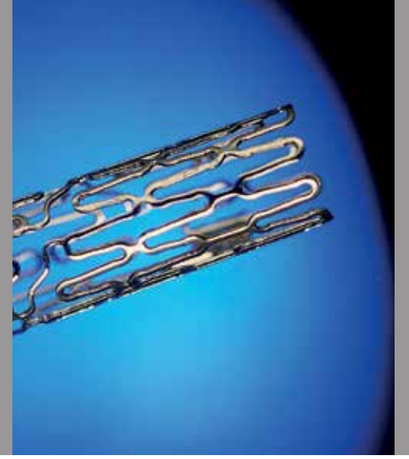
Fraunhofer
ILT

FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

PARTNER FOR INNOVATIONS








DR. PETER LEIBINGER Vice Chairman of TRUMPF GmbH + Co. KG and President of the Laser Technology and Electronics Division *"From the outset, the Fraunhofer ILT has been a close companion of TRUMPF Laser Technology. Again and again, we have found the ILT to be a competent and flexible partner, one who has shown excellent technical and scientific judgement – a basic requirement to show us trendsetting ways."*

DR. GREGOR KAPPMEYER Chief of Commodity Rotatives, Rolls-Royce Deutschland Ltd. & Co. KG *"Being able to maintain, repair and overhaul high-value aero engine components using Laser Metal Deposition, instead of being forced to exchange them, means significant cost savings. These repairs have been able to be developed, conducted and continuously improved directly at Fraunhofer ILT, whose expert know-how and the corresponding infrastructure – all combined at one location – have seriously convinced us."*

PROF. DR. INGOMAR KELBASSA Department Manager, Siemens AG, Division Power and Gas, Manufacturing Development and Industrialization *"By participating in the Research Campus Digital Photonic Production, we have entered into a strategic partnership with Fraunhofer ILT and the associated RWTH Aachen University chairs. For Siemens, this represents a form of cooperation in Additive Manufacturing which will help us develop new systems and systems technology, processes and integrated process chains far more efficiently! At the same time, we are using the valuable contacts that result from the networking at the Aachen location."*

PROFESSOR DR. MED. MICHAEL STARKER Head Physician of the Orthopedic Clinic of St. Johannes Hospital in the Catholic Clinic of Duisburg *"As the first user of tailor-made laser-generated acetabular cups, we appreciate the advantages that the procedure developed by the Fraunhofer ILT has enabled us. Thanks to each individual prosthesis geometry, we no longer need to adapt implants during the operation – this shortens the operation time. What is also a great advantage is the freely shapeable surface structure, which allows the bone to grow into the implant. Last but not least, due to the quick production process, we see a great potential for the use of lasers in medical technology."*

FRAUNHOFER ILT – PARTNER FOR INNOVATIONS

We light up new paths: Whether car manufacturing, photovoltaics, aircraft industry or medical engineering, the most diverse branches of industry are profiting from the brilliant power of the laser.

As a tool, light is indisputably an innovation driver. Germany occupies a top position worldwide in the field of optical technology and is holding its own as the world leader in laser manufacturing technology. And, thanks to the intensive research it carries out at the cutting edge between science and practice, the Fraunhofer Institute for Laser Technology ILT has been making its own contribution to this success – for more than 30 years.

Fraunhofer ILT: opening up new perspectives
With over 500 employees, the Fraunhofer ILT is among the world's premier institutes for contract research and development in this branch of industry. On more than 19.500 m^2 usable floorspace, we offer a flexible, state-of-the-art environment for managing technological projects. Our entire infrastructure is not only cutting-edge, but is enhanced by facilities and prototypes from the next generation of technology. On average, Fraunhofer ILT researchers register a new patent every month and handle several hundred contract research projects per year.

