

Method

This maintenance faces a particular challenge since the components to be cleaned are complex and there is limited access to the surfaces of the individual parts. In particular cases, the CAD component data is also missing, e.g. due to the age of the component, so that this data has to be reengineered by scanning the component in 3D and transferring the measurement points to mathematical surfaces. This data is then used to simulate the accessibility, to break down the processing into scannable segments by means of path planning, and then to clean the component automatically in a multi-axis processing machine using the adapted laser parameters. The laser beam focus is tracked while the part geometry is processed.

Results

Pulsed laser radiation can be used to automatically clean both blade and rotor surfaces in the assembled compressor rotor. The path planning for the laser treatment takes into account the dynamics of the axes as well as the required high processing speeds – in the range of several m/s. A 5 + 3 axis system (5 mechanical axes + 3 scanner axes) was used for this purpose.

Applications

Provided accessibility is given, the system can be used to clean other components with complex 3D geometrical shapes and to remove other contaminants from almost all industrial components, e.g. injection molds and coating chambers. With suitable process control, worn coatings or functional layers (e.g. non-stick, anti-wear or anti-corrosion coatings) can also be removed, if necessary, in order to replace them efficiently with new functional layers.

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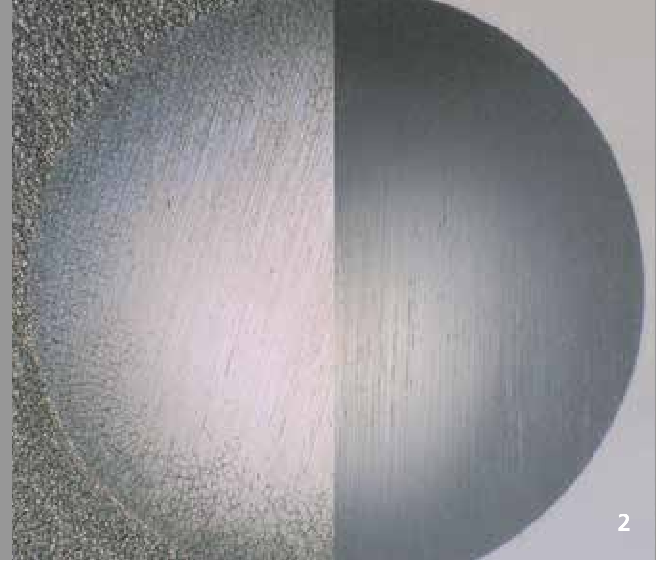
1 Compressor rotor cleaned with laser radiation, two blades are in the uncleaned state.



HYBRID PROCESS CHAIN FOR THE PRODUCTION OF GLASS OPTICS

Task

Optical components made of glass are usually produced in complex process chains consisting of multiple grinding and polishing steps. The brittle fracture behavior of the glass materials is the main reason this staggered manufacturing process is needed since the forces acting during mechanical processing cause tiny subsurface damage (SSD) below the machined surface layer. The SSD depth during mechanical processing is usually < 100 µm and it can only be removed mechanically by ablation. In this process, the applied force and, thus, the depth of new SSD are successively reduced at the expense of the removal rate. As a consequence of this iterative process, the highest quality optics can only be produced at slow throughput times and, therefore, high costs.

Method

The virtually ablation-free healing of SSD by laser polishing at depths of up to 1000 µm has already been successfully demonstrated. A single laser polishing step replaces several grinding and pre-polishing steps and can, thus, reduce process time and increase material yield. For this purpose, Fraunhofer ILT integrated laser polishing into the process chain, consisting of rough grinding, laser polishing and corrective polishing. Then, it compared the process time to achieve optical standard quality for N-BK7 and fused silica optics with that of a conventional process chain. The result was a trade-off between smoothing and thermal distortion at the laser polishing/corrective polishing interface.

Results

When laser polishing at process times of a few seconds is used, the material removal required for fused silica can be reduced from 40 µm (SSD depth) to 5 µm (thermal deformation), thus reducing the duration of post-processing by about 70 percent. Due to higher thermal deformation, the remaining removal depth for N-BK7 is currently 16 µm (from 25 µm SSD depth), resulting in a reduction in polishing time of about 30 percent.

Applications

The hybrid process chain for manufacturing optics can be used to reduce the complexity of process chains and, thus, lower lead times and unit costs. In particular, this applies to the production of aspheres and free-form surfaces.

The R&D project HyoptO underlying this report was carried out on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi) under the funding code IGF-20308 N.

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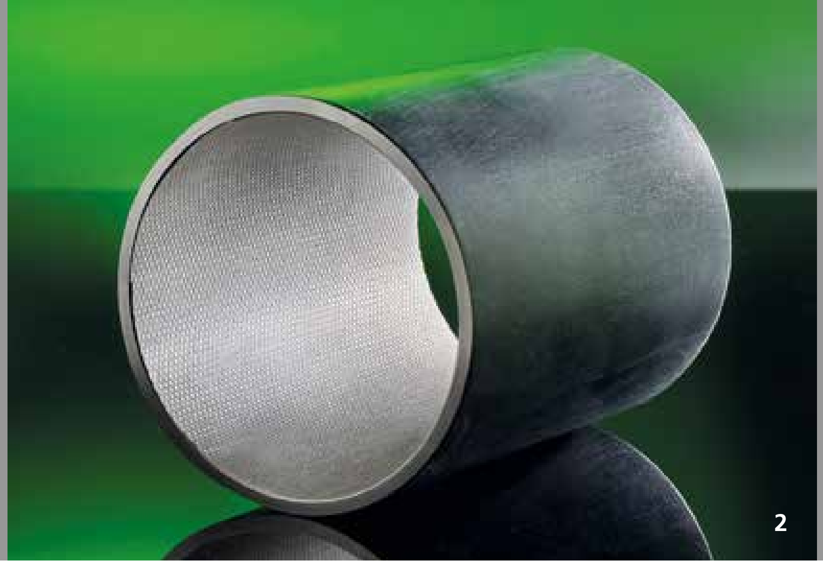
2 Ground (left) and laser polished (right) fused silica surface with etched dome cut for SSD detection.

3 Laser-polished glass optics.



FLEXIBLE BATTERY DESIGN THROUGH HIGH-RATE LASER ABLATION

Task

As battery-powered electronic devices increasingly penetrate markets and as new areas of application are developed for them, there is a constant demand for lithium-ion batteries with different geometrical shapes. While battery manufacturers need to increase productivity, they are also confronted with the challenge of producing a wide variety of cell formats on a single production line. The coating of the metallic carrier film, which is only a few micrometers thick, with the so-called active material constitutes a central production step. Since the electrodes are subsequently contacted via so-called tabs, parts of the metal foil must remain uncoated, which means the coating process has to be interrupted and restarted repeatedly. What is needed, therefore, is not only a faster, but also a more flexible electrode production.

Method

One approach to solving this problem is to coat the entire surface of the film instead of coating it partially, which is technically very complex, and then use a laser to selectively expose the areas required for electrical contacts. Until now, this idea has failed because the laser ablation process was not productive enough. In addition, the quality of laser ablation with short pulse lasers did not meet the high demands placed on a contact point that could be welded reliably. To solve this conflict of goals, Fraunhofer ILT uses a powerful ultrashort pulse (USP) laser. The challenge here is to remove the entire layer of active material without leaving any residue in just one pass and without damaging the thin metal foil.

Results

The process developed by Fraunhofer ILT can remove graphite-based anode material from a 10-micrometer-thin copper foil at a rate of up to 1,760 mm³/min without damaging it. With today's common active-material layer thicknesses, this corresponds to an area rate of about 4 cm²/s. In the near future, it will be possible to increase the ablation rates even further by using the new generation of USP laser systems with multi-kW output powers, such as those currently being developed in the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS.

Applications

Highly productive USP laser ablation is particularly attractive for battery cell manufacturers. This flexible manufacturing process allows non-standard cell formats to be produced in an extremely productive manner. Such batteries are predominantly used in portable electronic end devices, where the lithium-ion battery must be adapted to the device design, which often has minimal space for the battery. In addition to use in the electronics industry, highly productive USP laser ablation on large areas is also of interest to the hydrogen or automotive industries.

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1 Selective ablation of graphite anode material from a 10 μm thin copper foil.

OPTICAL SYSTEM FOR MICROSTRUCTURING OF INNER SURFACES

Task

Among other applications, laser-based microstructuring is applied to functionalize surfaces. By selectively creating specific surface structures, users can adapt certain surface properties independently of the material used. Microscale surface structures, for example, can be used to minimize friction and wear during mechanical stress, to generate self-cleaning or antibacterial properties, to change optical properties or to optimize surfaces in terms of aero- or fluid-dynamics. For many fields of application, however, the surface to be processed is located in a tube or cavity, so that limited accessibility has prevented the use of laser structuring to a greater extent.

Method

A special processing optical system has been developed for structuring internal surfaces. This system is designed for use with nanosecond or ultrashort pulsed laser radiation and can be immersed in cavities as well as integrated into existing structuring systems. A particular problem is preventing the optical system from being contaminated by the ablated material.

Results

The optical system developed at Fraunhofer ILT can be used to structure tubes or other cavities of up to 400 mm immersion depth. Thanks to a newly designed solution for protecting the optical components, the system can be applied in productive processes with high material ablation rates over a comparatively long period of time. By using a CAD/CAM solution based on grayscale bitmaps, the researchers at Fraunhofer can also create complex structures on internal surfaces.

Applications

The system can be applied for optimizing fluid dynamic properties in particularly stressed pipelines as well as for generating internal self-cleaning surfaces and structures for wear optimization for internal mechanical stressed surfaces. Other fields of application include the de-coating or cleaning of hard-to-reach areas.

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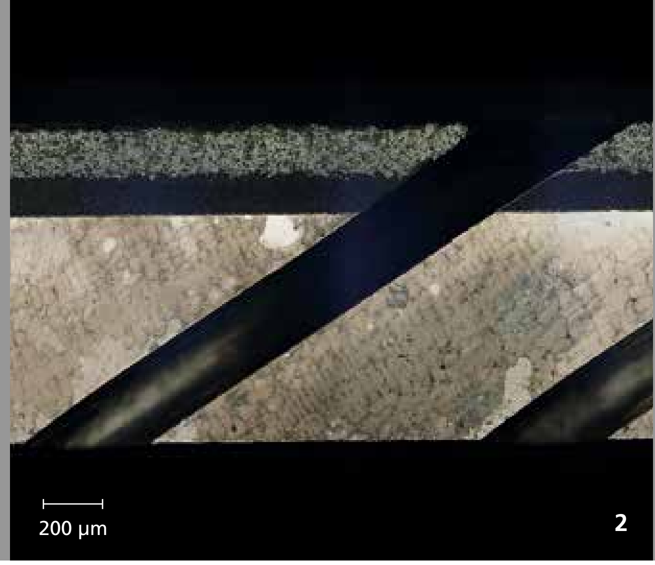
2 Internally structured tube.



PRECISE DEEP DRILL HOLES WITH ULTRAFAST LASERS

Task

Deep drill holes with a high aspect ratio can be produced productively with long pulse lasers, but defects such as recast layers and cracks on the drill wall occur. Another drawback is that a certain fluctuation of the bore diameters cannot be avoided. Although ultrashort-pulsed (USP) laser radiation can be used to produce high-precision holes without defects, comparable drilling depths and aspect ratios have not yet been achieved, and productivity is also several orders of magnitude lower than with long pulse drilling.

Method

By comprehensively investigating ablation behavior at high fluences and high average powers, research has laid the foundation for the development of deep drilling processes with USP laser radiation. In addition to these advances, Fraunhofer ILT has developed a new optical drilling system that makes it possible to drill significantly deeper and ablate at much higher rates. The institute has applied for a patent on this system.

Results

Using the fundamental investigations, Fraunhofer ILT could identify a suitable range of process parameters and develop a design tool for the new optical drilling system. This tool is used to determine the required optical components and process parameters for a desired drill hole geometry. The tool can also be used to determine in advance which set of process parameters is most productive. With this so-called deep-drilling optical system, holes with a diameter of 200 to 1000 µm can be drilled with an aspect ratio of up to 20 in materials such as metals or ceramics. In addition, this optical system can be used to create shapes at the hole entrance in the same process step before or after drilling.

Applications

Precise, deep micro drill holes are needed in many high-technology applications, such as vent holes for tooling dies, cooling holes in gas turbines, or holes used as lubricant feeds for (forming) tools. In addition, many other drilling processes currently still using long pulse lasers can benefit from the increased precision and drill-hole quality provided by USP drilling.

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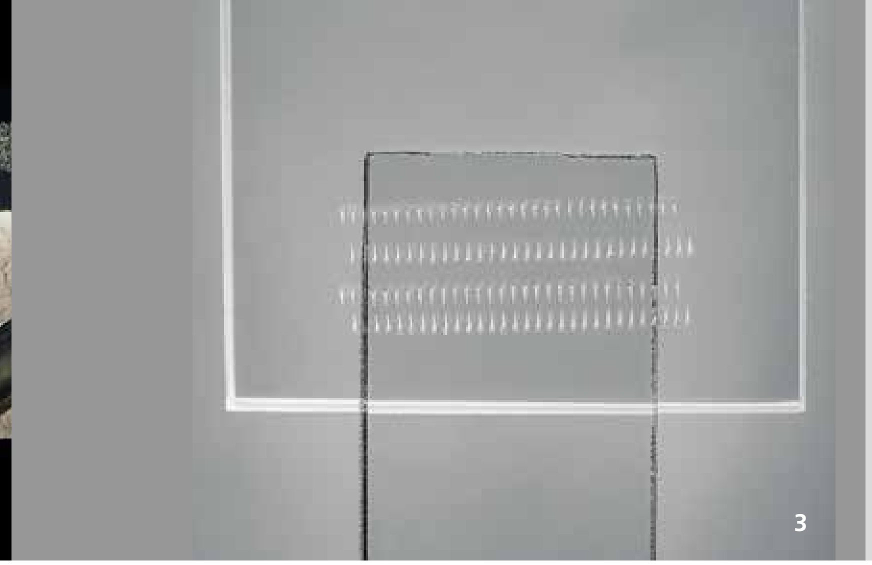
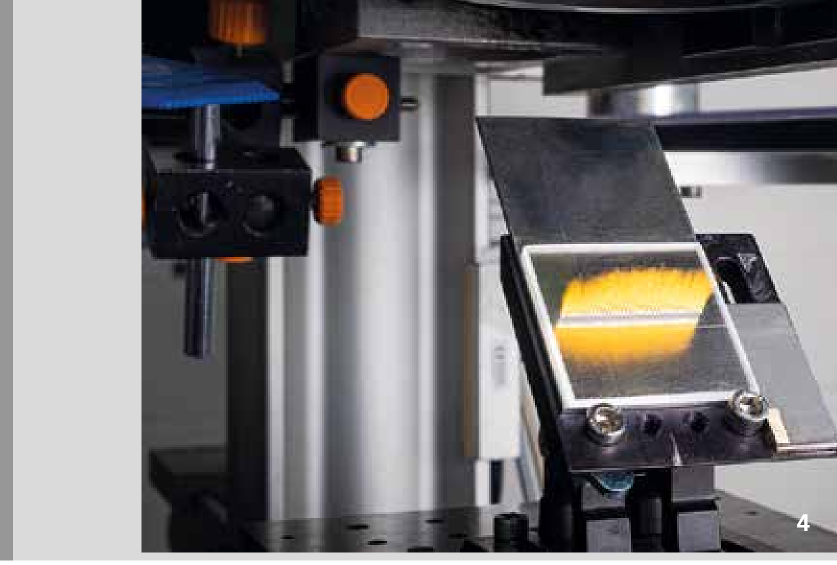
1 Machining of a turbine blade.
2 Longitudinal section of a sample drilled with USP laser radiation.





LASER-BASED PRODUCTION OF GLASS-PLASTIC HYBRID JOINTS

Task

Transparent functional and design elements are often composed of glass and plastic materials. While glass materials are scratch-resistant and insensitive to temperature, plastics can be more easily shaped. When both classes of materials are combined, the industry could use the advantages each has to offer. Normally, they are connected with adhesives or bonding agents, but these bonds are often not temperature-resistant, or mechanical stresses arise due to different expansion coefficients.

Method

Fraunhofer ILT has developed a laser-based manufacturing process that joins the two materials – within the NRW research project HyTraM and in cooperation with the industrial partners Hella (Lippstadt), SIMCON (Würselen) and Krallmann (Hiddenhausen). In this two-stage process, laser structuring is first used to create defined undercuts in the glass; depending on the application, either a CO_2 or a USP laser is used as the beam source. For the subsequent joining process, a thulium fiber laser is used, which emits radiation in the intrinsic absorption range of the plastics. The laser radiation penetrates the glass sample and melts the plastic. The molten plastic flows into the previously created microstructures, so that a form-fit joint is formed after the melt has cooled.

Results

Additives such as adhesion promoters or adhesives are not required in this laser-based production of glass-plastic hybrid joints. The project partners also demonstrated that the mechanical strength of the joints is critically dependent on the structure density and orientation. In future work, they will overmold structured glass samples with injection molding in order to establish this process in an industrial environment.

Applications

Glass-plastic hybrid compounds can be used wherever the specific advantages of both material classes should be exploited. Possible fields of application include automotive headlights.

The work was carried out as part of the North Rhine-Westphalia project HyTraM and funded by the European Regional Development Fund (ERDF) under the code EFRE-0801113.

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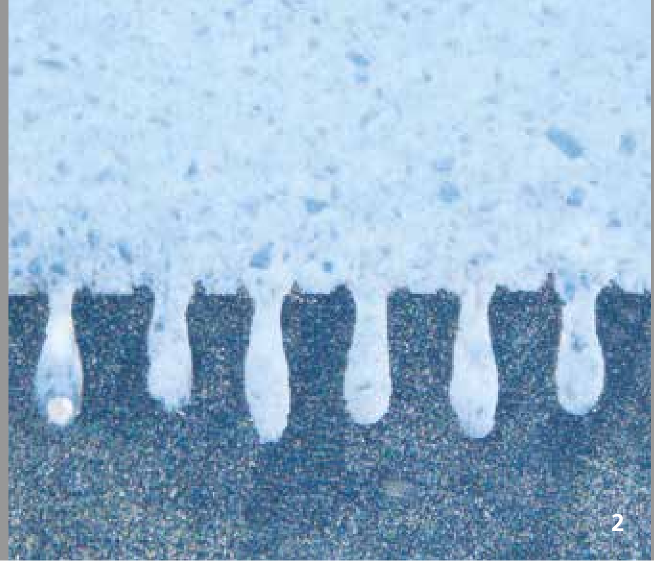
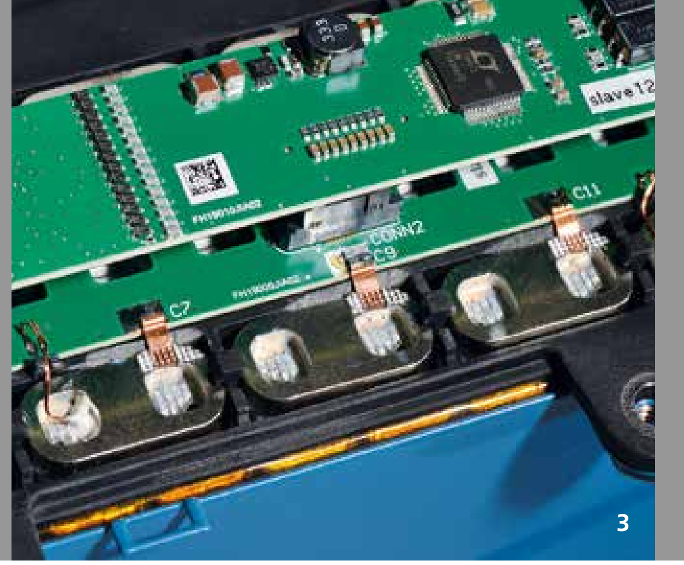
3 Glass-plastic hybrid joint after joining process.
4 Laser structuring of a glass sample.





REUSABLE PLASTIC-METAL HYBRID JOINT

Task

Joining dissimilar materials poses major challenges for almost all sectors of the manufacturing industry. By combining the use of different materials in a hybrid compound, such as plastics with metals, manufacturers can not only add functional enhancements, but also save weight. While plastics are particularly light, inexpensive and easy to shape, metals can be subjected to significantly higher mechanical loads thanks to their mechanical properties. However, a direct material bond between the two materials has so far failed due to their chemical and physical differences. A connection by positive locking or the use of filler materials is, therefore, necessary. However, a material-to-material bond is difficult to undo after joining, making it difficult to separate the two components by type or to replace a component for repair.

Method

Fraunhofer ILT has developed a process chain for joining plastic to metal in which laser radiation is first used to generate microstructures in the metallic joining partner. In the subsequent laser joining process, the plastic is plasticized and positively bonded by allowing it to claw into the microstructures. This connection can be easily released again with local heating, so that an assembly can be separated by type or a part can easily be exchanged.

Results

The tensile shear connection investigated is made of die-cast aluminum and a polycarbonate (Makrolon©). The joint strength measured immediately after the joining process is approx. 18.4 MPa. The measured strength value corresponds to the range of a structural adhesive bond. After the bond was loosened by mechanical testing, polycarbonate was rejoined to the structured metal and subsequently tested. The strength of the joint was measured, reaching 18.8 MPa, proving that it was possible to rejoin the structured metal samples without a loss of strength.

Applications

Hybrid components combine the specific advantages of their different materials, resulting in lightweight and rigid components with additional functions at the same time. The laser-based joint can also be dissolved and rejoined several times without loss of strength. Furthermore, it offers great potential in terms of sustainability and reusability. The approach presented here is particularly suitable for the aerospace and automotive industries.

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1 Reusable electronics housing made of die-cast aluminum with PA6 plastic cover.