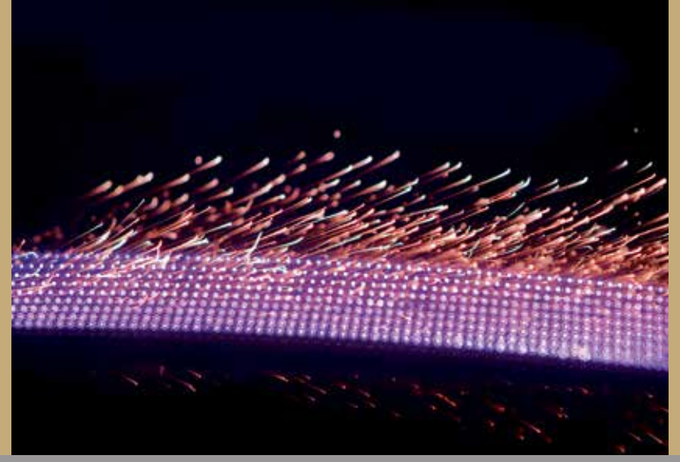
Our core activities cover a wide array of topics: from laser sources and optical components, laser measuring technologies and laser materials processing, through to medical engineering and biophotonics. We develop new beam sources and optical systems as well as processes and facilities for installation at our partners' premises. With the aid of simulations, we are paving the way for process optimization, process monitoring and control, and new optical concepts.

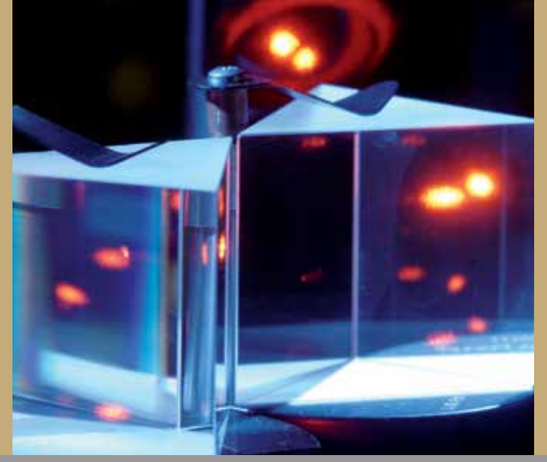
Laser technology: the fascinating tool that is light
We are convinced that the laser is the optimal tool. It impresses with its productivity, quality and flexibility. Many applications in manufacturing, environmental technology or communication were made possible only through laser technology. And the potential of this tool is by no means exhausted.

What inspires us is the opportunity to set international standards for our customers through technological excellence and pioneering industrial applications.

Without lasers, microprocessing would long since have reached its limits; in the field of nanoprocessing lasers are indispensable; and in the mechanical engineering and automotive sectors lasers have enabled new production processes. Last but not least, laser technology is opening up new diagnostic methods in the life sciences and the medical engineering field, accelerating the development of new drugs, and making more targeted therapies possible.

Our close partnerships and strategic ventures with German and international research institutes, with laser manufacturers, end users and associations all help assure us a top position internationally in the transfer of laser technology to industrial applications. With a broad palette of resources at our disposal, we can offer solutions from a single source – from basic research and process development, system development and consulting, through to the licensing of our know-how. That is why we are a sought-after partner for innovations.





HIGH-TECH-PREMIERES OF THE FRAUNHOFER ILT

Tailor-made materials processing, new types of analysis techniques, innovative system technology: the tool "laser" has revolutionized production processes.

1985 - 2002

1985 **Device** for CO_2 Laser **Beam Diagnostics**

1989 **High Frequency Excited Axial Flow CO_2 Laser** developed in Cooperation with ROFIN-SINAR

1990 **Laser Plant** to **Reduce Hysteresis Losses** in Electric Sheets

1991 **Active Microcoolers** made of Copper for **High-power Diode Lasers**

1992 **Prototype of a Laser Cutting Plant** to Slit Metallic Thin Sheets at up to 250 m/min

1994 **Fully Automatic Laser Ablation Process** for Laser Milling Machines

1995 **Axial Flow 40 kW CO_2 Laser** Developed in Cooperation with TRUMPF

1995 **Use of the Selective Laser Melting (SLM)** with Pure Metal Alloys

1995 **High-power Diode Laser** Operating in kW Range

1995 **Staircase Mirror** for Beam Shaping of High-power Diode Lasers

1996 **Hand-held Laser Cleaning Device**

1997 **Industrial Use of Diode Lasers to Join** Plastic Components

1997 **Industrial Diode-pumped High-power Solid State Lasers** with 5 kW

1997 **Maintaining Motors** and Transmissions from the Automobile Sector **with Laser Metal Deposition (LMD)**

1997 **Diode-pumped INNOSLAB Laser**

1997 Plant for **Inline Flatness Measuring** of Coarse Sheets **with Laser Triangulation**

1998 Plant for **Inline Identification Testing** of Pipe Components **using Laser Spectroscopy**

1999 Use of **High-power Diode Lasers for Deep Welding**

2000 **Series Laser for Subsurface Engraving of Glass**

2001 **Commercialization of the INNOSLAB Laser** by EdgeWave, a Spin-off of ILT

2002 Use of a **Laser to Polish Metals**

2002 Prototype of an **EUV Beam Source for Chip Exposure** developed in Cooperation with Philips

2002 **Manufacturing Implants by** means of **SLM**

2002 Plants to **Analyze Slag Specimen**

2003 - 2016

2003 Commercial Use of **SLM to Produce Dental Prostheses** Developed in Cooperation with Bego Medical

2003 **Combi-head for Sequential Laser Cutting and Welding** without Retooling

2004 **Pilot Plant for Quick Identification of Aluminum Scrap** for Materials Recycling using Laser Spectroscopy

2005 **Qualified Repairing Procedures with LMD for Turbine Components** developed in Cooperation with Rolls-Royce Deutschland

2005 **Manufacturing Internally Cooled Die-cast Tools** by means of SLM

2007 **Using Shadow® Laser Process for Microwelding** in the Watch Industry

2007 **Demonstrator Device for Measuring Scattered Light in Sub-microliter Volumes** to Monitor Protein Crystallization

2009 **Femtosecond Laser with over 400 W** Output Power

2009 **Prototype for the Inline Analysis of Bore Dust** during Exploratory Drilling using Laser Spectroscopy

2010 Demonstration of a **Laser with 600 fs Pulse Duration and 1.1 kW Average Output Power**

2012 **Cylinder Laser Engraving Machine with High-power USP Lasers** for Printing and Embossing Applications at Schepers

2013 **Prototype of a Laser Bonder for Power Electronics** in Cooperation with F&K Delvotec Bondtechnik

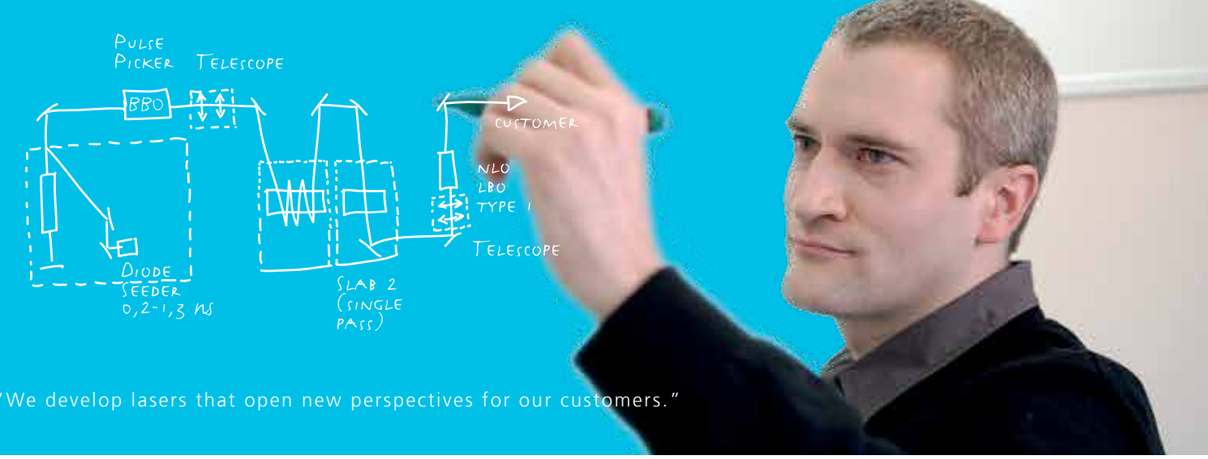
2015 **Prototype of a Car Door with a CFRP-Metal Connection** based on an ILT-Joining Process Developed in Cooperation with Groupe PSA