2 Cross-section of a die-cast aluminum alloy.

LASER BEAM WELDING OF BATTERY CELLS FOR HYBRID VEHICLES

Task

The European Union's climate targets pose major challenges for the automotive industry in Europe. To meet them, the EU project ADVICE is intended to promote the acceptance and spread of hybrid vehicles. Various types of hybrid drives are being investigated and further developed on the basis of demonstrator vehicles. As part of the project, a high-performance battery system is being developed for a VOLVO S90.

Method

Limited space and high power requirements are the main challenges. The high power or current requirement for discharging and charging by recuperation also affects the design of the laser beam process used for contacting the battery cells. So that the 186 prismatic cells can be interconnected per module with the lowest possible electrical resistance, large connection cross-sections must be achieved on a small area. At the same time, the thermally sensitive battery cell must not be subjected to excessive thermal stress during the welding process.

Results

By simulating the thermal load, Fraunhofer ILT and project partners were able to optimize the process control and reduce the maximum temperatures. With the resulting laser-beam welding process, the battery cells could be welded semi-automatically. In order to achieve the necessary current-carrying cross-section, four parallel weld seams, each with a seam width of around 600 µm, were generated in the overlap configuration. The assembled battery system was successfully integrated into the vehicle and tested by the project partners.

Applications

The developed system can be used in the field of electromobility and battery technology to advance research in this area. The results can also be transferred to applications with high demands on the electrical current carrying capacity of the connections.

The work was carried out as part of the EU project ADVICE under grant number 724095.

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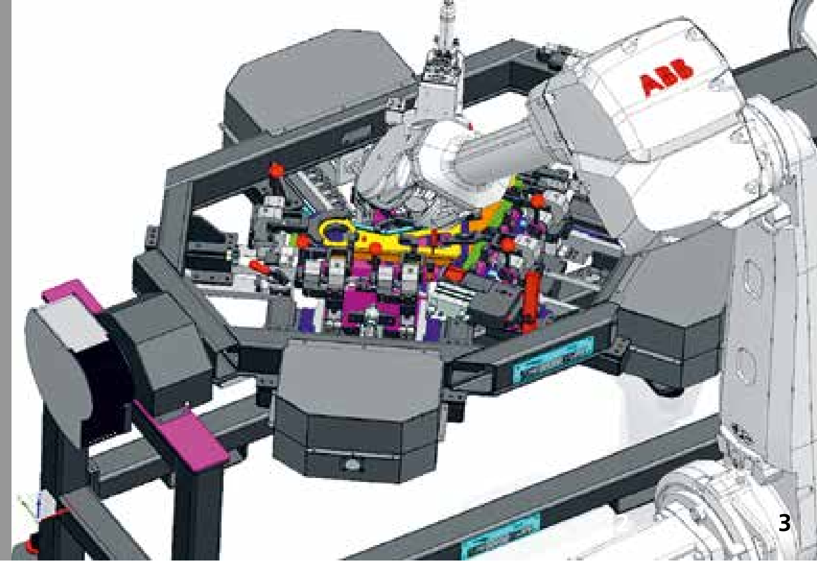
3 Laser-welded battery connector.

4 Battery module for the hybrid Volvo S90 Recharge.



HIGH-SPEED WELDING AND CUTTING OF STAINLESS STEEL BIPOLAR PLATES

Task

In fuel cells, hydrogen and oxygen, spatially separated, are synthesized into water via electrochemical reactions that release electrical energy and heat. In addition to the membrane electrode unit, the bipolar plate is the central component of the repeating unit of a fuel cell stack. Overall, when a plate is produced, the steps required do not currently allow the use of a cost-efficient concept since the process involves manufacturing in batches and long transport distances. As a member of the CoBIP project, Fraunhofer ILT is developing and integrating a roll-to-roll laser welding and laser cutting module to create an innovative overall solution for manufacturing high-quality bipolar plates.

Method

The challenge in using laser microwelding for this application is twofold: the welds of a bipolar plate must have a certain tightness and the feed rate must increase significantly. Fraunhofer ILT is investigating scanner-guided remote cutting as well as gas-assisted high-speed cutting with lasers to determine if they are suitable to cut bipolar plates in single layers, double layers or as a hollow structure in the area of the cooling channels. In addition, a newly developed clamping concept must make it possible to press formed sheets together without a gap forming.

Results

The joining cross-section can be adapted to the technical requirements with the laser making an oscillating motion superimposed on the linear feed. By suitably selecting the various welding parameters, the institute is able to generate defect-free welds in an argon atmosphere at feed rates of up to 30 m/min. Cutting speeds of well over 100 m/min can be achieved without burrs, so that the dynamics of the axis system are the limiting constraint in the cutting process due to the small size of the contours.

Applications

By reliably joining and contouring metallic double-walled bipolar plates in a gas-tight manner and at high process speeds, this process lays a foundation for efficiently producing bipolar plates or fuel cells.

The R&D project underlying this report was carried out on behalf of the German Federal Ministry for Economic Affairs and Energy BMWi under the grant number 03ETB020A.

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MULTIFUNCTIONAL LASER ROBOT FOR CUTTING, JOINING AND ADDITIVE MANUFACTURING INCL. A DIGITAL TWIN

Task

If components are to be flexibly produced for electric vehicles, multifunctional tools, especially in the area of small and medium quantities, are required. To spur their development, a digital twin supports commissioning them and preparing their production and will also ensure seamless monitoring of production in the future.

Method

The starting point is the development and construction of a flexible laser processing head in which cutting, joining and additive manufacturing are integrated. A digital twin maps the robot kinematics and the complete system control – including the PLC-programmed head functions and clamping device. This enables virtual commissioning and accelerated changeover of the process chain and product. In the future, the feedback of sensor signals from the hardware and the process will be used to monitor and optimize the overall system.

Results

The beam parameters to be adapted for the individual processes can be set in the multifunctional laser head through variable beam shaping. Integrated in the head are devices for the supply of working media and additive materials as well as for the capturing of process signals. The digital twin of the laser robot cell has been largely configured and now allows users to program PLC-controlled functions virtually and to design the production sequence optimally.

Applications

For the first time this development will make a tool available that can perform all three manufacturing processes without retooling. Thanks to the virtual model, the entire system can be commissioned quickly and production preparation is less susceptible to errors. Applications can be found wherever industry needs high variant diversity, fast product changeovers and agile manufacturing in small to medium quantities. The development is aimed at the production of electric vehicles, but can also be transferred to numerous other product classes.

The MultiPROmobil project is being funded by the European Regional Development Fund (ERDF) and the state of North Rhine-Westphalia under the number EFRE-0801253.

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1 Bipolar plates with welded outer contour.
2 Laser-beam cutting of bipolar plates.

3 Simulation of component, fixture and machining head in the digital twin.

SAFE LASER CUTTING WITH MINIMALLY INVASIVE POWER MODULATION

Task

Monitoring and controlling the laser cutting process are essential methods for increasing the performance of laser cutting systems. Using them can result in controlled and safe processes that can be managed stably even with low reserves. An essential prerequisite is reliably diagnosing the process and system state in a wide parameter and state space. Even or especially under varying process conditions, it must be possible to assess these states reliably with simple diagnostic tools. The minimally invasive power modulation (MIPM) method developed at Fraunhofer ILT offers excellent possibilities for this.

Method

Special modulation patterns of the laser power are used to induce responses in the process signal, which are detected by a simple, coaxially observing photodiode. Analysis of the transfer behavior from the input signal (laser power) to the output signal (photodiode) provides a much more accurate and robust identification of the process state than an evaluation of the photodiode signal of a non-modulated process using classical signal analysis methods. For example, the process responds in a significantly different manner to power changes in a critical process state near the maximum speed than in a stable state. The modulation strength can be set so low that there are no disturbing effects that reduce the quality of the cutting result. The modulation patterns are generated dependent upon the cutting parameters or regulated by the feedback of the photodiode signal.

Results

With the aid of the characteristic response patterns of the photodiode signal, Fraunhofer ILT is able to reliably monitor the cutting success even in the case of process signals that cannot otherwise be evaluated unambiguously, as is typical, for example, in high-speed cutting. Fast process data processing based on an FPGA makes short response times possible: in the range of less than one to a few milliseconds in real time. Standard cutting processes also benefit from MIPM, as critical states are announced in time and proactively avoided.

Applications

In the current stage of development, the method is used to monitor laser cutting systems and will be extended to process control in the future by means of feedback on the process parameters. Machine learning algorithms play a central role as they will be applied to analyze the complex characteristic patterns. It is also planned to transfer the method to laser welding.

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1 Development on process monitoring with minimally invasive power modulation.

IDENTIFICATION AND UTILIZATION OF ACOUSTIC RESONANCES IN LASER BEAM CUTTING

Task

Using high-speed video analysis of the melt film on the cutting front, research has recognized that the cut edges have the lowest roughness depth precisely in the areas where the melt film exhibits high-frequency waves directed downwards. The associated frequencies decrease with the sheet thickness to be cut and are believed to be in the vicinity of acoustic resonances of the gas column in the kerf. An innovative approach aims to amplify and exploit this positive effect. To this end, Fraunhofer ILT is developing an acoustically tuned cutting nozzle design that causes a resonant »cutting whistle« to form, thus improving the achievable cutting edge quality.

Method

The cylindrical part of the nozzle outlet is adapted in the first step of developing a cutting whistle. Its geometry was dimensioned according to the known physical laws of acoustics, and its effect was then compared with that of a standard nozzle. An optical microphone was used to verify the acoustic signal when the gas stream exits the nozzle into free space. Furthermore, a fiber laser with 4 kW output power was used to cut stainless steel sheets with a thickness of 6 mm, while the gas pressure was varied.

Results

The investigations confirm that the acoustic waves can be adjusted specifically by adapting the nozzle geometry. Even without taking into account the total resonance system nozzle-joint, which is planned in the next step, the institute was able to reduce the maximum value of the roughness depth Rz by 15 percent. The aim is to halve the roughness depth in the future.

Applications

In laser-beam fusion cutting, acoustic resonances can open up great potential and provide an example of how taking acoustic effects into account – in a simulative, diagnostic and practical manner – can improve laser material processing in general.

The project is funded by the German Research Foundation (DFG) as part of the Collaborative Research Center SFB 1120 »Precision from Melt«.

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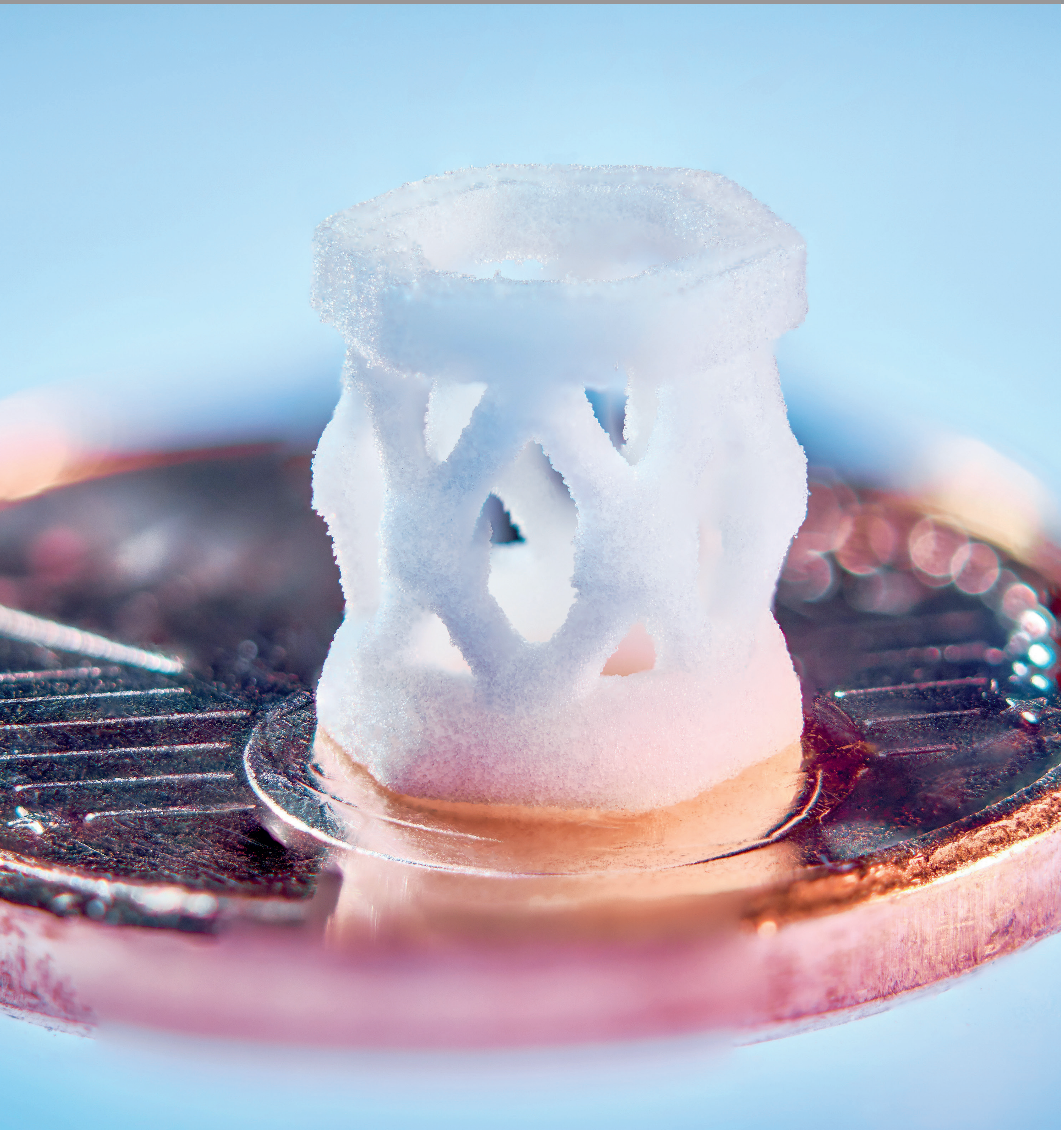
2 High-speed videography of the cutting process provides new insights.

MEDICAL TECHNOLOGY AND BIOPHOTONICS



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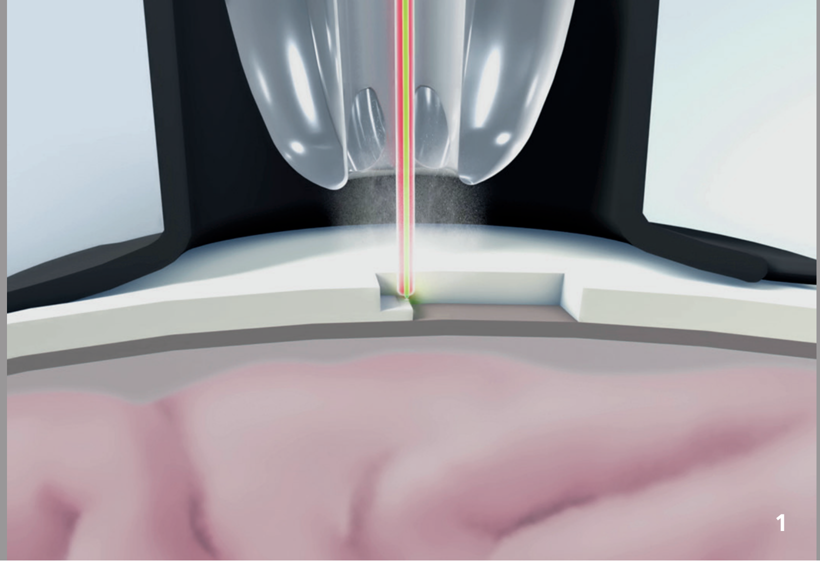

LASER OSTEOTOME FOR AWAKE BRAIN SURGERY

Task

For neurosurgery, researchers have developed novel therapeutic methods that not only significantly improve the quality of life, but also the survival rate of critically ill patients. These methods require, however, that the patient be operated on while awake since complex functions such as speech must be tested during awake brain surgery, yet removing bone from the skull with drills and burrs causes the patient extreme stress. For this reason, a laser osteotome is being developed at Fraunhofer ILT in close collaboration with experts in neurosurgery. This laser osteotome can be used to open the skull bone without vibration or noise, thus significantly reducing the psychological stress as well as the risk of injury for the patient.

Method

For a safe, vibration-free and low-noise ablation process, the drill and cutter are replaced by a MIR (Mid-Infrared) laser beam source, which emits nanosecond pulses with pulse energies in the millijoule range. To ensure that the cutting process is efficient and does not cause any thermal tissue damage, the laser pulses with kilohertz frequencies must be distributed along the cutting line in such a way that a continuous deep kerf is created. This cutting function is made possible by an applicator with an integrated 2D mini-scanner for beam guidance, focusing optics with adjustable focus position and a spray nozzle for wetting the bone surface. Synchronized with the cutting process, an OCT (optical coherence tomography) measuring beam determines the local cutting depth and residual thickness of the bone to control and stop the cutting process shortly before the bone is cut through. In this way, the cutting depth control protects the structures of the brain located under the skull bone.

Results

Process parameters for an efficient laser cutting process were determined in systematic ablation experiments on bovine bone samples. The ablation rates achieved were above $dV/dt = 4\ mm^3/s$. The maximum cutting depth was 7 mm with a cutting width of 2 mm. In addition, Fraunhofer ILT has developed a digital model of the laser osteotome, which can be used to simulate the entire operation sequence and develop a hardware control system.

Applications

Fields of application for the laser osteotome are awake operations for the treatment of complex movement disorders. Awake operations are also becoming increasingly important in the surgical treatment of low-grade gliomas (brain tumors).

The project is being funded by the Fraunhofer-Gesellschaft as part of the ATTRACT research program under the project name STELLA.

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1 Applicator for implementing the laser cutting process on the skull bone.

2 Laser cut on a bovine bone with an aspect ratio of 16:1.

FAST AUTOFOCUS FOR HIGH-CONTRAST HIGH-SPEED PUPILLOMETRY

Task

In a diagnostic pupillometry examination, 1000 images per second are taken using a high-speed camera. The diagnostic measurement may or may not succeed depending largely how long the process lasts since a patient is not allowed to move his/her eye, thus requiring constant concentration. For this purpose, the focusing process preceding the measurement should be completed within one second, and the eye should be exposed for a very short period of time to avoid causing it any damage. To accomplish these – preventing damage and ensuring a short exposure – the Chair for Technology of Optical Systems TOS is helping design a fast (F# < 2.4) as well as high contrast (MTF > 0.6 @30 lp/mm) autofocus system.

Method

The system consists of three elements: a fast zoom lens, a fast focusing unit, and a fast and precise image evaluation algorithm that controls the focal length of the focusing unit. To achieve the highest possible resolution, TOS has designed an optical system to fully expose the camera's sensor size and developed a low-cost, robust, high-contrast system using optical components available from a catalog. The average distance between the objective and the eye is 45 mm and varies individually by ±10 mm. Since a liquid lens has been integrated into the system, the focal length of the objective can be changed by adjusting the lens curvature. The speed can be adjusted within a few milliseconds, and the objective has an adjustable focal length from -500 mm to +330 mm.

Results

By combining a liquid lens with a high-contrast, high-speed objective (MTF > 0.7 @30 lp/mm; F# < 2.4), TOS has developed a high-performance optical system available for medical pupillometry. As the optical system is robust, the lenses can be held by spacer sleeves in a tube without needing further adjustment. The software-based autofocus requires an average focusing time of less than 0.65 s for image evaluation and focus tracking. This increases the time window for the subsequent diagnostic measurement by several seconds compared to manual focusing.

Applications

This autofocus system is primarily designed for medical diagnostics. Further fields of application can be found in police traffic control, facial recognition, camera surveillance and monitoring of driving ability.

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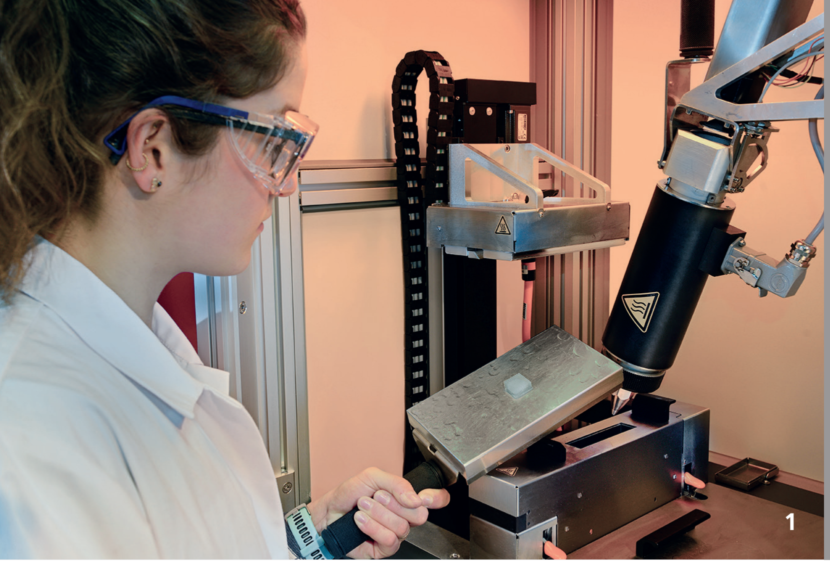
3 High-speed pupillometry in use.



ARCHITISSUE – 3D ARCHITECTURE OF BIOHYBRID HEART VALVES MADE WITH ADDITIVE MANUFACTURING

Task

As life expectancy rises, society in general ages and diseases typical of old age increase. One of the most common of these diseases is heart failure, the cause of which includes diseases or malfunctions of the heart valve. Today's heart valve replacements, whether of biological or technical origin, have several disadvantages. Biohybrid soft tissue implants represent a promising alternative in this respect. By using a durable, reinforcing scaffold as technical component surrounded by the patient's own cells as a biological component, research can exploit the innovative potential of heart valve replacements specifically adapted and highly compatible to the patient. The production of the required 3D scaffold structures is being examined using laser-based stereolithography.