2015 **App Software for Process Simulation for Short-pulse Laser Drilling** of Gas Turbine Blades

2016 **Successful Demonstration of the "Future Laser Platform" for LIDAR-supported Atmospheric Research** in Thermal Vacuum Tests in Cooperation with Airbus

2016 Implementation of the Patented **Extreme High-speed LMD Process,** EHLA, at IHC Vremac Cylinders for the Protection of Hydraulic Cylinders.

LASERS AND OPTICS



"We develop lasers that open new perspectives for our customers."

Both compact and efficent, the diode laser does great things - for example, in outer space.

DAZZLING PRECISION

With their greater precision flexibility and power, new beam sources are not only helping to optimize laser production techniques, they are also opening up whole new applications such as laser polishing. For our clients, we develop new beam sources, frequency converters and optical components.

Solid state and fiber lasers: performance and efficiency
Solid state and fiber lasers – in both continuous-wave and pulsed mode – are already firmly established in industry, and new application areas are being found for them in the fields of medicine, manufacturing engineering, metrology and research. We optimize all aspects of solid state and fiber lasers – individual components, oscillators and amplifiers, and even customized systems.

Frequency conversion: broadening the spectrum
By combining lasers and frequency converters in an optimal manner, we can create made-to-measure laser sources. Our customers benefit from efficient and cost-optimized systems that are adapted to suit their specific processes across a wide range of applications.

Getting to the core of optical design
Whether for simple lenses, complex optical systems or multifunctional free-beam optical systems, we have a large number of design methods at our disposal for beam guidance and shaping. Patented solutions for beam transformation and homogenization enable the efficient use of laser beams.

Precision assembly: it's all about good connections
It is mainly thanks to their solid assembly that diode and solid-state lasers render such reliable service in the aerospace, materials processing and medical engineering industries. We implement economical customized solutions for bonding and soldering laser components. Our innovative processes enable us to assemble optical components such as lenses or crystals at low cost yet with high precision and stability.

Diode lasers: strong and compact beam sources
Diode lasers are characterized by their compact dimensions and low cost. We focus on the automation of assembly techniques, the enhancement of output and beam quality as well as the optimization of beam guidance and shaping systems.

Ultrashort pulse lasers: impulses for science and industry
For more than fifteen years now, the Fraunhofer ILT has been conducting research into the development, characterization and application of ultrashort pulse lasers – those with pulse durations in the region of pico- and femtoseconds. In the high-power field we have already broken numerous world records with fs lasers. We support our customers in the design, simulation and prototype construction of beam sources, and in the adaptation of applications.

Our range of services

- Development of solid-state lasers for materials processing, medical engineering and metrology
- Design, implementation and testing of ultrashort-pulse lasers
- Development of continuous-wave and pulsed fiber lasers, fiber laser components and production processes for fiber-based systems
- Optical design for beam guidance and shaping systems
- Simulation, optimization and assembly of optical frequency converters
- Packaging, characterization and testing of high-power diode lasers
- Automation of high-precision assembly processes for laser and optical systems

LASER MATERIAL PROCESSING

"Our goal: making production processes more efficient."

Where laser meets material, production potential is maximized.

TAPPING POTENTIAL – SYSTEMATICALLY

Whether in aircraft construction, electronic or medical engineering, laser-based materials processing offers numerous benefits in a whole range of industries. Our goal is to exploit this potential even further – in close cooperation with our customers and partners.

Laser additive manufacturing: repair beats replacement
Even the most minor damage to high-tech machine components can necessitate their full replacement – and that can be costly. In branches of industry such as turbine production it makes sense to consider repairing the damaged component using laser additive manufacturing. This high-precision deposition of material with the aid of a laser allows worn areas to be coated and repaired to exactly fit the required contour.

Cutting and welding: adding value
State-of-the-art production systems must deliver high productivity and flexibility at low cost. Cutting and welding by means of laser technology are already well-established processes. Our combi-head allows you to carry out both these processes without retooling and in any sequence. The result for our customers is a hitherto unmatched level of economy, flexibility and quality.

Individualized mechanical engineering
The development and qualification of highly productive laser processes are accompanied by systems engineering support to provide integrated process monitoring and control. Our tailor-made prototype production units and manufacturing solutions make it easy for our customers to implement laser technology.

Microprocessing: faster, finer and more precise production
The advantage of laser processes in microtechnology and nanotechnology is that they offer a high degree of processing selectivity and have a minimal impact on component integrity.

Lasers are an ideal tool for electrical engineering and photovoltaic applications. High-speed drilling for modern cell concepts or efficient laser processing in battery technology are only two practical examples of technologies we steadily develop.

Polishing: laser processes for complex geometries
Automated laser polishing of metal, silica glass or plastic is another milestone of our R&D activities. Compared with conventional – usually manual – polishing, this process can help achieve much higher productivity with complex geometries such as tools, implants or free-form optical elements.

Our range of services

- Cutting and joining processes for metals, plastics, ceramics and semiconductors
- Precision cutting and drilling, microablation & nanoablation
- Polishing
- Laser microsoldering and microwelding
- Microbonding of glass, semiconductors and ceramics
- Laser-assisted bending, adjustment, punching and stamping
- Laser-based hybrid processes
- Surface treatment such as hardening, alloying and structuring
- Laser Material Deposition
- Functionalization of thin-film coatings and cleaning
- Additive Manufacturing
- Modeling and simulation
- Feasibility studies, sample series and test series
- Sensor-based process monitoring and control
- Design of machining nozzles and optical systems
- Design and implementation of prototypes and pilot plants
- Control systems and CAD/CAM solutions

MEDICAL TECHNOLOGY AND BIOPHOTONICS

Analyses with fluorescent microscope give insight into laser-structured surfaces.

"With innovative methods, we continue to drive medical progress forwards."

INDIVIDUAL SOLUTIONS FOR A LONG LIFE

New types of therapy, individualized early diagnosis and better chances of recovery: Together with our practitioner partners we are at the cutting edge of research in the fields of medical engineering, biotechnology and applied medicine.

Personalized implants from the 3D printer
Tailor-made implants at the touch of a button: Selective Laser Melting (SLM) is an additive process we have developed that enables the tailored production of implants using medical image data. Mimicking similar processes in nature, SLM employs biocompatible materials to generate joint, bone and dental prostheses or temporary supporting implants.

Light through the keyhole: microsurgical systems
Minimally invasive surgery is the key to patient-friendly therapies. In cooperation with our partners in clinics, we are developing new systems and techniques for use in surgery, tissue therapy and wound treatment, including medical laser systems with adapting wavelengths, miniaturized instruments and new, laser-based approaches to treatment.

Precision for medical engineering and biotechnology
Nanoanalysis and picoliter analysis, minimally invasive surgery and point-of-care diagnostics all require high-precision instruments, new optical analysis techniques and low-cost, disposable micro-fluidic components. To this end, we are developing innovative production techniques for joining, structuring and functionalizing materials with nanometer accuracy and without any influence on the material.