Method

To fabricate 3D scaffold structures, the Chair for Laser Technology LLT and Fraunhofer ILT are using current insights into photoinitiator-free photochemical polymerization to combine it with innovative stereolithography for processing hot-melt photopolymers. The biofabrication group is developing high viscosity thiol-ene photopolymers to improve their mechanical stability and elasticity as well as their biocompatibility, and processing them with high resolution stereolithography. To tailor the mechanical properties of the 3D scaffolds, the group is also systematically exploring different unit cell designs as well as their spatial arrangement.

Results

Laser stereolithography was used to manufacture 3D scaffold structures and to adapt their mechanical properties by both dimensioning the scaffold architecture and adjusting the photopolymer composition. The unit cells used range in size from a few micrometers to a few millimeters in edge length. Proliferation and cytotoxicity tests were used to demonstrate that the polymers are biocompatible.

Applications

Biocompatible scaffolds are mainly produced for novel implants in regenerative medicine and for organoid test systems in the pharmaceutical industry. Furthermore, 3D microstructured polymeric materials can be used to open up new possibilities for producing adaptive components in the plastics industry.

The ArchiTissue project is funded by the German Research Foundation (DFG) under the reference number 403170227.

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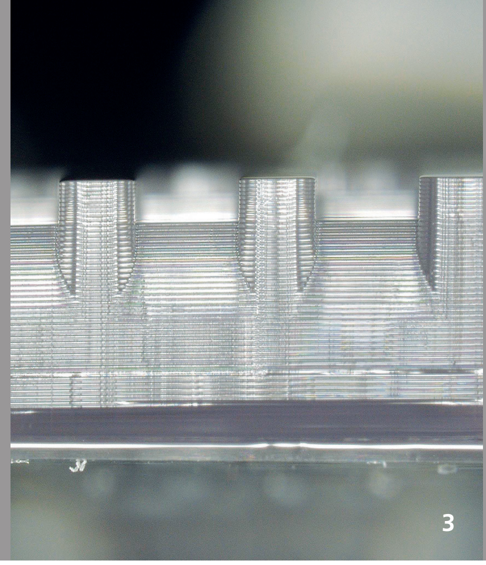
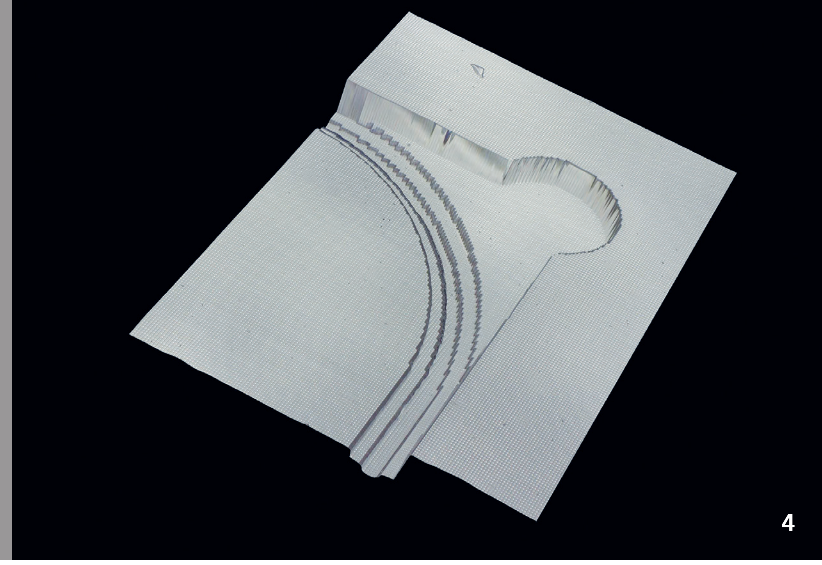
1 Removal of a 3D scaffold green body from the SLA system.
2 Light microscopic image of a 3D scaffold structure.





HIGH-RESOLUTION 3D-PRINTING BY PHOTO-CROSS-LINKING WITH SCROLLING DIGITAL LIGHT PROCESSING

Task

Injection molding is commonly used to produce microfluidic chips for diagnostic procedures, a process that makes developing new chips lengthy and expensive. Until now, sufficiently high resolution could not be achieved under economic conditions using 3D printing methods.

Method

In electronics manufacturing, the scrolling DLP (Digital Light Processing) process is already used to expose ultra-fine conductor tracks at a resolution of a few micrometers. Here, a photoresist is irradiated in a layer thickness of a few micrometers. Fraunhofer ILT has adapted the scrolling DLP process to the requirements of 3D printing and tested a machine-based solution with which components up to several centimeters high can be produced.

Results

The image field of the DLP projector is about 10 x 20 mm² with a pixel size of 10 µm. When the projector is moved (scrolled) during exposure, a large area of, for example, 40 x 100 mm² can be exposed at high resolution. The image information is scrolled line by line and synchronized with the movement so that the entire area can be exposed seamlessly and homogeneously.

Applications

The process is particularly suitable for quickly developing diagnostic chips and processes for the rapid diagnosis of pathogens and environmentally harmful substances. It can be used to produce inexpensive initial test samples for testing both the design of the chips and the functionality of the approach.

This project was funded by the European Regional Development Fund (ERDF) as part of the NRW-funded HoPro3D project under the reference number EFRE-0801252.

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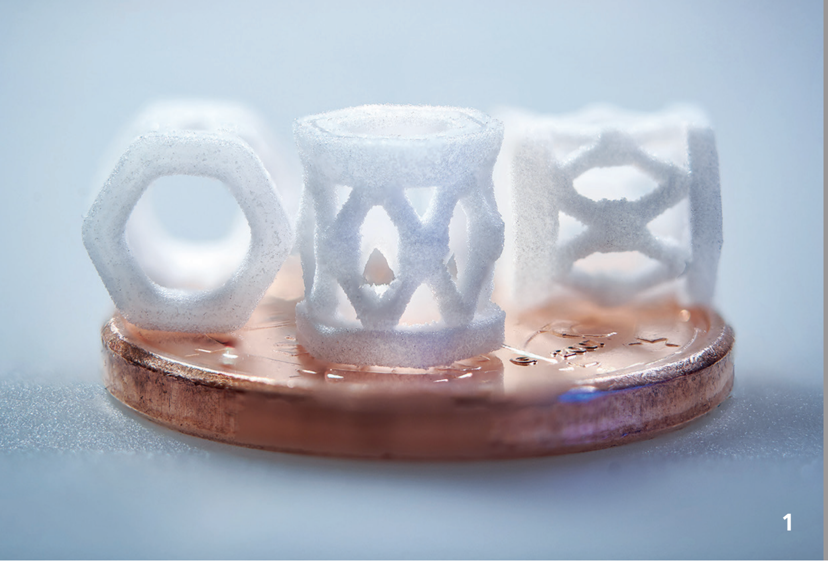
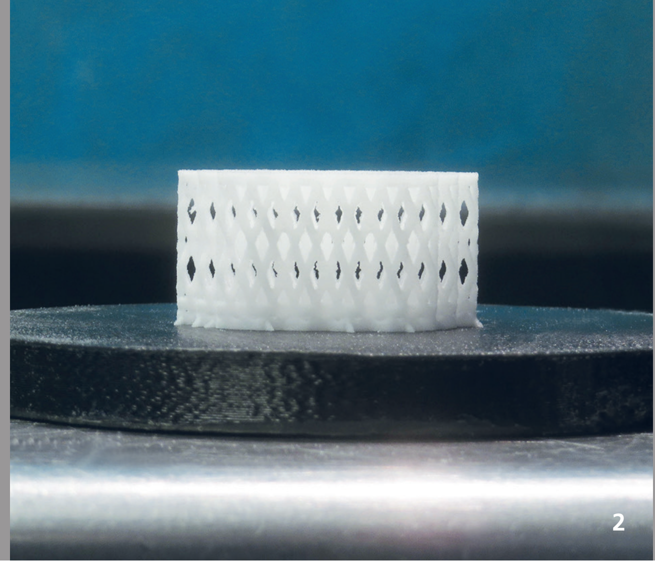
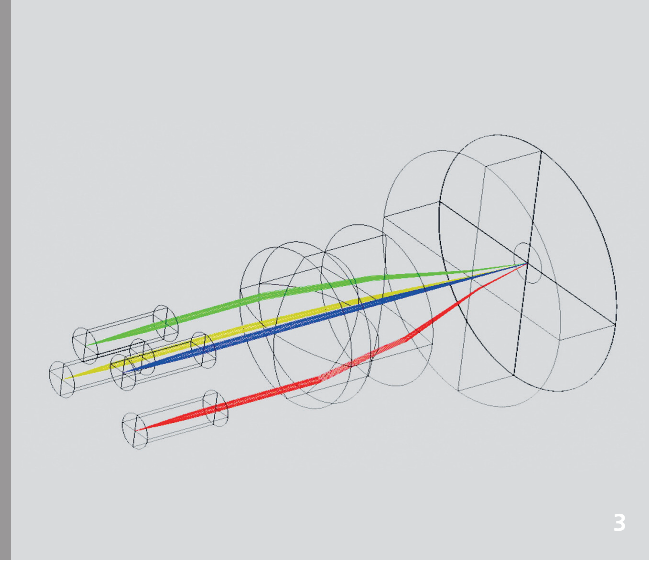
3 Side view of a microfluidic chip fabricated with DLP.
4 Microfluidic channel structure fabricated with a pixel size of 10 µm.







SELECTIVE LASER SINTERING OF BIORESORBABLE SCAFFOLDS FOR BONE REGENERATION

Task

To induce the body to regenerate bone cartilage tissue and bone via an intermediate cartilage phase, Fraunhofer ILT is developing a two-component biomaterial (a mechanical-hybrid scaffold). It consists of a soft collagen component with a directional internal control structure and bioactive microparticles in combination with a resorbable, mechanically supporting secondary structure. This secondary structure should be additively manufactured from the material PCL (polycaprolactone) by a laser sintering process so that its mechanical stability can be specifically adapted.

Method

Before support structures can be manufactured from PCL with selective laser sintering, suitable process parameters need to be determined. The challenge here lies in producing maximally fine structures to provide as much volume as possible for bone growth when the scaffold is placed in the body. At the same time, mechanical stability must be ensured by a high density achieved in the volume material. Fraunhofer ILT uses a flexibly adaptable laboratory facility for process development, which means that it can investigate boundary conditions such as powder deposition or deionization of the powder, in addition to the process parameters.

Results

With optimized process control and adapted process parameters, the institute has produced support structures with strut thicknesses less than 0.45 mm. However, structures with strut thicknesses of 0.6 to 0.7 mm turn out to be more advantageous since these structures achieve a compressive strength of greater than 35 MPa. Furthermore, in combination with collagen, mechano-hybrid scaffolds can be produced. These have already been successfully tested in animal experiments and their biocompatibility has been demonstrated in vivo.

Applications

Mechano-hybrid scaffolds can be used, for example, as medical devices to treat osteochondral defects as well as bone defects or vertebral body fusion.

The R&D project ECHO underlying this report was carried out on behalf of the German Federal Ministry of Education and Research BMBF under grant number 13XP5048C.

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1 Support structure for mechano-hybrid scaffolds for small animals.

2 Support structure for mechano-hybrid scaffolds for large animals.

OPTICAL PROCESS ANALYSIS FOR THE CHARACTERIZATION OF NANOPARTICLES

Task

In the EU project PAT4Nano, Fraunhofer ILT is cooperating with nine European partners from research and industry to develop new tools for the real-time characterization of nanosuspensions. The project is focused on applications in the fields of pharmaceuticals, dyes and fine chemicals. Based on user requirements, the group is developing metrological processes for determining the size distribution of nanoparticles and their chemical composition as well as testing them in an industrial environment.

Method

Fraunhofer ILT is using the dynamic light scattering (DLS) method to determine the size of nanoparticles from their diffusional motion. To ensure that the method can also be used in a process, the institute has equipped the optical probe with a special »inline probe head«. The DLS method is based on the temporally resolved detection of single scattered photons from a small measurement volume in the nano- to picoliter range. So that the method can be used in suspensions with high particle concentrations, photons that have been scattered many times must be suppressed since they overlay the measurement signal. This is done by cross-correlating signals from two similar light scattering events at the same position in the sample. To this end, Fraunhofer ILT is developing a compact optical system and incorporating it into an immersion probe that can be used to characterize nanosuspensions in ongoing chemical processes without having to take samples.

Results

The inline DLS probe, which has been patented by Fraunhofer ILT, was further developed to improve its flow behavior. As a result, successive measurements can be performed with even further reduced cross-contamination. The probe's optics for the cross-correlation DLS method were developed, manufactured and integrated into an immersion probe, whose focus can now be adjusted precisely.

Applications

Nanoparticles play an important role in chemical, pharmacological and biotechnological processes. In the PAT4Nano project, the focus is primarily on dispersion processes. Fields of application include the grinding of crystalline pharmacological active ingredients, the production of inks from color pigments, and the production of nanoparticulate fine chemicals for catalysts or batteries, for example.

The project is funded by the EU under the Horizon 2020 R&D program (call DT-NMBP-08-2019).

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3 Optics simulation for the cross-correlation DLS probe with two excitation and two detection channels.

4 Cross-correlation DLS probe.

LASER MEASUREMENT AND EUV TECHNOLOGY

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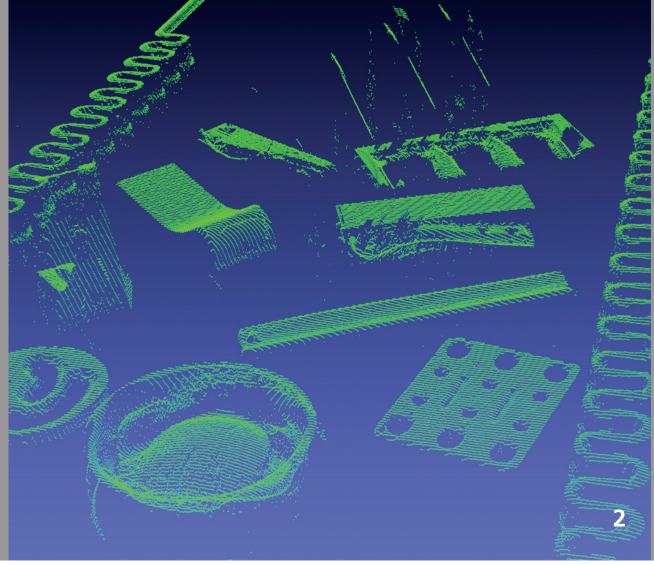

PILOT PLANT FOR LASER-ASSISTED SORTING OF SPECIAL ALLOYS

Task

Metals are valuable raw materials, some of which are crucial to industrial supply chains. They can be recycled without loss of quality, provided they are available in unmixed fractions. However, scrap metal may not be sorted manually without limitations. For this reason, a fully automated sorting process for special alloys was developed and validated in practice.

Method

Fraunhofer ILT has developed a process for laser spectroscopic, non-contact and rapid multi-element analysis (LIBS) of parts on a moving conveyor belt, a process that can identify the alloy class of scrap metal pieces. The patented approach ensures that even complex-shaped and contaminated parts are analyzed correctly. After a part has been analyzed, a delta robot grabs it and – depending on the chemical composition identified – directs it to the assigned sorting fraction. The geometric information for laser analysis and robotic discharge is captured by a laser light-sectioning sensor and calculated from the 3D images with automated image processing.

Results

Together with its project partners, Fraunhofer ILT has set up a pilot plant and put it into operation at an industrial recycling facility. This has since been used for sorting scrap metal pieces on an industrial scale. High-speed steels, titanium alloys and hard metals can be sorted into a total of up to 21 sorting fractions thanks to modern classification processes. The intelligent combination of image processing and laser spectroscopy also makes it possible to detect and correctly sort composite materials, for example an HSS drill bit with a steel shank.

Applications

The process established here can also be transferred to other areas of recycling and material testing. Using resources efficiently and sustainably requires sorted recycling in all areas and precise knowledge of the material streams involved. By automatically acquiring and evaluating measurement data on chemical composition and geometry, this process shows how future technologies, in this case intelligent data processing, can significantly expand the application potential of laser-based sorting.

The R&D project underlying this report was carried out on behalf of the German Federal Ministry of Education and Research BMBF under grant number 033R181B.

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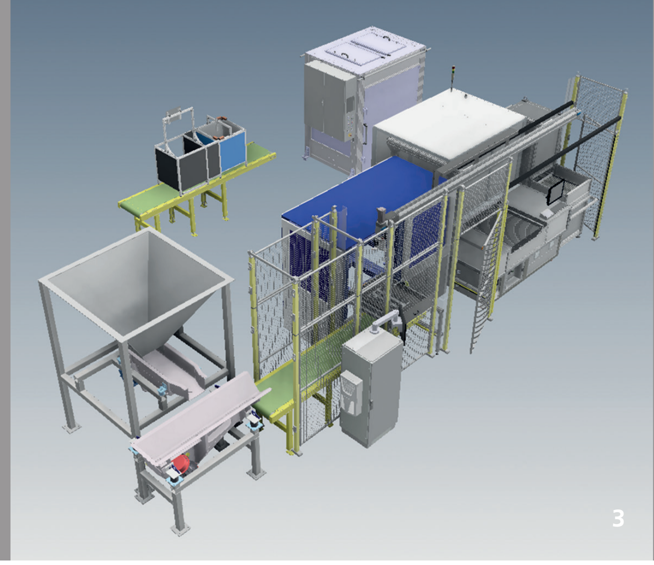
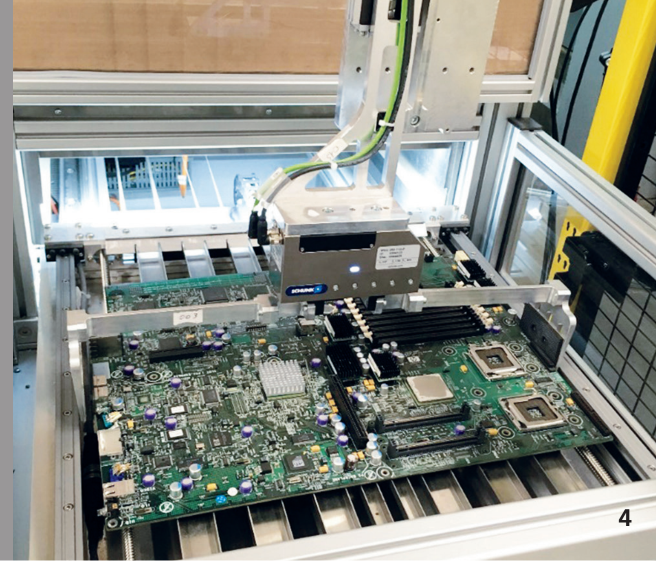
1 Pure grade titanium scrap.
2 3D detection of parts on a conveyor belt.





DEMONSTRATOR SYSTEM FOR LASER DETECTION OF ELECTRONIC COMPONENTS

Task

Modern electronic devices contain a large number of different materials, only some of which are recovered at the end of their service life by current recycling processes. However, other valuable technology raw materials can be recovered in a circular economy if they are separated into fractions with high concentrations of the target materials.

Method

The consortium of the EU project ADIR has developed an automated demonstration line for the targeted removal of electronic components from end-of-life electronics. A key point here is to provide information on where which components are assembled and which materials they contain. This information is obtained using image processing, 3D laser measurements and laser spectroscopy, and then stored in a database.

Results

An inspection system was built and integrated into the demonstrator: It receives electronic circuit boards from preprocessing, produces high-resolution color images, and then measures the 3D height structure on the board. The results are compared with those of known printed circuit boards (PCBs) already stored in the database. The materials of unknown components are identified using laser-induced breakdown spectroscopy (LIBS); the components are evaluated – supported by image processing software – to identify which target fractions are present. This system creates a digital twin of all processed PCBs, which can be used in the subsequent process step to selectively remove and sort valuable components by laser de-soldering. The process has already been successfully tested in field trials at a recycling plant. Specialized metallurgical plants have recovered valuable materials, such as tantalum as a secondary raw material, from the enriched sorting fractions. The ADIR project consortium demonstrated that the entire recycling concept operates efficiently at both the Berlin Recycling and Secondary Raw Materials Conference on March 2–3, 2020 and the Mineral Recycling Forum on March 10–11, 2020 in Aachen, Germany. The system sorted around 1000 disassembled cell phones and more than 800 printed circuit boards.

Applications

When information about the structure and material composition of end-of-life devices is lacking, recycling raw materials at high-quality faces a great obstacle. This is where digitally networked optical measurement technology can close the gap and enable society to efficiently recycle and save resources.

The work was carried out as part of the EU project ADIR under grant number 680449.

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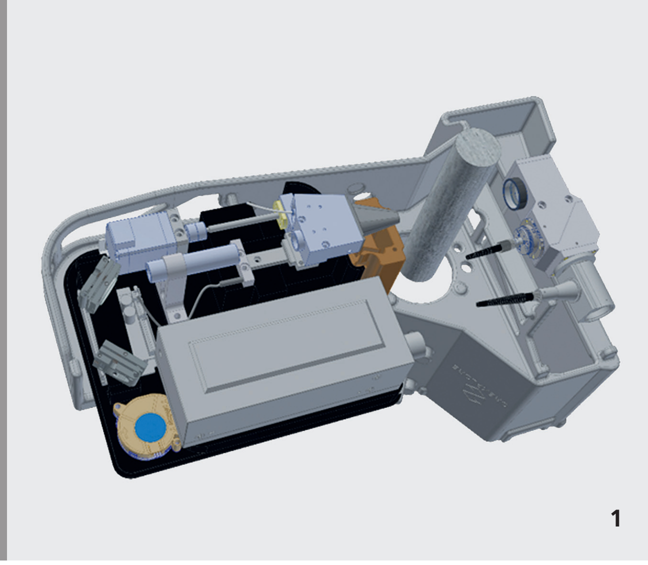
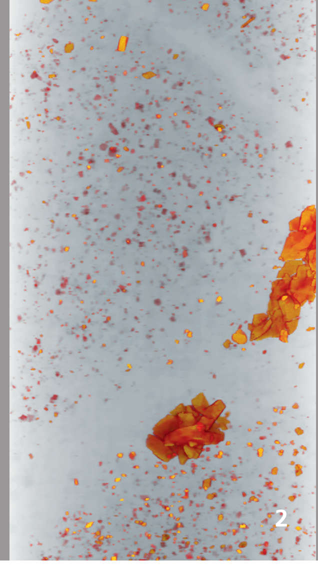
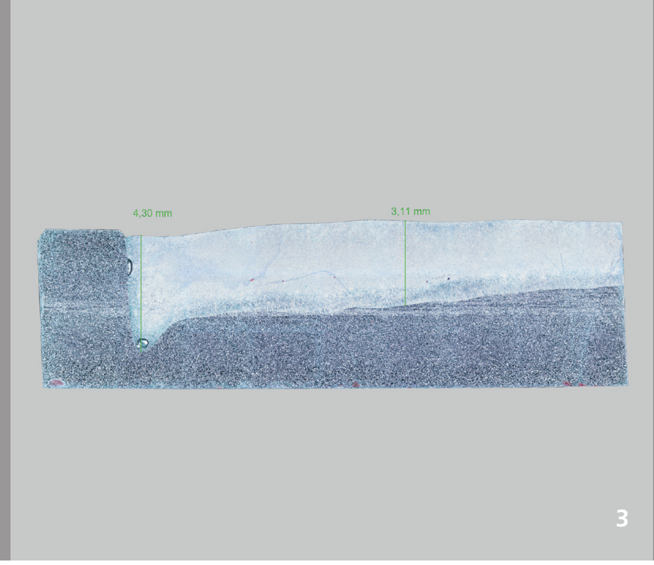
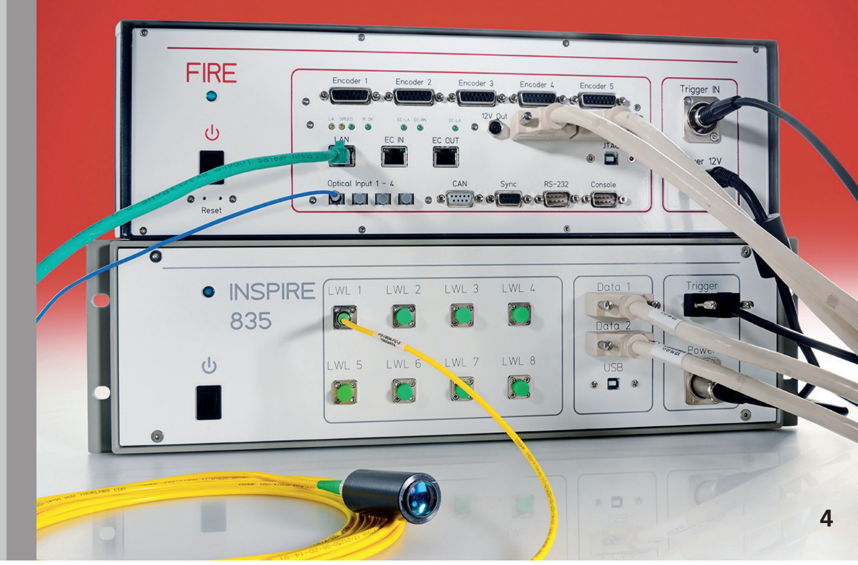
3 CAD drawing of the demonstration line.
4 Automatic transfer of a printed circuit board to the inspection system.









SPATIALLY RESOLVED ANALYSIS OF LIGHT ELEMENTS IN DRILL CORES

Task

During geological exploration, drill core samples must be examined in detail to identify rock formations. These core samples can provide clues to deposits of valuable raw materials. In order to examine the materials automatically, the industry has developed drill core scanners with X-ray technology that can detect, above all, heavy elements. Laser analytics is being examined, however, to detect additional elements as well as minerals.

Method

Laser-induced breakdown spectroscopy (LIBS) can measure almost all chemical elements, including the light elements, which are of great importance for the evaluation of rock samples. Such samples can be spatially analyzed with focused laser excitation. Fraunhofer ILT has developed a measurement process that can be set up with a compact sensor module; a second measuring system based on laser Raman spectroscopy is able to identify chemical bonds. This way, the process is able to specifically detect which individual minerals are present.

1 Laser sensor for integration into a drill core scanner.

2 3D representation of the chemical composition of a drill core (© Orexplore).

Results

To integrate laser analysis into an existing industrial drill core scanner, Fraunhofer ILT has developed a concept to arrange the optical sensors precisely in the free installation spaces of the scanner. This allows the laser spectroscopic measurements to be performed simultaneously with the X-ray measurements. While the drill core is rotated, the sensors travel the entire length of the core to obtain a spatially resolved image of its composition.

Applications

The combined measurement process speeds up the analysis of drill cores obtained during geological exploration and simplifies the interpretation of their composition. The geological formations at the site of investigation can, thus, be examined more efficiently for the presence of valuable raw materials or for properties such as rock stability.

The project demonstrates how compact laser spectroscopic sensors can be integrated into existing systems, thus considerably expanding their possible applications.

This project was funded by the European Institute of Innovation and Technology EIT RawMaterials under the reference number 16275.

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WELDING DEPTH MEASUREMENTS WITH RAPID VARIATION OF LASER POWER

Task

In laser welding processes, camera systems and pyrometers are commonly used to monitor the melt pool and document the treatment process. Another important process parameter is the welding depth, which can be controlled using easily adjustable system parameters such as laser beam power and traverse speed. When components have complex geometric shapes, varying distances between the welding optics and the workpiece surface can lead to different spot diameters and, thus, to variations in the welding depth.

Method

Fraunhofer ILT has developed inline-capable, interferometric sensors for geometry measurement meeting the highest accuracy requirements. These sensors of the »bd-x« family have already been successfully put into operation for inline thickness measurement on rolled metal strips and foils. Now, for the first time, the »bd-x« sensors have been tested under various process conditions for measuring the welding depth in laser-beam welding. At fixed feed rates between 6 m/min and 14 m/min, the laser beam power was varied linearly between 0.5 kW and 6.0 kW in each case. On a welding length of 40 mm, the spot diameter of the welding laser was 600 µm. The spot diameter of the interferometric sensor was 70 µm; it was initially aligned to the keyhole at a feed rate of 8 m/min and was not changed during the entire test series.

Results

When measuring at a frequency of 70 kHz, the interferometric sensor system delivered 30 to 60 depth readings per millimeter of welding length, depending on the traverse speed. In superimposed images of microscopic cross-sectional micrographs, these measured values could be clearly assigned to the local welding depths.

Applications

In combination with FIRE – the real-time capable data processing electronics developed at Fraunhofer ILT – the interferometric sensor technology can be used to control production processes, e.g. by adjusting the laser beam power during the welding process. With a delay time of only 110 µs between measurement and output of an analog control voltage, the interferometric sensor technology can quickly and accurately control welding processes with high quality requirements.

INSPIRE, the collaborative R&D project underlying this report, was carried out with funding from the German Federal Ministry of Education and Research BMBF, among others, under grant number 13N14290.

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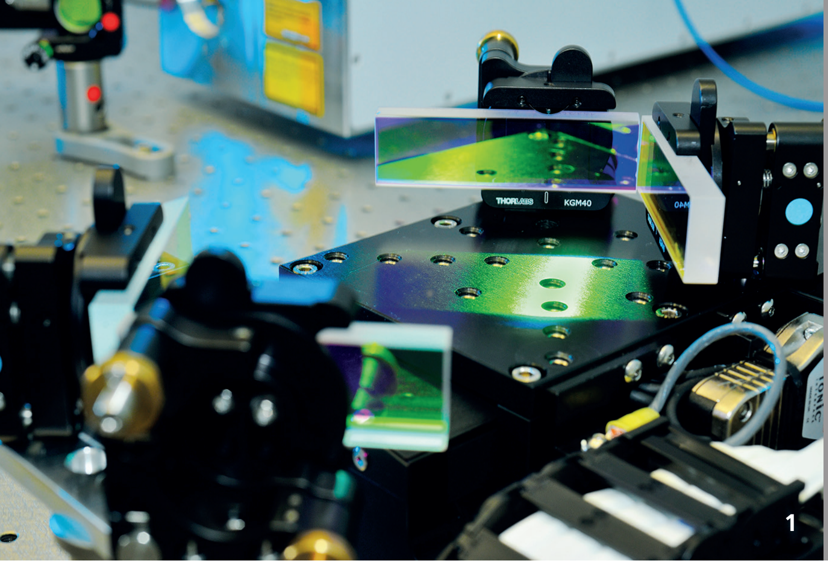
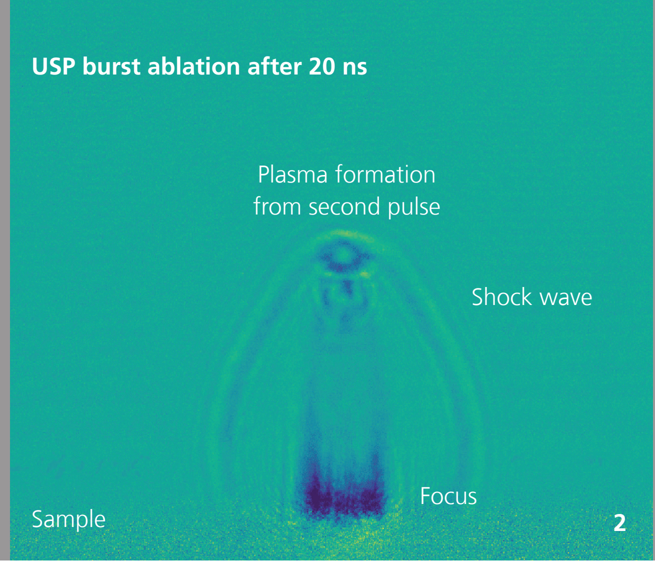
3 Transverse micrograph of the blind weld with linear variation of the laser beam power.

4 »bd-4« sensor technology and data processing electronics.





IN-SITU ANALYSIS OF LASER MACHINING PROCESSES USING PUMP-PROBE MICROSCOPY

Task

Although machining processes using ultrashort pulsed (USP) laser radiation provide high quality results, their productivity is still currently low compared to conventional processes. To increase productivity using high-power beam sources, research is using approaches based on high pulse-repetition rates for faster beam deflection, pulse bursts and multi-beams for parallel processing. Furthermore, scaled material processing can yield additional accumulation and shielding effects, as well as altered absorption. Understanding these effects is essential to control energy deposition in the workpiece. Pump-probe microscopy makes it possible to analyze and observe these excitation, shielding and accumulation effects during the process.

Method

A pump-probe system with high repetition rates and burst configuration has been developed to observe accumulation effects. The sample pulse is used for shadow photography of the modification generated by the pump pulse. The USP beam sources, which were specially developed by project partner TRUMPF GmbH & Co. KG, enable shadowgraphs to be made over a particularly long observation period. A microscanner from the project partner LightFab GmbH is used for rapid beam deflection.

Results

With the system implemented at Fraunhofer ILT, the institute was able to analyze shielding effects between burst pulses on material surfaces with a time resolution of 300 fs. In addition, it could investigate nonlinear absorption effects in the volume of transparent materials. The system is particularly suitable for analyzing pulse-to-pulse interactions for almost any spatially shaped beam distributions. Thus, a wide variety of tailored USP ablation processes can be depicted and analyzed in-situ.

Applications

The system offers high-resolution spatial and temporal process diagnostics for highly repetitive USP processes on surfaces of almost all materials and, moreover, in the volume of transparent materials. Applications range from large-scale de-coating processes for the glass industry, to scaling for the fabrication of microfluidics for medical technology, all the way to the creation of minute geometries for the semiconductor industry, or devices for quantum technology end-use applications.

The R&D project underlying this report was carried out on behalf of the German Federal Ministry of Education and Research BMBF as part of the funding initiative »Femto Digital Photonic Production« (Femto DPP) under grant number 13N13307.

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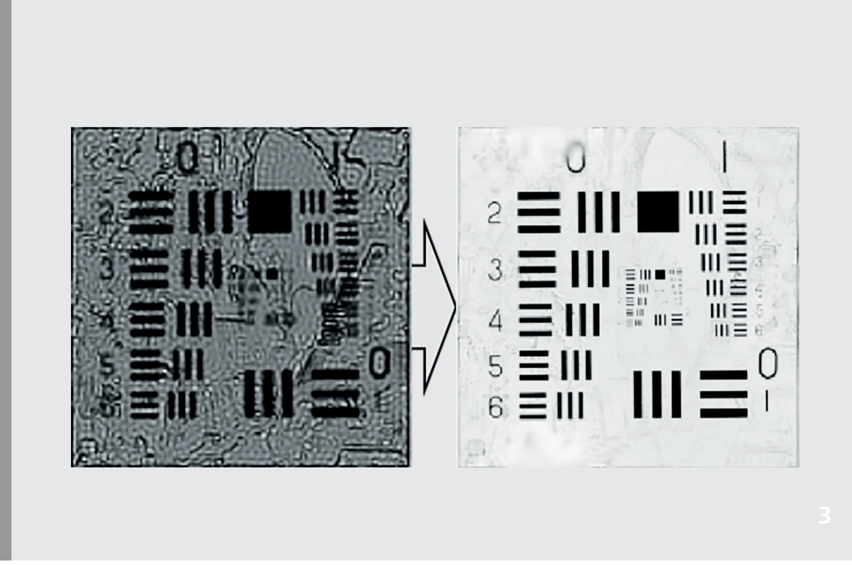
1 Highly repetitive pump-probe system (processing station).
2 In-situ analysis of multispots.



FOURIER PTYCHOGRAPHY FOR FAR-FIELD MICROSCOPY

Task

Process monitoring is becoming an increasingly relevant topic in almost all industrial processes in the Fourth Industrial Revolution. In metal processing, for example, light microscopy is often used for this purpose: to detect and analyze surface defects. However, the microscopes used are expensive and the complete scan of a macroscopic object is extremely time-consuming.

Method

The Chair for Technology of Optical Systems TOS is developing an optical setup based on Fourier ptychography, which, with a laser and a CCD camera, can generate algorithm-based images at a higher resolution than those generated conventionally by optical methods. This is achieved by mechanically moving an aperture to different positions and taking a low-resolution image after each shift. From the sum of these images, a single, higher-resolution image can now be recalculated using an optimization process. Thus, with inexpensive components and a working distance of about 50 cm, the setup can generate wide-angle images whose resolution can compete with that of conventional light microscopes.

Result

TOS has successfully implemented an optimization algorithm to generate the high-resolution image. Furthermore, it has set up an experimental system that has increased image resolution. Future developments include further increases in resolution by adapting the measurement method and algorithm.

Applications

The process can be applied to all industrial systems that use optical methods for process monitoring. It is particularly useful in those processes that benefit from microscopic imaging, but that cannot be used with the small working distance of conventional microscopes.

This project has been funded by the German Research Foundation (DFG) as part of the German Federal and State Excellence Strategy – EXC-2023 Internet of Production – 390621612.

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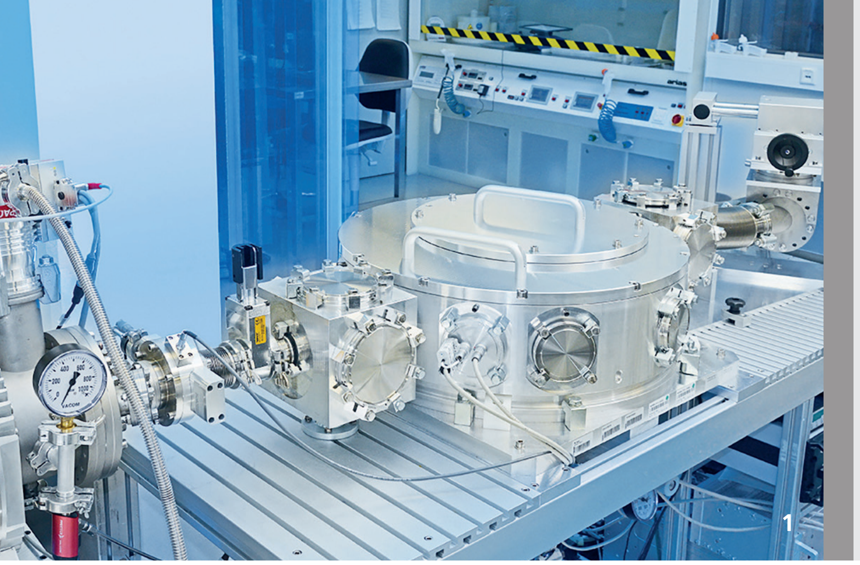
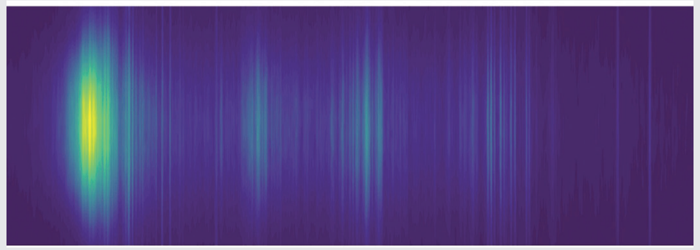
3 Resolution enhancement by iterative algorithm.





EUV MEASUREMENT TECHNOLOGY FOR INDUSTRIAL SEMICONDUCTOR PRODUCTION

Task

For the latest generation of microchips, the semiconductor industry commonly uses lithographic processes – with radiation of ever shorter wavelengths, currently extreme ultraviolet (EUV) radiation at 13.5 nm – to fabricate ever smaller and more complex structural arrays. Supporting metrology processes are required to meet the increasing demands resulting from this miniaturization. Compared to conventional photonic measurement processes, EUV metrology offers considerable advantages because it is highly sensitive to structures with nanoscale dimensions that lie within the resonance range of the radiation. Moreover, EUV radiation can also be used for actinic measurement processes, i.e. processes that use the same wavelengths as lithography systems.

Method

An EUV spectrometer is used to measure the reflectance of material and nanostructured samples in the wavelength range from 8 nm to 17 nm at various angles of grazing incidence. The optical constants and other geometric and chemical properties of the sample can be reconstructed from the determined reflectance values using model-based methods. These include the nanoscale structural dimensions of periodic surface structures, layer thicknesses and roughnesses of multilayer systems, and the stoichiometry and density of materials.

Results

The optical constants of novel materials could be determined in the EUV spectral range from 8 nm to 17 nm. Nanoscale grating structures and multilayer systems can be characterized at a resolution in the sub-nm range.

Applications

The development of the measurement process goes hand in hand with the latest generation of semiconductor products. For example, this process can be used to characterize novel absorber materials for mask fabrication. In addition, the compact design of the EUV spectrometer makes it suitable for direct process monitoring in semiconductor manufacturing.

The work presented here was funded by the EU within the framework of the ECSEL Joint Undertaking under grant number 783247 and by the German Research Foundation (DFG) under reference number 415848294.

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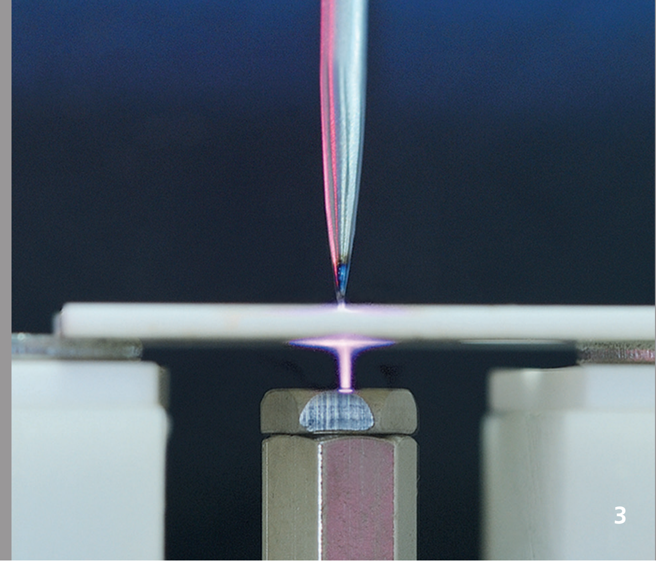
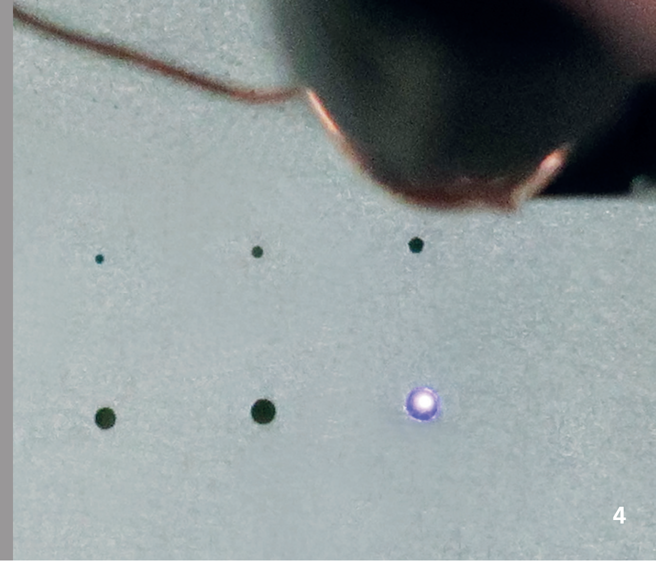
1 Experimental setup of the EUV spectrometer.
2 Measured EUV spectrum.