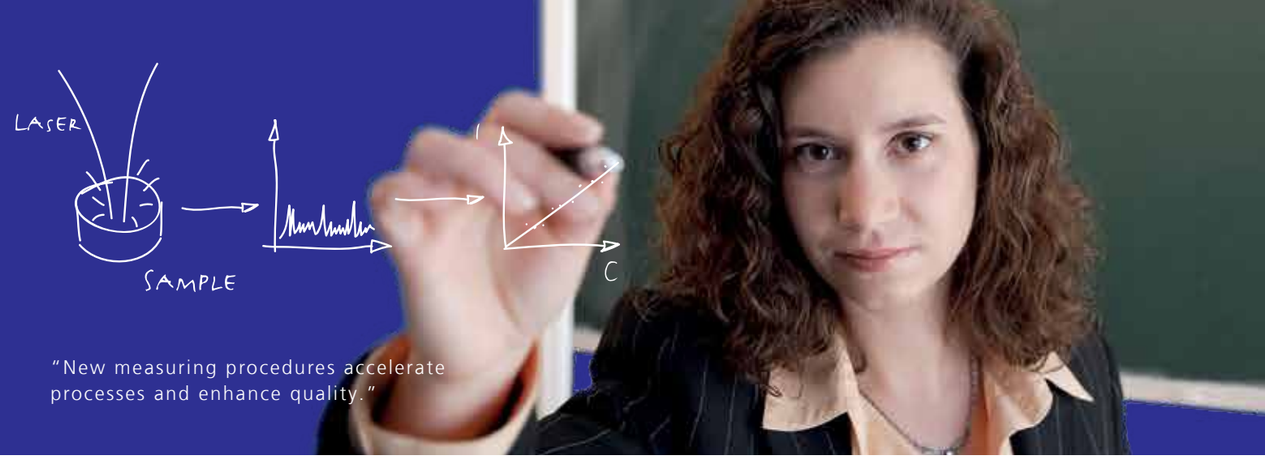
Bioanalysis and clinical diagnostics: exact results
Detecting binding processes between molecules in minimal-volume samples, tracking the process of protein crystallization, identifying pathogens in microfluidic chips – all these tasks can be carried out quickly and sensitively with laser measurement procedures. High-throughput laser spectroscopy can be used to collect molecule-specific information. With the aid of antibodies, it is possible to mark and detect toxins with high sensitivity in foodstuffs or the pathogens that cause blood poisoning.

Biofunctionalization: cell analysis and organ replacement
Going forward, cell-based analysis systems will form the foundation for functional medical diagnostics and made-to-measure drugs. Biofunctional surfaces are key to the development of artificial organs using patients' own cells. For that purpose we use powerful technologies: nanostructuring, photochemical surface modification and micro-scale topography modification.

Our range of services

- Microjoining for medical engineering and bioanalysis products
- Precision cutting, drilling and ablation
- Additive Manufacturing
- Microstructuring and nanostructuring
- Biofunctionalization of surfaces
- Tissue engineering
- Laser-assisted tissue sealing
- Precision ablation of hard and soft tissue
- Optical systems for laser-based therapy
- Bionanalysis and clinical diagnostics
- Laser scanning microscopy and multiphoton microscopy
- Fluorescence lifetime microscopy
- Optical near-field microscopy
- Fluorescence analysis in microfluidics
- Fluorescence polarization analysis
- Raman spectroscopy
- Laser scattered-light analysis in minimal volumes

LASER MEASUREMENT AND EUV TECHNOLOGY



"New measuring procedures accelerate processes and enhance quality."

With our laser sorting plants, we render material composition transparent.

PROPER TESTING IS THE KEY TO SUCCESS

Measurement technology is required in a wide variety of application areas – from industry and bioanalysis to medicine and environmental technology – and our material analyses using laser beams are opening up new dimensions in inline process control and quality assurance.

Production quality: faster checks with laser
Defects in metallic materials can result in defective components. The inline measurement of physical and chemical properties makes for much more efficient process control. Within the shortest possible time, a laser can identify a material or generate a precise map of its chemical structure, detecting for example oxide inclusions. That enhances transparency, cuts testing times, speeds up feedback to the process and ensures consistently high product quality.

Recycling by laser: an exact analysis of materials
Quite apart from the environmental aspect, the recycling of scrap metal has economic advantages, as the growing scarcity of resources pushes up their price. A more exact chemical characterization means a higher degree of reusability. This is where laser-induced breakdown spectrometry, a highly reliable measurement procedure, comes into its own. A brief laser impulse creates a plasma on the surface of the metal, the light from which contains information on the concentration of the individual elements. This procedure can also be used to efficiently characterize and sort raw materials as well.