COMPACT AND BRILLIANT UV-VIS LIGHT SOURCE FOR ANALYTICS

Task

Barrier discharges have long been used as efficient light sources, e.g. as excimer emitters. In such sources, short-lived plasma filaments are generated in a gas at atmospheric pressure by applying a pulsed or high AC voltage, thus efficiently converting electrical power into light. It should then be possible to create a radiation source of high brilliance if the light can be coupled out along the filament axis and if the filaments are always ignited at the same position. Such an approach has not yet been pursued.

Method

Fraunhofer ILT has conducted initial experiments to investigate how light can be generated and radiation coupled out along the filament axis. The electrode system used consists of a pointed electrode and a flat counter electrode with an opening. The tip allows the filaments to be ignited in a stationary manner; the emission is coupled out along the axis through the opening of the counter electrode.

Results

First, the institute demonstrated that the stationary ignition of the filaments was feasible. Figure 3 shows the emission in temporal average whereupon it reaches a diameter of a 100 to 300 µm. Experiments with ambient air showed that the emission of the intense nitrogen lines between 300 nm and 400 nm is comparably high from axial and lateral directions of observation. For excimer radiation this is given by the mechanism of light generation in the plasma.

Applications

The generation of single-filament discharges makes it possible to design very compact brilliant light sources, which in particular enables new applications in online analytics. One example is compact 2D fluorescence probes, in which different wavelengths are generated in an array of several single-filament discharges in combination with spectral filters for fluorescence excitation of a target.

The 2D intensity distribution can be used to draw conclusions about pollutants contained in water, for example. Thanks to this technology, significantly more information can be obtained than with the absorption measurements at a fixed wavelength, which are widely used in water analysis today.

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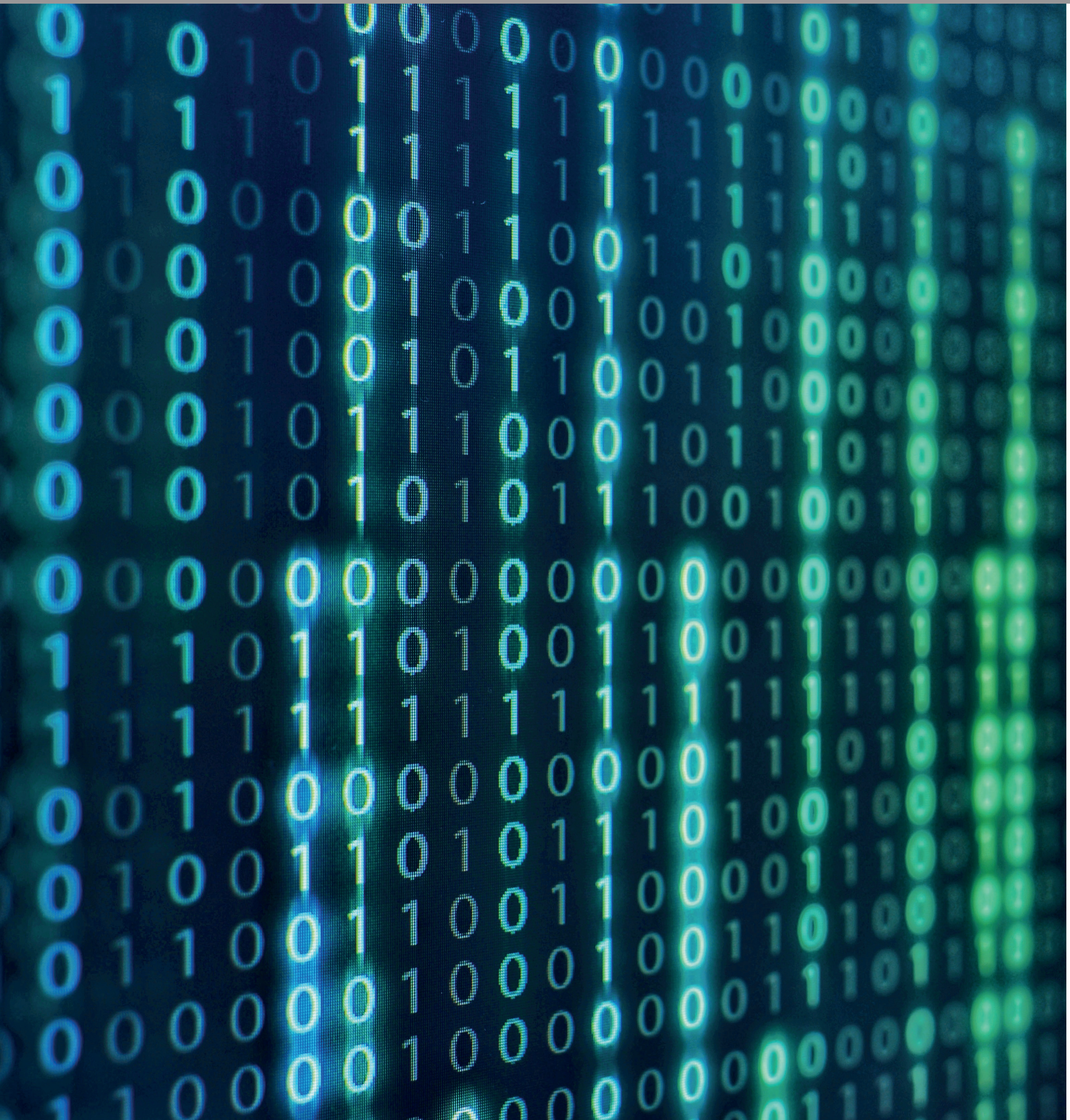
3 Side view of a single filament barrier discharge.
4 Single filament barrier discharge in axial direction of observation.

DIGITALIZATION



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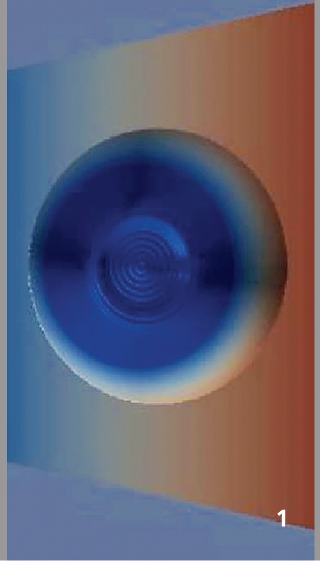

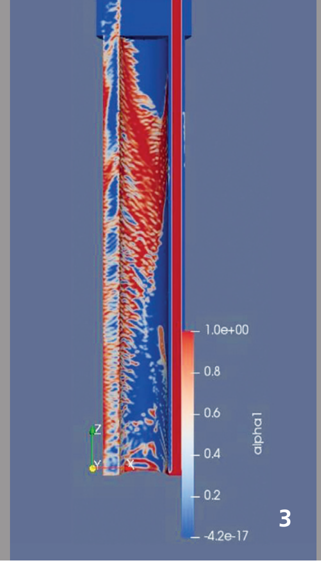

SIMULATION OF THE STABILITY OF A WATER-JET-GUIDED LASER BEAM

Task

Drilling and cutting with water-jet-guided laser radiation is an established manufacturing process. To better understand its physical limits and technical potential, research uses modern numerical tools such as OpenFOAM to develop reduced models and run simulations having short computation time. The reduced models are calibrated with experimental data and can correctly describe relevant properties. Moreover, they generate a large number of computational results to predict the geometric shape of the ablation, the dynamic stability of the water jet and the thermomechanical loading of the material. These powerful reduced models are applied to advance the manufacturing process and flexibly develop the product using a data-based »process map«.

Method

The so-called volume-of-fluid (VoF) method makes it possible to calculate the flow of multiphase interacting phases, i.e. the liquid phase of a water jet, which guides the laser radiation, and the gas phase surrounding the gas jet. By taking into account how compressible the outflowing vapor and the surrounding gas are, Fraunhofer ILT is able to analyze the stability and range of the light-guiding water jet in a spatially three-dimensional ablation cavity. The simulation is run with a parallelized OpenFOAMCode to reduce the computation time of the dynamic process. Automatic image processing is used to calculate the integrity of the water jet to then quantitatively characterize its degree of stability in the ablated cavity. In a multidimensional process map, the degree of stability is presented as a function of the parameters for the manufacturing process and the geometric characteristics of the ablation cavity.

Results

A simulation – using automatic post-processing to analyze water-jet stability – is organized into a spatial three-dimensional cavity as a tool chain. The virtual tools can be used to quantify stability of the water jet in the Laser MicroJet® (LMJ) process.

Applications

The dynamic simulation of a multiphase flow and its tools for analysis developed at Fraunhofer ILT are applied to evaluate the achievable quality of the LMJ process and improve its productivity. The virtual tool can be transferred to other manufacturing processes that have dominant ablation by melt removal.

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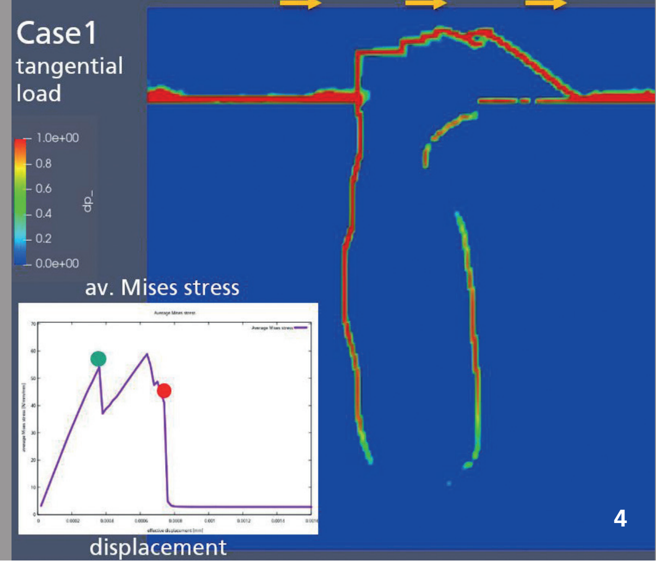
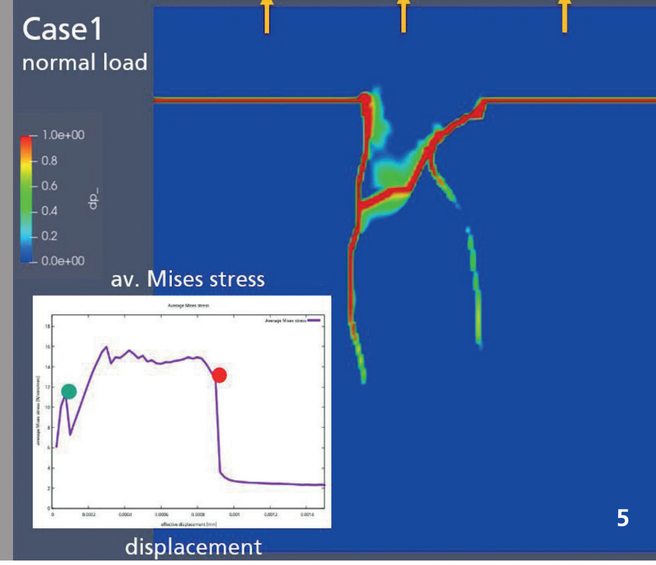
1,2 Simulation of an inclined borehole, side view (1) and top view (2).

3 Simulation of the flow of a water jet in a trepanning borehole.





SIMULATION OF THE BONDING OF METAL-PLASTIC COMPOUNDS

Task

The industry is increasingly using material joints made of plastic and metal in lightweight construction or assemblies made of hybrid materials. Metals are usually applied, however, in places where high mechanical loads are present. Depending on the requirements, many components can be made of plastics, which have the advantage of being lighter. The challenge of combining such materials is often the joining technology. Bonding them with lasers raises questions, however, concerning adhesive strength. The interface between metal and plastic plays an important role and is defined by the shape of the metallic joining partner to be structured beforehand.

Method

Laser-beam bonding consists of two manufacturing steps, namely structuring the metallic joining partner and heat conduction joining. By simulating the structuring of a metal surface and evaluating the image of the experimental results, Fraunhofer ILT can provide input variables for calculating the strength of a joint. When the mechanical properties of metal, interface and plastic are combined and then characterized as linear elastic, orthotropic linear elastic and nonlinear hyperelastic, the behavior of the joint under load can be determined and calculated numerically. Furthermore, when the mechanical properties of a single structural element are calculated as a »Representative Volume Element RVE«, these properties can be transferred to more complex structures. For example, the properties of a single line can be used to calculate the properties of multiple or crossed lines.

Results

The depth, width and undercut of the structured surface of the metal are relevant features for designing the geometric shape of the metal-plastic interface and, thus, determine the achievable strength as well as the behavior during failure. The results for loading in the tangential (Fig. 4) and normal directions (Fig. 5) help us fundamentally better understand the dominant influence of the strength of the plastic as well as the geometric shape of the structured metal surface. Furthermore, they establish criteria for determining the material combinations and structural parameters.

Applications

The mechanical simulation approach can be transferred to a wide variety of layered (orthotropic) structures, such as assemblies containing electrically conductive and electrically insulating parts, or layers for thermal insulating turbine components.

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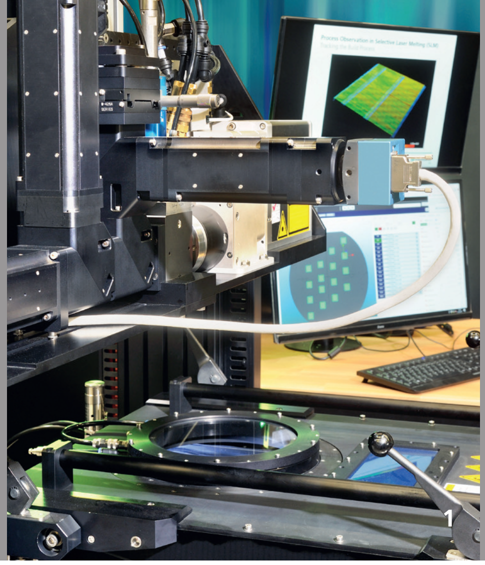
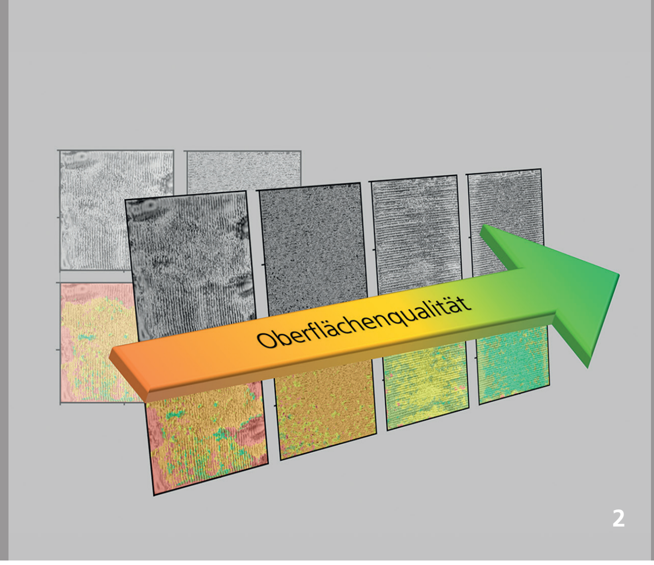
4 Onset of failure (green) and fracture (red) under tangential loading.

5 Failure under load in normal direction (arrows).





REINFORCEMENT LEARNING FOR THE OPTIMIZATION OF SURFACE ROUGHNESS IN LASER POWDER BED FUSION

Task

In addition to recognizing patterns in complex data streams, artificial intelligence can make further contributions to increasing the efficiency and quality of laser material processing. In practice, it has been shown time and again that unwanted deviations in component surface quality occur during laser powder bed fusion (LPBF) since a wide variety of variables influence the results. To compensate for such cross-layer process deviations, conventional control systems are often unsuitable for representing the complex interaction mechanisms in laser material processing due to the assumptions made during the design phase.

Method

Machine learning processes can provide a remedy by having an AI algorithm integrated into the machine learn an optimized strategy to meet the defined process goals based on real measurement data. To this end, Fraunhofer ILT is developing a process for laser powder bed fusion (LPBF) that first uses a convolutional neural network (CNN) to evaluate the surface roughness of LPBF components layer by layer using high-resolution HDR camera images of the component surface.

In the next step, reinforcement learning (RL) is used for the software agent to learn a strategy so that it can set the process parameters for the next component layer. Based on the surface image data evaluated by the CNN, the agent learns how to select process parameters adapted to the situation, a selection that results in the lowest possible surface roughness and a low number of surface defects.

Results

The process has been tested on the basis of real data under laboratory conditions and shows that it successfully improves surface quality while needing only a few layer-by-layer parameter adjustments. In further investigations, Fraunhofer ILT will examine the ability of the system to automatically and continuously adapt the learned parameter strategy to new process situations and target variables.

Applications

The method can basically be transferred to other machining processes and also used to optimize as well as control a process in real-time if the measurement technology is adapted accordingly.

The work was carried out as part of the EU project QU4LITY under grant number 825030.

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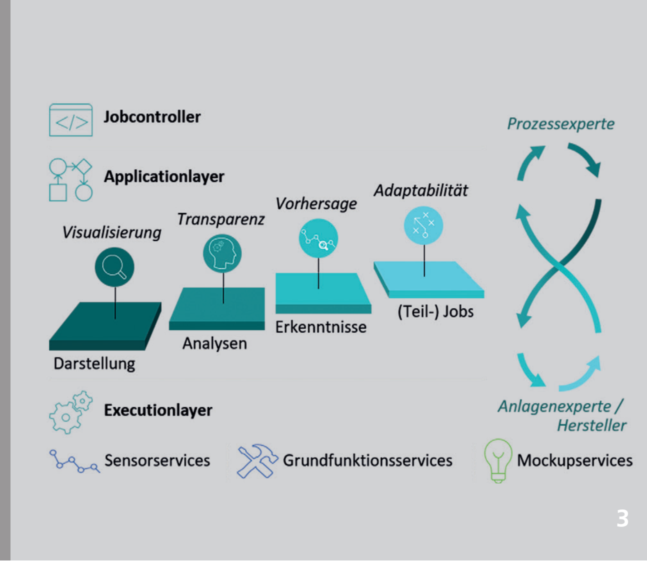
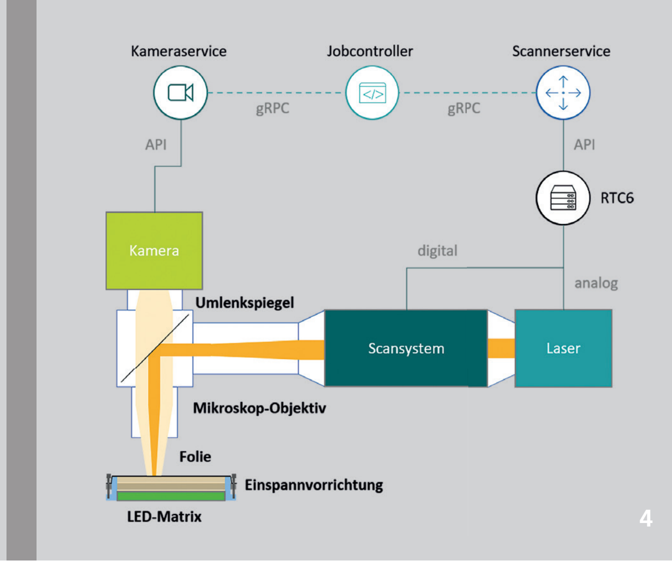
1 Experimental setup for in-situ process monitoring during LPBF.
2 AI-based roughness analysis of LPBF component surfaces.





DIGITAL MICROSERVICES FOR LAYER-BASED LASER PRODUCTION

Task

Laser-based production benefits from the initiative arising out of the Fourth Industrial Revolution and the concomitant digitalization of plant technology, the latter of which increases flexibility in production. The individual composition of digital services can positively influence the laser, characterized by its precise and fast positioning, and improve its features for production.

Method

Digital service processes make it possible to detect imperfections in layer-based laser manufacturing processes such as ultrashort pulse (USP) laser processing and laser powder bed fusion (LPBF) and react to them dynamically in the subsequent layer. These digital services can both monitor quality or be used for process control. Since control processes are dependent upon product, process and sensor, they must be adapted dynamically – to accomplish this, machine learning can be used. Based on real measurement data, an AI algorithm learns a strategy to achieve the desired process goals. The hardware platform chosen allows the process target agents to be replaced easily or updated.

Results

In collaboration with the Chair for Laser Technology LLT at RWTH Aachen University, Fraunhofer ILT has developed a platform that dynamically loads control algorithms from on-premise data centers or the cloud into the processing system. Analysis, monitoring and control services can be automated and accessed in seconds with this platform, which is scalable to an unlimited number of plants.

This workflow helps users develop further services. Errors in programming are detected at an early stage by virtual machine components, thus reducing development times. The platform enables new business models such as subscription-based leasing of analysis algorithms.

Applications

The platform can be transferred to other machining processes and, if adapted accordingly, can also provide components and services for other processes.

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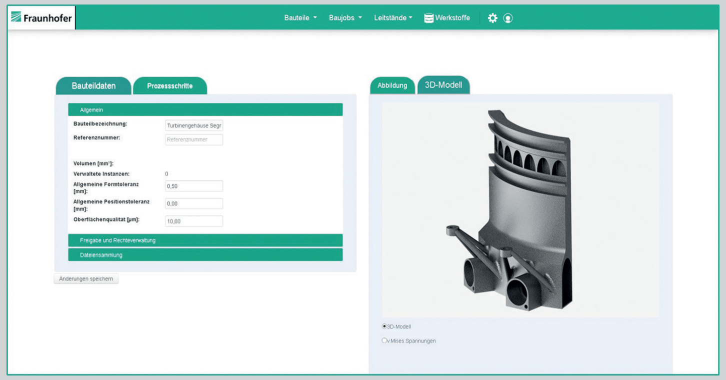
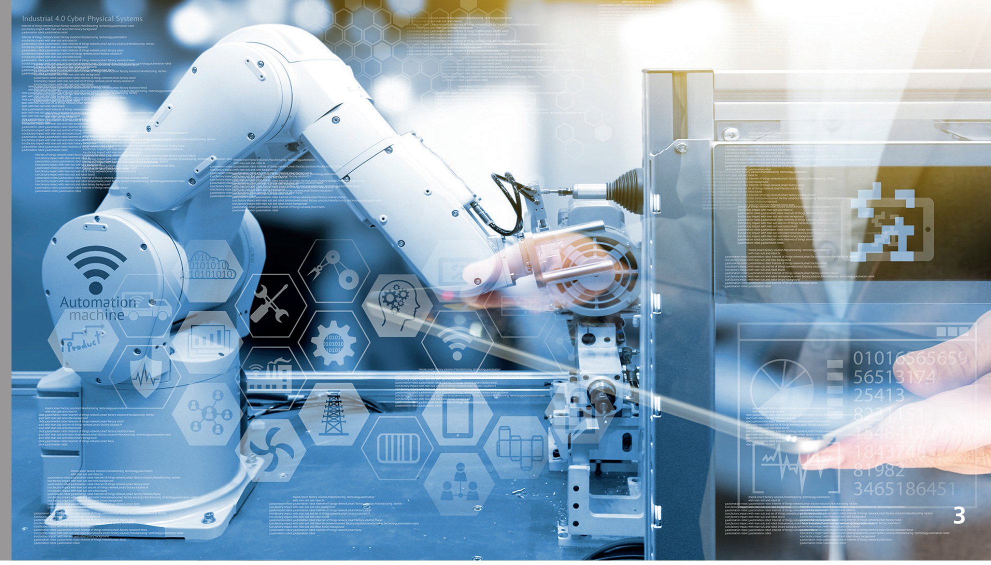
3 Schematic representation of the services framework for fulfilling various maturity levels of the Fourth Industrial Revolution.
2 Communication flow between scanner and camera services in the context of adaptive control for USP.





VIRTUAL LAB – CENTRAL DATA STRUCTURE ACCORDING TO THE AM PROCESS CHAIN

Task

In the Fraunhofer lighthouse project futureAM, the expertise of four Fraunhofer institutes was combined to achieve technological leaps along the entire additive manufacturing process chain. These institutes have broad and deep technological know-how as well as unique technical equipment in the field of additive manufacturing. The project aimed to make this know-how digitally available via a central data structure and to enable efficient cooperation between the institutes. To this end, they accelerated the development of a »Virtual Lab«.

Method

Based on the requirements, a distributed system was implemented, consisting of the Virtual Lab itself (centralized) as well as several database instances internal to each institute (decentralized). The back end of the Virtual Lab is based on a comprehensive data model; the front end on so-called dashboards according to the core competencies of the four participating institutes: part management and design (Fraunhofer IAPT), process and machine condition monitoring (Fraunhofer ILT), powder and material characterization (Fraunhofer IWS), and post-processing and acceptance (Fraunhofer IWU).

Results

Each entity (machine, part, etc.) is assigned a digital image and links to other entities. Thanks to the Virtual Lab, it is possible to assign parts to machines (e.g. depending on machine utilization), to adjust relevant process parameters in the production flow (e.g. process route depending on machine availability) as well as to take product (surface quality etc.) and production targets (lead times, delivery times) into account. Thus, an internal product memory has been realized, whereby required master and transaction data are mapped along the product life cycle. Live data (e.g. sensor data) are queried during the manufacturing and post-processing processes using OPC-UA and published in the Virtual Lab via the institutes' database instances.

Applications

The Virtual Lab can be used as a central platform to manage and transfer data along the entire AM process chain and forms the basis for efficiently planning and monitoring production processes.

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1 Physical part.

2 Digital part storage.

SCIENTIFIC DATA HUB

Task

Today, interdisciplinary teams of experts are increasingly needed to develop new solutions in design and manufacturing. When different departments cooperate closely and when there are many alternatives for a technical solution, data accumulate in such a variety that they cannot be properly structured and maintained with classic tools. Often, new materials or processes have to be adapted to changed requirements even during the process and equipment development.

Method

The core of integrated development is being able to trace and replicate the procedure and the data thus generated and to evaluate them correctly. Ideally, users should be able to comprehend how the knowledge was gained at any time, while also taking into account the boundary conditions. Systematic storage of experimental results is just as important here as following workflows when tests are carried out. The simple use of the solution must always be in the foreground.

Results

The concept of the Scientific Data Hub implements the best of software development, content generation on the web and systematic procedures in scientific research. Workflows are specified at critical points, versions saved during analyses, and status reports summarized by all users jointly. This procedure creates an environment with maximum flexibility and is comprehensible for sustainable development of manufacturing technologies.

Applications

The principles of the Scientific Data Hub are essentially aimed at solving tasks in the field of research and development. When transferred to industrial sector, the hub could also open up potential to continuously improve quality and efficiency in manufacturing.

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3 Data from production in central access, © zapp2photo – stock.adobe.com.

QUANTUM TECHNOLOGY

CONTENTS

QUANTUM IMAGING WITH NON-DETECTED PHOTONS IN THE MID INFRARED RANGE

Task

Entangled photon pairs with widely shifted wavelengths can be generated by means of spontaneous parametric down conversion (SPDC). The Fraunhofer QUILT project is investigating how this can be used for imaging applications in wavelength ranges that are difficult to access.

Method

Within the QUILT project, Fraunhofer ILT is developing quantum interferometers that allow imaging analyses in the near (NIR) and mid infrared (MIR). Here, measurement wavelengths in the range from 1.5 to greater than 4.5 µm can be demonstrated. The associated detection wavelengths are in the visible spectral range and can be evaluated with sophisticated and cost-effective silicon-based camera systems. The photon pair sources newly developed for the application are based on lithium niobate crystals pumped by an optically-pumped semiconductor disk laser at 532 nm.

Results

In a first interferometer with measurement wavelengths in the near infrared, it was possible to investigate fundamental interactions and to derive optimization criteria for the performance of the systems. Subsequently, Fraunhofer ILT developed an MIR quantum interferometer with which it was now possible to demonstrate imaging in the mid-infrared for the first time. To cover as large a wavelength range as possible in a single setup, the interferometer is constructed in a special long-pass configuration with broadband-coated optics.

Although the interferometer is illuminated at extremely low photon rates (~100,000,000 photons/second), short integration times of the CMOS camera – well below one second – can be used for imaging. Currently, the institute is analyzing methods for image acquisition with optimized imaging quality and refining them on the basis of this interferometer.

Applications

The existing setup will be used to carry out investigations for applications in life sciences and materials testing, among others. Furthermore, the results of this work will be transferred to a demonstrator for quantum coherence tomography, which will be used in industrial manufacturing processes.

The work is being financially supported by the Fraunhofer-Gesellschaft as part of the QUILT lighthouse project.

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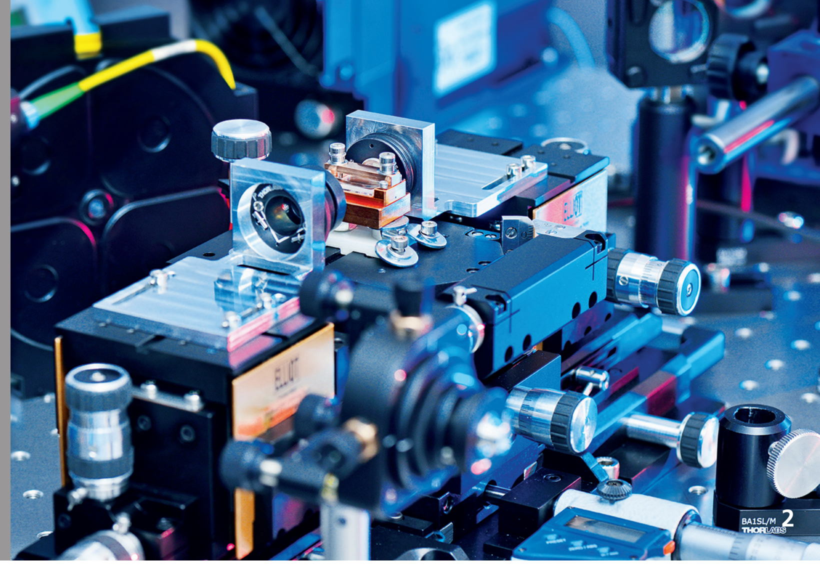
1 Nonlinear interferometer for quantum imaging.



CHARACTERIZATION STATION FOR WAVEGUIDE-BASED PHOTON PAIR SOURCES

Task

Sources of single photons and entangled photon pairs may play an important role in quantum communication and imaging in the future. Parametric fluorescence (spontaneous parametric down conversion SPDC) can be used to generate them. Due to their small dimensions, sources based on waveguide structures are particularly interesting for application integration, but optimizing such structures requires the precise characterization of the components in the development process.

Method

As part of the Fraunhofer project NESSiE, Fraunhofer ILT is developing and building a measuring station for correlation measurements of the generated photon pairs of highly integrated SPDC sources. The institute is testing and optimizing its functionality on the basis of initial measurements. The laboratory setup is designed in such a way that the incoupling unit, the driving laser beam, the crystal holder and the photon detector can be exchanged in a modular way. Thus, the setup can be used flexibly to investigate different photon pair sources.

Results

To measure waveguide structures with lateral dimensions of 10 µm and below, the optical and mechanical design of the measurement station makes it possible to image the laser radiation in a diffraction-limited manner and to position the waveguide in the submicrometer and microrad range both precisely and stably for the long-term. The characterization station can detect emission rates in the kHz range and filter out the ambient light and the driving laser field, both of which are typically many orders of magnitude stronger than the generated photon pairs. To characterize the sources, the generated photon rate, the coincidence-to-noise ratio, and the second-order correlation function are measured automatically.

Applications

As part of the NESSiE project, laser-structured waveguides in periodically poled lithium niobate were developed at Fraunhofer CAP in Glasgow and characterized at Fraunhofer ILT. For further measurements, AlGaAs waveguides will be provided by Fraunhofer IAF in Freiburg.

This project is funded by the Fraunhofer-Gesellschaft as part of the Joint Capability Building Program JCAP.

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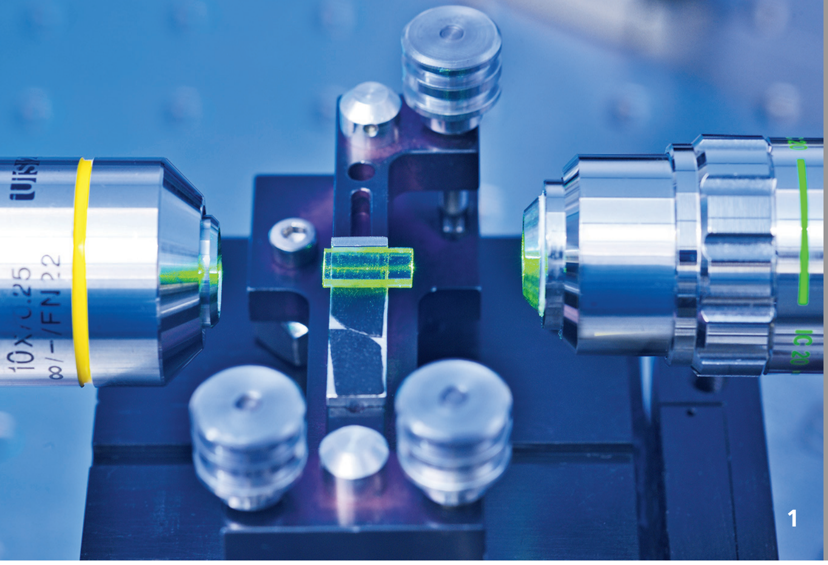
2 Characterization setup.



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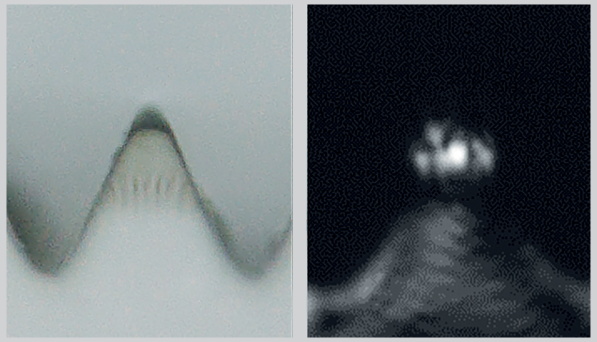

2

WAVEGUIDES IN LITHIUM NIOBATE FOR QUANTUM TECHNOLOGY

Task

In the context of the second quantum revolution, novel technologies have been developed by selectively exploiting fundamental quantum effects, and first application examples demonstrated on a laboratory scale. In order to ensure that the developed technologies can be transferred to a broad range of applications, the industry needs new fabrication methods and manufacturing concepts to miniaturize and integrate quantum system components on chip level. Core components are optical waveguides in non-linear media such as lithium niobate, which enable different assemblies to be interconnected optically. Microstructuring using ultrashort pulsed laser radiation makes it possible to directly produce high-quality waveguides with high geometrical freedom and productivity.

Method

A two-stage process using ultrashort pulsed laser radiation is used to fabricate the waveguides in periodically poled lithium niobate. First, the starting material is modified with infrared laser radiation a few micrometers below the surface so that a boundary surface with reduced refractive index is created there. Subsequently, the surface is ablated to create the geometric outer contour of the ribbed waveguide using ultraviolet laser radiation.

Results

Fraunhofer ILT determined which process and geometry parameters were relevant to manufacture the waveguides. The interface structuring with a height of about 15 µm spatially limits the guidance of the mode field to a small area of the waveguide. The geometrical requirements for widths and heights of 5 to 50 µm each and a sidewall angle of 60° were developed. The institute could fabricate complex waveguide networks by suitably developing the laser scanning strategy. Compared to lithographic methods, laser structuring is significantly more productive.

Applications

Waveguides in periodically poled lithium niobate enable efficient optical frequency conversion and can be integrated at a chip level. They can therefore be applied, for example, in optical networking technologies for wavelength division multiplexing (WDM) or in the life sciences for photonically integrated chips (PIC). The waveguides can also be used to generate entangled photons – a promising approach for applications such as quantum spectroscopy or quantum imaging.

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1 Free beam coupling into the waveguide.
2 Light microscopy and mode guiding of a waveguide.

KUNDENREFERENZEN

ABB · arnold RAVENSBURG · Aurubis · Bartels mikrotechnik · BASF
BEGO · Berlin Heart · BMW GROUP · BOMBARDIER · BOSCH
BRAUN · COHERENT · DILLINGER · DOM · EMERSON
eos · EVONIK · FEV · GE Additive · HEIDELBERG INSTRUMENTS
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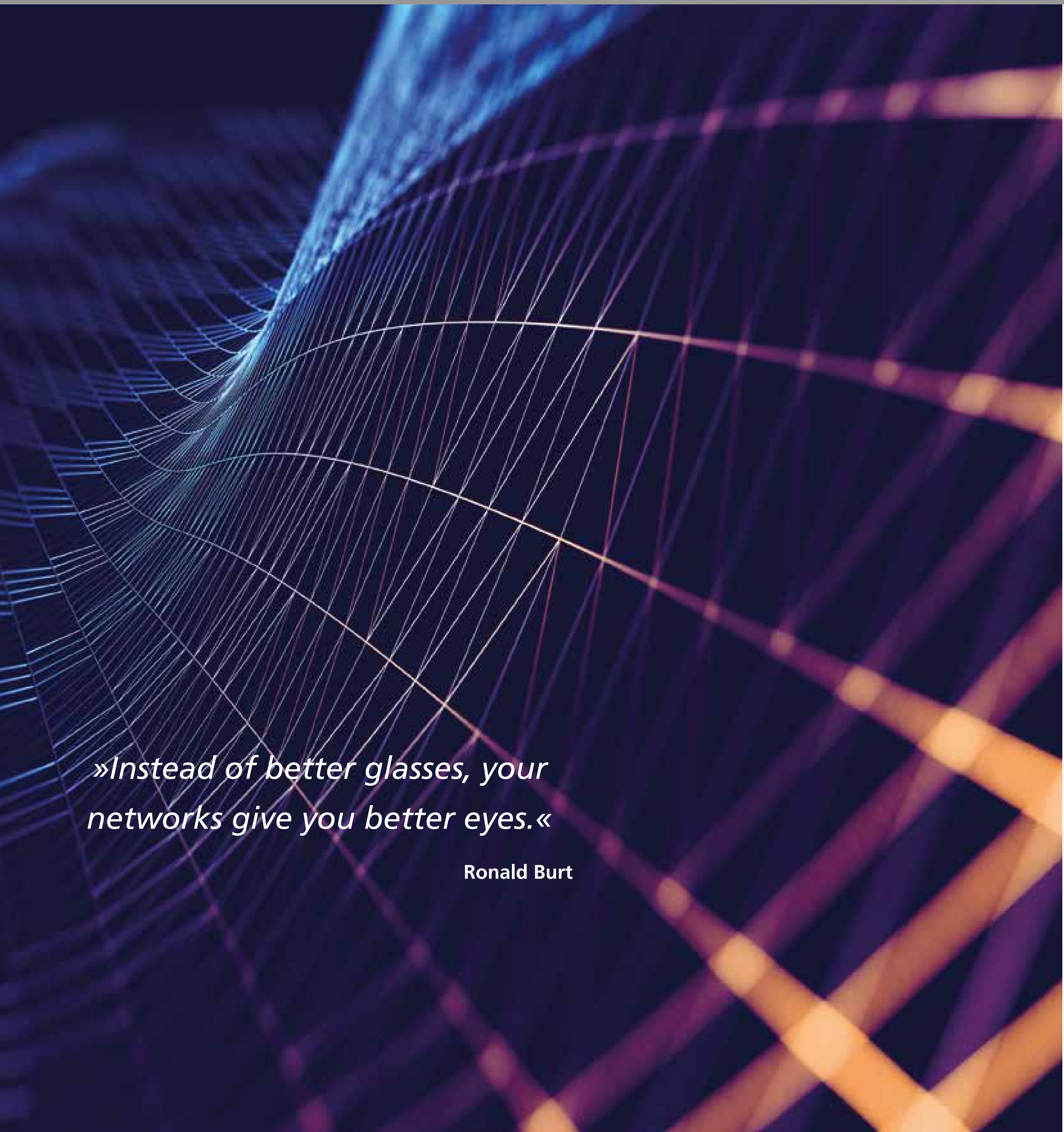
NETWORKS AND CLUSTERS



THE FRAUNHOFER-GESELLSCHAFT AT A GLANCE

THE FRAUNHOFER-GESELLSCHAFT

The Fraunhofer-Gesellschaft is the world's leading applied research organization. With its focus on developing key technologies that are vital for the future and enabling the commercial exploitation of this work by business and industry, Fraunhofer plays a central role in the innovation process. Based in Germany, Fraunhofer is an innovator and catalyst for groundbreaking developments and a model of scientific excellence. By generating inspirational ideas and spearheading sustainable scientific and technological solutions, Fraunhofer provides science and industry with a vital base and helps shape society now and in the future.

At the Fraunhofer-Gesellschaft, interdisciplinary research teams work together with partners from industry and government in order to transform novel ideas into innovative technologies, to coordinate and realize key research projects with a systematic relevance, and to strengthen the German and the European economy with a commitment to creating value that is based on human values. International collaboration with outstanding research partners and companies from around the world brings Fraunhofer into direct contact with the key regions that drive scientific progress and economic development.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 75 institutes and research institutions. The majority of our 29,000 staff are qualified scientists and engineers, who work with an annual research budget of 2.8 billion euros. Of this sum, 2.4 billion euros is generated through contract research. Around two-thirds of Fraunhofer's contract research revenue is derived from contracts with industry and publicly funded research projects. The remaining one-third comes from the German federal and state governments in the form of base funding. This enables the institutes to work on solutions to problems that are likely to become crucial for industry and society within the not-too-distant future.

Applied research also has a knock-on effect that is felt way beyond the direct benefits experienced by the customer: our institutes boost industry's performance and efficiency, promote the acceptance of new technologies within society, and help train the future generation of scientists and engineers the economy so urgently requires.

Our highly motivated staff, working at the cutting edge of research, are the key factor in our success as a scientific organization. Fraunhofer offers researchers the opportunity for independent, creative and, at the same time, targeted work. We therefore provide our employees with the chance to develop the professional and personal skills that will enable them to take up positions of responsibility at Fraunhofer, at universities, in industry and within society. Students who work on projects at Fraunhofer Institutes have excellent career prospects in industry by virtue of the practical training they enjoy and the early experience they acquire of dealing with contract partners.

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.

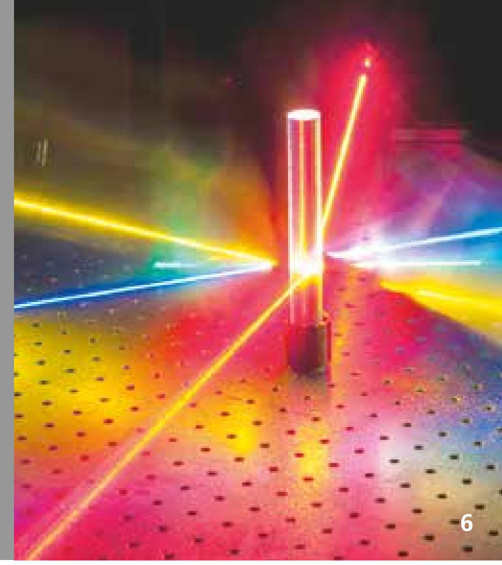
FIELDS OF RESEARCH

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

- Health and environment
- Security and protection
- Mobility and transport
- Production and supply of services
- Communication and knowledge
- Energy and resources





FRAUNHOFER GROUP LIGHT & SURFACES

Competency by networking

The Fraunhofer Group Light & Surfaces concentrates the scientific and technical competencies in the Fraunhofer-Gesellschaft for optics, laser, measurement and surface technology. The approximately 1900 employees of the six Fraunhofer institutes organized in this group solve complex application-oriented customer issues at the highest scientific and technical level. However, the Fraunhofer institutes are not only innovation partners, but also a source of young scientific and technical talents. In cooperation with local universities, young scientists at the Fraunhofer institutes bring science and industry together.

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

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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

Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP works on innovative solutions in the fields of vacuum coating, surface treatment as well as organic semiconductors. The core competences electron beam technology, plasma-assisted large-area and precision coating, roll-to-roll technologies, development of technological key components as well as technologies for the organic electronics and IC/system design provide a basis for these activities. Thus, Fraunhofer FEP offers a wide range of possibilities for research, development and pilot production, especially for the processing, sterilization, structuring and refining of surfaces as well as OLED microdisplays, organic and inorganic sensors, optical filters and flexible OLED lighting. Our aim is to seize the innovation potential of the electron beam, plasma technology and organic electronics for new production processes and devices and to make it available for our customers.
www.fep.fraunhofer.de/en

Fraunhofer Institute for Laser Technology ILT

With more than 500 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, laser measurement and EUV technology, medical technology and biophotonics, digitalization, quantum technology as well as 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 and systems 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 ecological and economical. Many years of experience with optical technologies 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 converters.
www.ipm.fraunhofer.de/en

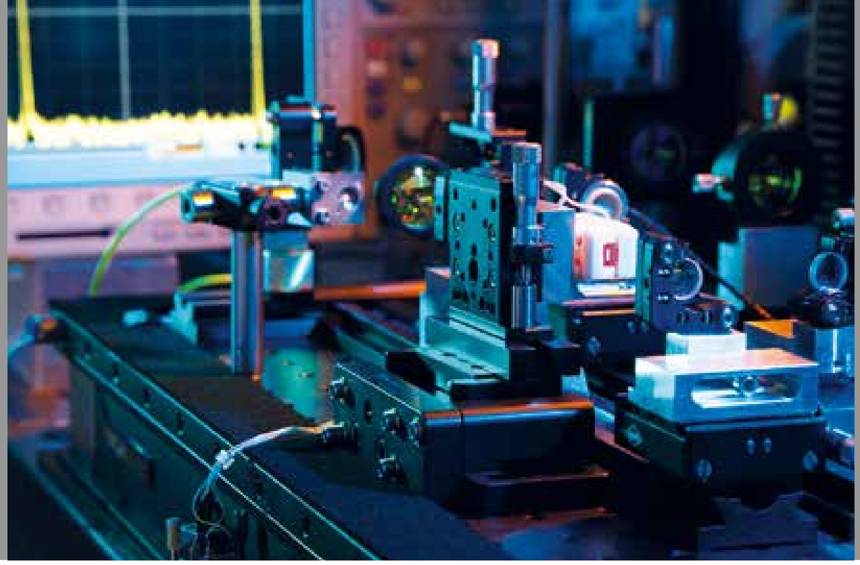
Fraunhofer Institute for Surface Engineering and Thin Films IST

The Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig is an innovative partner for research and development in surface technology, with expertise in the associated product and production systems. The aim ist to develop customized and sustainable solutions: from prototypes, through economic production scenarios, to upscaling to industrial magnitudes – and all this whilst maintaining closed material and substance cycles. 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



ICON-Project QFC-4-1QID: OPO as concept study of a low-noise quantum frequency converter.

FRAUNHOFER ICON-PROJECT »QFC-4-1QID«

Bringing quantum bits into the fiber optic network

Networking quantum computers over long distances using optical fibers and paving the way for the quantum internet: With this goal in mind, the Dutch research center QuTech and Fraunhofer ILT launched the ICON project QFC-4-1QID on September 1, 2019. The project marks the start of a long-term, strategic partnership between the research institutions, in which quantum frequency converters will initially be developed for connecting quantum processors to fiber optic networks. The new technology will be used in 2022 in what is expected to be the world's first quantum internet demonstrator.

»ICON – International Cooperation and Networking« is a funding program launched by the Fraunhofer-Gesellschaft and brings together top international researchers. Fraunhofer ILT and QuTech, the research center for quantum technologies at Delft University of Technology and the Netherlands Organization for Applied Scientific Research TNO began their collaboration within the framework of the project »Low-Noise Frequency Converters for the First Quantum Internet Demonstrator – QFC-4-1QID«.

Converter for customized photons

The quantum processors used in the Netherlands are based on diamond chips with voids deliberately introduced into the crystal lattice, the so-called nitrogen vacancies or NV centers. These qubits emit photons at a wavelength of 637 nm. So that quantum computers can be networked over long distances with low loss using optical fibers in the future, the photon wavelength must be converted to the range of the optical telecommunication bands (1,500 nm to 1,600 nm). So far, only the basic principle of corresponding quantum frequency converters (QFC for short) has been demonstrated. In the project, the partners are now investigating various design concepts on what performance characteristics the QFCs can achieve and how suitable they are for use in the quantum internet demonstrator. To this end, a converter has now been set up in the laboratory at Fraunhofer ILT and is currently being optimized for initial tests, which are scheduled to take place in a node in Delft in spring 2021. If QFCs can be developed with high efficiency and low noise in the output signal at the same time, the partners will have found an important key component to implement a fiber-optic-based quantum internet.

On the way to quantum internet

The world's first quantum internet demonstrator is expected to connect four cities in the Netherlands in 2022. With the QFC-4-1QID project, the Fraunhofer-Gesellschaft is contributing to the technological requirements for the first quantum internet and positioning itself as an international research partner in the field of new quantum technologies.

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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.

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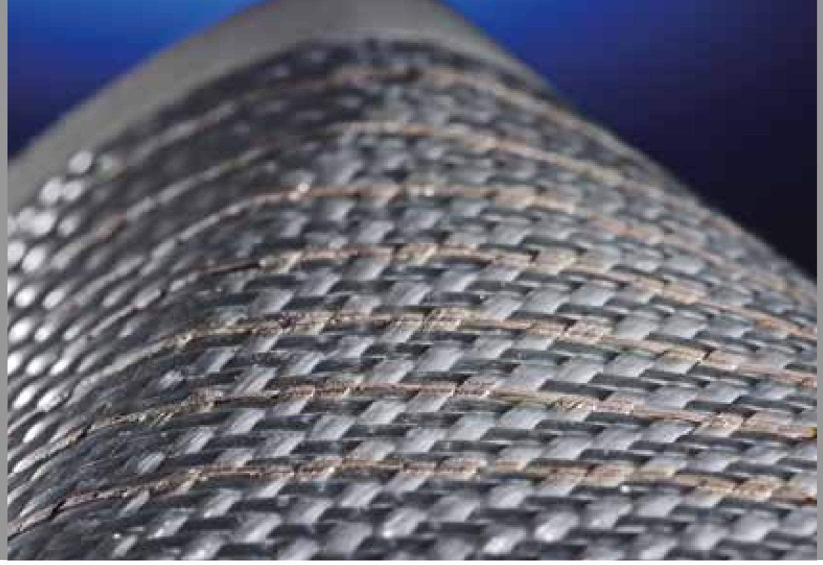
FRAUNHOFER ALLIANCES AND CENTERS OF EXCELLENCE



Additive manufacturing of electrical functional layers in fiber composite componets.

FRAUNHOFER LIGHTHOUSE PROJECT »GO BEYOND 4.0«

The six Fraunhofer Institutes ENAS, IFAM, ILT, IOF, ISC and IWU have succeeded to manufacture electrical conductor patterns, sensors, and high-tech lighting modules, individually integrated into components by using digital printing and laser technologies. The result: individualization of components in mass production environments with new opportunities for design, material savings and weight reduction.

In a short video about the lighthouse project »Go Beyond 4.0« (available online: www.ilt.fraunhofer.de/en/media-center/video-audio/centers.html), the feasibility of combining digital printing, laser processing and further latest production technologies is pictured based on the three technology demonstrators »Smart Door« - manufacturing domain automotive engineering, »Smart Wing« – production domain aviation and »Smart Luminaire« – production domain lighting.

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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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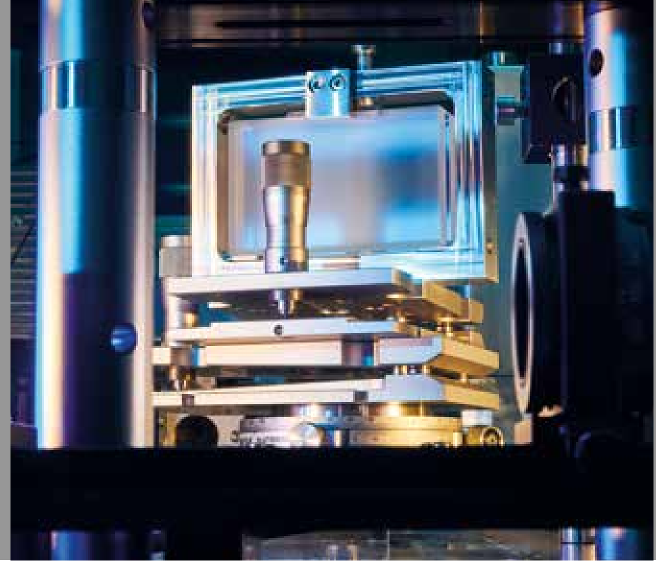
FRAUNHOFER CLUSTER OF EXCELLENCE

Setup for non-linear pulse compression.



Compression grating to generate the highest pump energies by means of CPA.

ADVANCED PHOTON SOURCES CAPS

With the Fraunhofer Cluster of Excellence »Advanced Photon Sources CAPS«, the Fraunhofer-Gesellschaft launched an ambitious project in January 2018. Its aim is to achieve international technological leadership in laser systems that achieve the highest performance with ultrashort pulses (USP) and to research their potential applications in collaboration with Fraunhofer partners. The new systems will exceed all existing USP 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

At present 13 Fraunhofer Institutes jointly develop applications for a new generation of extremely high-power ultrashort lasers. New fields of application are opened up, ultra-precise manufacturing processes in the industrial environment scaled and new pulse duration and wavelength ranges made available for research. The Fraunhofer Institute for Laser Technology ILT in Aachen and the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena coordinate CAPS.

USP lasers for high-precision applications

USP 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, USP lasers based on this technology have achieved average laser powers and a robustness that can also be used for industrial applications.

USP lasers have two major advantages for micro material processing applications: On the one hand, they can process practically all materials; on the other hand, 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 – USP lasers with beam powers in the kW range

The power of current USP lasers in the 100 W class is often insufficient with regard to economically relevant processing speeds when ultra-hard ceramic materials, metal foils, glass substrates or fiber-reinforced plastics are structured. 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

A major goal of CAPS is the early work on various applications. For this purpose, the coordinating Fraunhofer institutes – IOF in Jena and ILT in Aachen – provide two application laboratories with several kW-USP laser sources and the necessary system technology. The application laboratory at Fraunhofer ILT, which opened on September 17, 2019, is located directly next to the laser development laboratory and equipped with a separate beam source. This allows parallel experiments to be prepared and carried out in three different rooms. In 2019, a source with 500 W, pulse energies of up to 1 mJ and pulse durations of less than 100 fs was initially available, which was expanded to a second source with 1.5 kW up to 10 mJ in 2020. The laboratories of the User Facility are available to industrial partners for application studies. They can draw on the expertise of the various Fraunhofer partner institutes.

Broad spectrum of applications

In application development, research aims to investigate new processes and help known processes to achieve industrially relevant throughputs. Examples range from the microstructuring and surface functionalization of solar cells, ultra-hard ceramics and battery components to the cutting of glass and lightweight construction materials. In addition to breakthroughs in ultra-precise manufacturing with high productivity, the new USP sources will be used to generate coherent radiation into the soft X-ray range. The targeted photon fluxes are two to three orders of magnitude higher than those achieved so far. This is intended to establish applications in the materials sciences such as the precise localized generation of NV-centers in diamant. In addition, new possibilities are opening up for the semiconductor sector, lithography or the imaging of biological samples.

Furthermore, the sources developed in CAPS open up new possibilities for the imaging of biological samples as well as for the semiconductor and lithography sectors. The scaling of laser power is also interesting for basic research. In the future, laser particle accelerators will become much more compact and can, thus, even be integrated into existing laboratories. These so-called »secondary sources« can significantly boost growth in areas such as materials research and medical technology.

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LASER TECHNOLOGY AT RWTH AACHEN UNIVERSITY

JOINTLY SHAPING THE FUTURE

The RWTH Aachen University Chairs for Laser Technology LLT and Technology of Optical Systems TOS as well as Nonlinear Dynamics of Laser Processing NLD 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 chairs and at Fraunhofer ILT. University courses are drawn up jointly as well. Teaching, research and innovation – those are the bricks with which the three 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, laser material processing as well as digital photonic production 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 »Internet of Production«, 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 »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
- New concepts for innovative laser-based processing and strategies

Prof. Constantin Häfner (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

Nonlinear Dynamics of Laser Processing Instruction and Research Department NLD

Founded in 2005, the Nonlinear Dynamics of Laser Processing Instruction and Research Department NLD explores the basic principles of optical technology, with emphasis on modeling and simulation in the fields of application macro welding and cutting, additive manufacturing, 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.

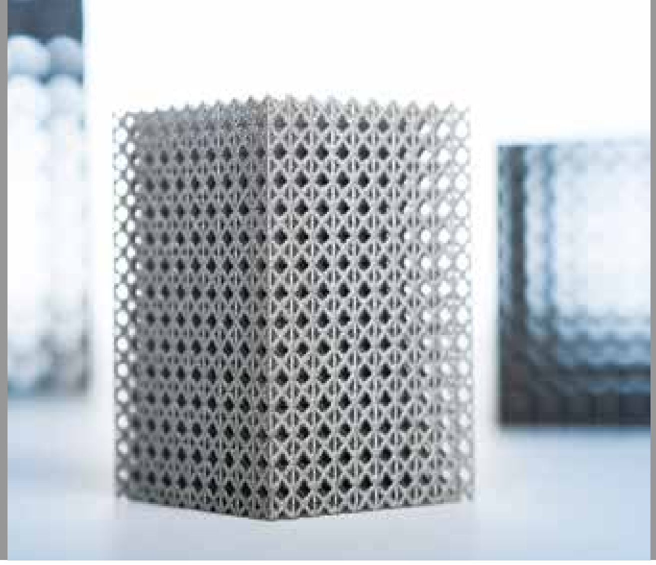
Prof. Wolfgang Schulz (Head of the department)
www.nld.rwth-aachen.de

Department of High Power Processes in Production Engineering and Additive Manufacturing at the FH Aachen

At the end of August 2019, Prof. Dr. Andreas Gebhardt retired from the Aachen University of Applied Sciences; he handed over his department »High Power Processes in Production Engineering and Additive Manufacturing« in the Department of Mechanical Engineering and Mechatronics to the long-standing expert for 3D printing, Sebastian Bremen, from Fraunhofer ILT on September 1, 2019. In the summer semester 2016, Sebastian Bremen received his first teaching assignments for laser technology and rapid prototyping at Aachen University of Applied Sciences and has since expanded his expertise in this field.

In 2013, Aachen University of Applied Sciences and the Fraunhofer ILT founded the Aachen Center for 3D Printing to jointly develop the future of additive manufacturing. Fraunhofer ILT and the Aachen University of Applied Sciences renewed this cooperation agreement in early 2019. Together they operate a laser powder bed fusion (LPBF) system, which is currently the world's largest commercial system for LPBF. Both institutions use this LPBF system to further develop metallic 3D printing. Prof. Bremen continues to head the Aachen Center for 3D Printing, thus continuing to foster the link between FH Aachen and Fraunhofer ILT.

Prof. Sebastian Bremen (Head of the department)
www.goethelab.fh-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 have been evolving into rapid manufacturing techniques for the direct production of functional components. Rapid manufacturing techniques have already been used in a lot of facilities for industrial production in 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.

In 2012 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.

RESEARCH CAMPUS DPP

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

RESEARCH CAMPUS DIGITAL PHOTONIC PRODUCTION

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 two buildings on the RWTH Aachen Campus: the Industry Building DPP and the Research Center DPP. Here the partners from business and science can research together under one roof as part of the Research Campus DPP.

Further information at: www.forschungscampus-dpp.de

Road mapping process

The collaboration of the two Fraunhofer Institutes ILT and IPT, the chairs of RWTH Aachen University and the around 30 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).

Start of the second funding phase

The establishment of the DPP Research Campus has been supported by the German Federal Ministry of Education and Research BMBF since 2014 as part of the funding initiative »Research Campus - Public-Private Partnership for Innovation«. At the end of 2019, the DPP Research Campus was evaluated by an independent jury, which recommended it receive a second five-year funding phase. On October 1, 2020, the DPP Research Campus began this phase, working with around 30 partners and a new structure with adapted content. It conducts application-oriented basic research on key technologies, competencies and components at the highest level within the competence areas Digital, Photonic and Production as well as the application fields Additive Production and Subtractive Production. Thanks to a further developed, flexible and agile project organization, there is an increased and efficient exchange between the partners.

Digital competence area

- Digital process chain
- Digital shadow
- Artificial intelligence
- Automated algorithmic design
- The Fourth Industrial Revolution and cloud-based production

The digital competence area focuses, for example, on research into integrated, efficient and resource-saving AM processes and their integration into industrial process chains. Moreover, it looks at the automated, algorithmic design of filigree component structures for both surfacing and ablative manufacturing processes.

Photonics competence area

- Novel scanner concepts
- Multi-beam systems
- Application-adapted, local and temporal intensity distributions
- Process sensor technology

Within the photonics competence area, fundamentally new optics and scanner concepts are developed, evaluated and prototypically implemented. Here, the partners do research on both optics for multi-beam processing and for application-adapted, local and temporal intensity.

Production competence area

- Systematic cost and benefit assessment
- Material development

The heat input into materials can be used in a targeted manner since interaction times can be controlled in laser-based manufacturing processes at high precision. The long-term goal is the development of a new alloy adapted to the laser-based manufacturing processes which, in addition to more robust processing, also exhibits improved properties with regard to corrosion and temperature resistance.

Additive production and subtractive production application areas

- Interaction
- Scaling

Processes are fundamentally better understood when their interaction processes are researched, which is a prerequisite for making manufacturing technologies more robust, precise and productive. Here, the engineers at the campus not only characterize existing processes, but also integrate and validate new solutions from its competence areas. In the area of scaling, they analyze existing processes from additive and subtractive manufacturing on their increasing efficiency. Furthermore, they investigate scaling the process parameters as well as the component size and the possible processing field.

Agile project management in the Research Campus

Currently, 17 interdisciplinary sprint teams, each consisting of three to eight employees from science and industry, meet in regular two-week sprints and set themselves new content-related goals every six months. In doing so, the sprint teams draw on resources from the competence and application areas. The sprint teams present their results, also semi-annually, at the plenary meetings of the DPP Research Campus. These thus develop into a regular »marketplace of opportunities« for all partners.

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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.

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 was initiated by Prof. Poprawe (Director of Fraunhofer ILT until the end of September 2019). The cluster's large premises offer sufficient space for, on the one hand, scientific institutions to cooperate in an interdisciplinary manner and, on the other hand, 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, worked 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 about 20 companies as well as R&D teams of Fraunhofer ILT and the Chair for Laser Technology at RWTH Aachen University.

2019 saw 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. On an area of 4,300 square meters, 16 chairs of the RWTH Aachen University from 6 faculties 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 almost 30 partners from industry can do research under one roof at the Research Campus DPP. These include large companies such as TRUMPF, 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 Industry Building DPP (r.) and Research Center DPP (l.) at the Photonics Cluster, © Forschungscampus DPP, Aachen.

2 Entrance of the Industry Building DPP in the Photonics Cluster, © Forschungscampus DPP, Aachen.

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« as well as the actual Excellence Cluster »Internet of Production« were 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.

The DPP Research Center, which opened in 2019 and became fully operational in 2020, offers scientists space for basic research in the field of photonics on approximately 4,300 square meters of floor space – including 2,800 square meters of laboratory, clean room and hall space.

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 ultrashort 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 cooperating chairs – LLT, TOS 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 terchnology. The DPP Industry Building thus provides the necessary infrastructure for long-term, strategic cooperation within the framework of the DPP Research Campus. Premises such as laboratories and offices can be rented as needed through the private operator. This cooperation benefits from 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.

Partners from Industry in the Research Campus DPP

- ACAM Aachen Center for Additive Manufacturing GmbH
- Access e.V.
- Aconity GmbH
- AixPath GmbH
- Amphos GmbH
- BeAM S.A.S.
- BUSCH Microsystems Consult GmbH
- Conbility GmbH
- EdgeWave GmbH
- EOS GmbH Electro Optical Systems
- ESI Group
- EXAPT Systemtechnik GmbH
- Ford-Werke GmbH
- GKN Sinter Metals Engineering GmbH
- Hegla GmbH & Co. KG
- Innolite GmbH
- LightFab GmbH
- MDI Advanced Processing GmbH
- ModuleWorks GmbH
- MTU Aero Engines AG
- Oerlikon Surface Solutions AG
- Saint-Gobain Sekurit Deutschland GmbH & Co. KG
- SCANLAB GmbH
- Siemens AG
- SLM Solutions Group AG
- TRUMPF Laser- und Systemtechnik GmbH
- TRUMPF Photonic Components GmbH

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

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

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.

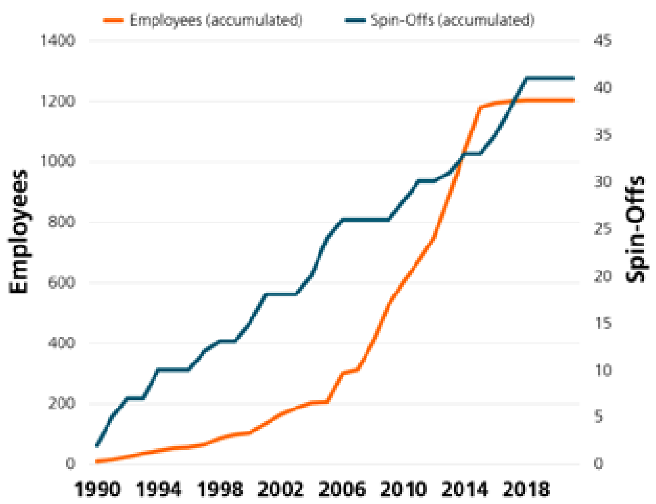
The DPP Research Campus forms the platform for intensive exchange with companies, institutes and consultants involved in the field of photonic production. Co-creation areas and open innovation concepts are also used at the research campus when required. In the DPP Industry Building on the RWTH Aachen 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 or 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 AC² 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 at a high level. 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. Of course, the spin-offs also provide added value for large established companies, 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.

1 Domicile of the spin-off RJ Lasertechnik GmbH in Übach-Palenberg, © RJ Lasertechnik GmbH.

REGIONAL INITIATIVES


Laser welding system for the production of battery modules.

Additive-manufactured letters with integrated lightweight structures.

BATTERY LAB

Fraunhofer ILT operates a Battery Lab in the laser plant park on an area of just under 140 square meters. Here, our researchers have access to a wide range of equipment for laser-based battery production. For example, they can test processes and further develop them for the production of lithium-ion batteries with liquid electrolytes, which are common today, and future solid-state batteries. To this end, around 3 million euros from the European Regional Development Fund (ERDF) have been invested in this new laboratory.

Next generation batteries

ERDF has already been funding the project »NextGenBat - Research Infrastructure for Future Battery Generations« since 2018 with the aim of strengthening the infrastructure in Aachen and Jülich in the field of battery research. The research infrastructure already in place in NRW will be expanded to create optimal conditions for regional companies to research and develop next-generation batteries. In addition to Fraunhofer ILT, other research institutes at RWTH Aachen University and Forschungszentrum Jülich are collaborating in this area.

More powerful batteries through roll-to-roll laser processes

Laser-based production processes in battery technology, such as the drying of electrodes and subsequent structuring, only realize their potential when integrated in roll-to-roll processes. An enlarged electrode surface in this way improves various properties of the lithium-ion cell, such as capacity, fast-charging capability and service life. At the end of 2020, such a system was put into operation. Furthermore, the Battery Lab has an argon-fueled GloveBox system that integrates state-of-the-art PVD coating technology and a high-temperature furnace. In this way, the partially air-sensitive solid-state cell materials processed by laser processes can be coated with metallic lithium, for example, and then assembled into test cells.

With laser technology from the electrode to the battery pack

Cutting and welding of battery components are further possible applications of laser technology to replace conventional production processes. USP lasers also enable damage-free processing of electrode foils directly in the roll-to-roll system in preparation for further production steps. In the end, battery cells are interconnected to form battery modules, modules in turn to form battery packs. An innovative plant technology for welding is available for making the necessary electrical connections using copper and aluminum conductors. Since two laser beam sources and intelligent image processing are integrated in it, it can compensate for the tolerances in the positioning of the battery cells that occur during the assembly of battery modules.

The Battery Lab is also equipped with various electrical and mechanical test benches that allow direct evaluation of the laser processes on the performance of the cell and module under thermal and electrical load.

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AACHEN 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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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 35 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 twelve-member steering committee comprises representatives of the participating industrial companies and research institutes.

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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, in particular, 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 Fraunhofer 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 other 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.

AKL
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«.

The AKL e.V. has about 180 members. Personal communication between the members forms the backbone of the association. Dr. Hartmut Frerichs (managing director), chairman Ulrich Berners and Dr. Bernd Schmidt (treasurer) are also represented on the board of AKL e.V. Since Prof. Reinhart Poprawe's departure, the new head of the Fraunhofer ILT, Prof. Constantin Häfner, has been acting as deputy chairman.

Innovation Award Laser Technology

Every two years the associations Arbeitskreis Lasertechnik e.V. and the European Laser Institute ELI e.V. award the Innovation Award Laser Technology, which is endowed with € 10,000. This European prize for applied science is aimed at both individuals and project groups whose skills and commitment have led to outstanding innovation in the field of laser technology. Potential participants are also people working in industry, universities or independent research centers in Europe who have successfully conceived and implemented an innovative idea in the field of laser technology. In essence, the work should deal with the use and generation of laser light for material processing and lead to an economic benefit.

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EVENTS AND PUBLICATIONS

PATENTS

PATENTS GERMANY

DE 102013000407.1 Verfahren zur Verbesserung der Benetzbarkeit einer rotierenden Elektrode in einer Gasentladungslampe

DE 102016211471.9 Anordnung und Verfahren zur winkelaufgelösten Streulichtmessung mittels einer Wellenleiter-Sonde

DE 102018214715.9 Verfahren zum Abbau von Schadstoffen in Wasser

DE 102015215559.5 Verfahren zur hochauflösenden Abbildung eines Oberflächenbereiches bei streifendem Einfall der Messstrahlung

PATENTS EUROPE

EP 2234749B1 Verfahren zur Herstellung einer Lötverbindung zwischen zwei Bauteilen

EP 3347156 Parameter beim Auftragschweißen bei oszillierender Erstarrungsfront (Siemens Hauptanmelder)

EP 2750825B1 Verfahren zur Strukturierung einer Oberfläche

EP 3500419B1 Hybrider Werkstoffverbund zwischen einer Metalloberfläche und einer polymeren Materialoberfläche sowie Verfahren zur Herstellung des hybriden Werkstoffverbundes

EP 2917985B1 Optisch endgepumpter Slab-Verstärker mit verteilt angeordneten Pumpmodulen

EP 3463811 Verfahren und Vorrichtung zur generativen Fertigung von Bauteilen

EP 3528982 Verfahren zur werkzeuglosen Entfernung von Stützstrukturen bei der generativen Fertigung von Bauteilen

EP 3024407 Vorrichtung zur Thermokoagulation mittels Laserstrahlung

36
Bachelor theses in 2020

PATENTS
16 Patents, 31 Patent applications in 2020

130
Scientific publications in 2020

58
Master theses in 2020

PATENTS

PATENTS KOREA

KO 10 2132846 Machining device and method for laser machining a surface

KO 10 2193056 Method for removing brittle-hard material by means of laser radiation

KO 20 2193167 Laser processing apparatus

PATENTS USA

US 10835994 Method for joining two components in the region of a joint zone by means of at least one laser beam and method for generating a continuous joint seam

PATENT APPLICATIONS GERMANY

102020200237.1 Verfahren zur Herstellung eines piezoelektrischen Mehrschicht-Sensors und/oder Aktuators

102020200599.0 Verfahren und Vorrichtung zur Steigerung der Fertigungsgenauigkeit beim pulverbettbasierten Strahlschmelzen mit einem verfahrbaren Bearbeitungskopf

102020201207.5 Anordnung zur Materialbearbeitung mit einem Laserstrahl, insbesondere zum Laserstrahl-Bohren

102020102514.9 Anlage und Verfahren zur teil- oder vollautomatisierten Demontage von Geräten

102020201558.9 Vorrichtung zur Reinigung einer Plasma-Strahlungsquelle

102020204003.6 Verfahren und Vorrichtung zur generativen Fertigung durch pulverbettbasiertes Strahlschmelzen

102020114811.9 Verfahren zur Stützung von Bauteilbereichen bei der additiven Fertigung

102020208086.0 Bauteil aus einer Aluminium-Nickel-Legierung sowie Verfahren zu dessen Herstellung und dessen Verwendung

102020119702.0 Vorrichtung und Verfahren zur Abtastung einer Zielebene mit mehreren Laserstrahlen, insbesondere zur Lasermaterialbearbeitung

102020125425.3 Vorrichtung und Verfahren zur Skalierung der Laserstrahlquellen u.a. für parallelisierte Lasermaterial-bearbeitungsprozesse

102020127431.9 Verfahren zur Herstellung einer kristallinen Siliziumschicht auf einem Substrat mit integrierten elektronischen Bauelementen

102020214259.9 Verfahren zum Polieren und Glätten mittels diskontinuierlichem Schmelzbad unter Einwirkung ultrakurz gepulster Laserstrahlung

102020131294.6 Verfahren zur Herstellung elektrischer Verbindungen hoher Stromtragfähigkeit sowie damit hergestellte elektrische Verbindung

102020133333.1 Verfahren und Vorrichtung zur Zug- und/oder Druckprüfung additiv gefertigter Proben

102020216597.1 Verfahren zur Erhöhung der Positioniergenauigkeit einer Bearbeitungsmaschine

102020134416.3 Verfahren zur Einstellung und/oder dynamischen Anpassung der Leistungsdichteverteilung von Laserstrahlung

102020134653.0 Justierbarer Optikhalter für ein optisches Element

PATENT APPLICATIONS EUROPE

PCT/EP2020/057115 Vorrichtung zur Erzeugung einer räumlich modulierbaren Leistungsdichteverteilung aus Laserstrahlung

PCT/EP2020/059882 Anlage zur Herstellung elektrischer Kontaktelemente mit selektiv veredelten elektrischen Kontaktflächen

PCT/EP2020/059856 Verfahren zur Terminierung optischer Strahlung sowie dafür ausgebildete optische Strahlfalle

20172131.3 Herstellung eines Kunststoff/Metall Verbundes durch direkte Applizierung eines schmelzflüssigen Metalls

PCT/EP2020/065207 Koaxiales Pulverdüsenspitzenmodul zur Oberflächenbearbeitung eines Werkstücks

PCT/EP2020/000107 Verfahren zum Bohren oder Schneiden durch Abtragen von schmelzfähigem oder verdampfungsfähigem Material eines Werkstücks

PCT/EP2020/065487 Vorrichtung und Verfahren zur Referenzierung und Kalibrierung einer Laseranlage

20178701.7 Verfahren zum Testen neuer Werkstoffzusammen-setzungen für das pulverbettbasierte Laserschmelzen sowie dafür ausgebildete Vorrichtung

PCT/EP2020/069261 Verfahren zum Beschichten einer Oberfläche eines Substrates durch Laserauftragschweißen

PCT/EP2020/075065 Werkstoffzuführungsvorrichtung

PCT/EP2020/076588 Vorrichtung zur Bahngenauigkeits-bestimmung einer stationären Bearbeitungsmaschine mithilfe eines Laserlinienscanners

PCT/EP2020/081699 Verfahren zum Fügen einer elektrischen Zelle und elektrischer Speicher

PATENT APPLICATIONS CHINA

PCT/EP2020/065207 Koaxiales Pulverdüsenspitzenmodul zur Oberflächenbearbeitung eines Werkstücks

PATENT APPLICATIONS KOREA

KO 10 20207037414 Vorrichtung zur Laserbearbeitung schwer zugänglicher Werkstücke

DISSERTATIONS

DISSERTATIONS

10.2.2020 – Karl Eduard Felix Haeckel (Dr.-Ing.)
Reproduzierbarkeit des Laserstrahlschmelzens im Hinblick auf einen Einsatz in der automobilen Serienproduktion

14.2.2020 – Philipp Lott (Dr.-Ing.)
Carbonisierung von Polyacrylnitrilfasern mittels Diodenlaserstrahlung

18.2.2020 – Laura Bürger (Dr.-Ing.)
Charakterisierung der Oberflächentopographie von Laser Powder Bed Fusion erzeugten IN718-Proben

15.5.2020 – SiljaKatharina Rittinghaus (Dr.-Ing.)
Laserauftragschweißen von γ-Titanaluminiden als Verfahren der Additiven Fertigung

5.6.2020 – Paul Josef Heinen (Dr.-Ing.)
Prozessfähigkeitserhöhung und Fehlerreduktion beim Laserstrahl-Mikroschweißen mit örtlicher Leistungsmodulation

15.6.2020 – Annika Völl (Dr.-Ing.)
Methodik zur Ermittlung und Realisierung anwendungsangepasster Intensitätsverteilungen für die Werkstoffbearbeitung mit Laserstrahlung

16.6.2020 – André Häusler (Dr.-Ing.)
Präzisionserhöhung beim Laserstrahl-Mikroschweißen durch angepasstes Energiemanagement

16.7.2020 – Sascha Engelhardt (Dr. rer. nat)
Zweiphotoneninduzierte Vernetzung zur Generierung mikroskaliger Zellumgebungen

28.8.2020 – Maximilian Schniedenharn (Dr.-Ing.)
Einfluss von Fokusshift und Prozessnebenprodukten auf den Laser Powder Bed Fusion Prozess

1.9.2020 – Kira Martina van der Straeten (Dr.-Ing.)
Laserbasiertes Fügen von Kunststoff-Metall-Hybridverbindungen mittels selbstorganisierter Mikrostrukturen

4.9.2020 – Markus Herper (Dr. rer. nat.)
Eignung von VECSEL-Strahlquellen für 3D-LiDAR-Applikationen

22.9.2020 – Chao He (Dr.-Ing.)
High-precision and Complex Geometry Helical Drilling by Adapted Energy Deposition

6.11.2020 – Marcel Prochnau (Dr.-Ing.)
Integration von Gestaltungsprinzipien der Industrie 4.0 bei der Montage optischer Systeme

27.11.2020 – Judith Kumstel (Dr.-Ing)
Steigerung der Flächenrate beim Laserpolieren von Stahlwerkstoffen

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

Live demonstrations during LSE 2020.

EVENTS

February 12–13, 2020
LSE 2020 Laser Symposium Electromobility
As automobiles are increasingly running on electricity, the demand for high-performance energy storage systems is growing. In order to meet the constantly growing challenges, new manufacturing methods are needed in the production of battery modules and packs. Already today, highly efficient laser processes are essential for the entire process chain, and the share of laser technology in manufacturing will continue to increase. The following topics were highlighted at the second LSE 2020 Laser Symposium on Electromobility organized by Fraunhofer ILT and presented by speakers from industry and research:
- Basics of laser technology in electromobility
- Laser processes for battery production
- Laser beam sources in electromobility
- Production equipment in laser material processing
- Process monitoring for laser manufacturing processes
- Treatment and processing of solid batteries

Prof. Arnold Gillner at LSE 2020.

September 9, 2020
LKH_2 Laser Colloquium Hydrogen
Online event
With the energy transition and in the course of the global challenges of climate change, the use of regenerative energy sources is becoming increasingly important. Here, the use of hydrogen by fuel cells is the focus of future-oriented research and development. Already today, highly efficient laser processes for the entire process chain are available for the production of fuel cells. Since lasers can be used with great flexibility and automated to the high degree, the share of laser technology in production will continue to increase. Sixty experts from industry and science participated in this online event. The following topics were highlighted at the first Laser Colloquium Hydrogen LKH_2 2020 organized by Fraunhofer ILT:
- Reliable cutting of preformed bipolar plates
- Hydrogen-tight laser beam welding of metal- and plastic-based bipolar plates for fuel cells
- Process monitoring systems in large-scale production
- Process chain for the production of fuel cells

September 16–17, 2020
LaP Conference on Laser Polishing
Online event
The »4th Conference on Laser Polishing – LaP 2020« was also held virtually for the first time. The aim of the conference was to present scientific and application-related results on laser polishing and to bring together experts working in this field worldwide. Networking helps to initiate new scientific collaborations – especially on an international level.

3rd EFFILAS Association Meeting in Aachen.

Fraunhofer ILT on the BMBF joint stand of Photonics West 2020.

Well attended: Fraunhofer ILT joint booth at LASER China.

The following focus topics were addressed:

- Laser polishing of metals (functional and design surfaces, additive manufactured parts, dies, tools)
- Laser polishing of glass and laser-based processes for manufacturing optical surfaces
- Machines and CAM-NC for laser polishing of metals

September 29–30, 2020
3rd EffiLAS Association Meeting

Major goals of efficient high power laser beam sources are to increase efficiency, output power, pulse energy, brilliance and reliability, to reduce costs and system complexity as well as to develop new wavelength ranges relevant for applications in production, metrology or environmental and life sciences. Possible concepts for efficient beam sources such as innovative diode and microchip lasers or diode-pumped solid-state lasers (DPSSL), disk and fiber lasers were discussed over two days at the 3rd EffiLAS Association Conference at the Aachen Quellenhof. Organized by the Fraunhofer ILT, the event offered participants a variety of presentations and panel discussions as well as a laboratory tour at Fraunhofer ILT.

Further information at:
www.ilt.fraunhofer.de/en/fairs-and-events.html

December 1, 2020 until November 16, 2021
Digital Aachen Polymer Optics Days
Online event series (1st quarter)

The spectrum of optical plastic components is constantly expanding to include new manufacturing technologies, materials and products. The aim of the established Aachen Polymer Optics Days is to address both material-side and technology-oriented as well as application-related aspects and to highlight them in the context of current trends and issues in the field of plastic optics.

The online session »Injection molded optics« is the kick-off event of the online event series »Digital Aachen Polymer Optics Days«, which is composed of the contents of the face-to-face conference of the same name. The face-to-face event, which was scheduled for October 2020, was cancelled due to security measures in the context of the coronavirus pandemic. Online sessions will now be held quarterly from December 2020 to November 2021 on the following topics:

- Injection molded optics (December 1, 2020)
- Materials in optics manufacturing (February 24, 2021)
- Tool and mold making for optical applications (May 18, 2021)
- Metrology for optical components (September 1, 2021)
- Optical systems (November 16, 2021)

The online sessions are aimed at an audience from science and industry and offer numerous technical presentations as well as a networking and discussion round. The Digital Aachen Polymer Optics Days series is a joint event of the three research institutions:

- Fraunhofer Institute for Production Technology IPT
- Fraunhofer Institute for Laser Technology ILT
- IKV Institute for Plastics Processing in Industry and Trade at RWTH Aachen University

FAIRS AND EXHIBITIONS

February 1–6, 2020, San Francisco, USA
Photonics West 2020
International Trade Fair for Optics and Photonics

Fraunhofer ILT was represented at the large BMBF joint stand with the following presentations and highlights:

- High power and high precision laser manufacturing from UV to IR: state of the art and future challenges
- Picosecond laser source at 3.4 microns for laser material processing of polymers
- Highly stable, high power hybrid fiber and INNOSLAB amplifier for narrow linewidth signals
- Bragg gratings in active multimode XLMA fibers for high-power kW-class fiber lasers
- High-precision ultrashort pulsed laser processing of metal foils using an advanced multibeam optical system
- Laser polishing using ultrashort pulse lasers

At Photonics West 2020 in San Francisco, Prof. Constantin Häfner also presented the PRISM Award from the International Society for Optics and Photonics SPIE to the French start-up Outsight for their 3D Semantic Camera technology.

July 3–5, 2020, Shanghai, China
LASER World of PHOTONICS China
International Trade Fair for Optics and Photonics

Fraunhofer ILT presented its technological developments at LASER World of PHOTONICS China via its strategic partner ACunity GmbH. The following topics were the focus:

- New helical drilling optics with smart sensor systems and automated adjustment
- Materials processing using ultrashort pulsed lasers
- Multi-beam laser processing
- Laser metal deposition and cladding

September 28, 2020
Virtual exhibition Battery Conference NRW
Online event

Participants and exhibitors met in virtual space and found an interesting marketplace for products and developments around the energy industry. The spectrum of topics ranged from battery chemistry to AI integration. Fraunhofer ILT participated in the online exhibition accompanying the conference.

October 8, 2020
Hydrogen Online Conference HOC

Hydrogen will be the energy carrier of the future and for this reason thousands of executives, engineers, scientists and policy makers virtually participated in the Hydrogen Online Conference HOC on October 8, 2020. Fraunhofer ILT participated in the online exhibition accompanying the conference.

Presentation of the SPIE PRISM Award at Photonics West 2020.

October 26–29, 2020
Fraunhofer Solution Days
Online – The Fraunhofer digital event in fall 2020

Within the framework of the Fraunhofer Solution Days, four topics of high relevance for the innovative strength of Germany and Europe were addressed:

- Health economy - new medical procedures
- Digital economy - using data intelligently and confidently
- Optimization of production processes in plant and mechanical engineering
- Mobility – drives and traffic routes of tomorrow

Visitors were able to listen to online presentations on current technology highlights, visit exhibitors virtually and exchange information with them via live chats. Fraunhofer ILT participated in the Fraunhofer Solution Days with an online booth. Research findings presented included:

- The sensing component from the printer
- The printed miniature actuator
- Scalable AM processes
- CAPS – Advanced Photon Sources

Online booth of Fraunhofer ILT at the Fraunhofer Solution Days.

November 10–12, 2020
formnext connect
Online event

Fraunhofer ILT presented innovative results online at formnext 2020:

- Additive manufacturing of large components using laser powder bed fusion (LPBF)
- »PETIT« as modular and miniaturized process chamber
- Adaptive process control in LPBF
- Sensor integration in LPBF components
- Fraunhofer lighthouse project futureAM

November 16–19, 2020
COMPAMED 2020
High-Tech Solutions for Medical Technology
Online event

At COMPAMED, Fraunhofer ILT presented itself in the virtual forum and provided information on the following topics:

- Laser-assisted process chain for the manufacture of a microfluidic chip
- Customized glass and microfluidic components
- Prototyping of 3D microfluidic chips from fused silica
- Customized flow cytometers and cell sorters for diagnostics
- Foil processing

The highlight was the laser-based process chain for manufacturing a microfluidic chip.

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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Annual report 2020 online

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Picture Credits
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Print
Druckspektrum Hirche-Kurth GbR, Aachen
www.druck-spektrum.de

Subject to alterations in specifications and other technical information.