Measuring coating thickness: even during operation
Thin zinc coatings are used to protect steel sheets against corrosion. Laser beams can penetrate these coatings, measuring their thickness inline on a moving production line with a high degree of precision. Wafer-thin coatings of light elements such as boron, carbon or even magnesium can also be measured using laser beams. The automated analysis offers an exact classification and evaluation of the material, thus shortening the response times for process control.

Plasma technology: EUV light for unparalleled precision
Pulsed, dense and hot plasmas emit light of extremely short wavelengths. Together with laser technology, these plasmas form another core competence of the Fraunhofer ILT. In a pulsed discharge, a powerful electric current is used to heat matter to temperatures of several thousand degrees centigrade, triggering an emission of short-wavelength light. Typical application areas for these light sources include EUV lithography, to be used in the production of semiconductors of the next generation but one, and x-ray microscopy.

Our range of services

- Development of laser measurement procedures for production, bioanalysis, medicine and environmental technology
- Construction and testing of laser measurement and testing systems
- Chemical analyses of solid, liquid and gaseous substances using laser spectroscopy
- Fluorescence spectroscopy
- Analysis of coating structures
- Microsurgical systems
- Real-time data evaluation
- Development of plasma-based EUV / XUV light sources and measurement systems
- Development of components for EUV / XUV systems
- Atmospheric plasmas for the sterilization of packaging materials and the functionalization of surfaces

PHOTONICS CLUSTER

Digital Photonic Production at its best

Digital Photonic Production – the future starts now
Digital Photonic Production allows the direct production of almost any component from digital data within a short period of time. Thanks to laser-assisted 3D printing, we can produce complex and functional components in small numbers, thereby making a contribution to expanding product portfolios and optimizing costs in various industries such as turbine construction, medical technology, tool manufacturing, as well as aircraft and automotive engineering. Furthermore, we use ultrashort pulsed lasers for precise structuring. Thus, functional surfaces with predetermined optical, haptic or tribological properties can be produced selectively. We view the related industrial process chains in an integrated way: from the construction design to the manufacturing process all the way to upstream and downstream production steps.

Business and science – efficient cooperation on location
Hand in hand with the new technological developments are topics such as mass customization and business innovation. At the Aachen location, we are systematically pushing ahead in new forms of cooperation between business and science. In the immediate vicinity of Fraunhofer ILT and the associated RWTH chairs – LLT, TOS, NLD and DAP – companies can set up offices with the intention of a strategic partnership. Their goal: to develop new components, systems, processes, process chains or business models in the field of optical technologies, especially for production technology. Facilities such as laboratories and offices can be rented as required. In open-space structures, mixed teams from industry and science interact. Education and advanced training have become quite efficient as companies "enroll" at RWTH Aachen University.

The Photonics Cluster – a guest at RWTH Aachen University
The Photonics Cluster on the RWTH Aachen Campus is coordinated jointly by the RWTH Aachen University Chair of Laser Technology LLT and Fraunhofer ILT. Two buildings have already been built by private and public investors in the Photonics Cluster. More than 20 companies have located in the 7,000 m^2 building specifically tailored to the industry shortly after it opened its doors. In a further building funded by the federal government and the state of NRW, the Research Center Digital Photonic Production, 16 institutes of RWTH Aachen University from six faculties are involved in the interdisciplinary and integrated research of digital photonic production chains. This is the starting point for further investments on location.

BMBF's Research Campus Digital Photonic Production DPP
The Research Campus Digital Photonic Production DPP is a 15-year strategic funding initiative of the German Federal Ministry of Education and Research (BMBF) that will systematically explore new methods and basic physical effects for the use of light as a tool in the production of the future. The Research Campus DPP has established a new form of long-term and systematic cooperation between RWTH Aachen University, the Fraunhofer-Gesellschaft and the industry. Under one roof, we bundle complementary resources into common application-oriented basic research. Now that's Digital Photonic Production at its best!

OUR PARTNERS

If you want to pioneer something, you not only need the right infrastructure, but also the best of contacts. That is why, above and beyond our integration in the Fraunhofer-Gesellschaft, we cooperate with numerous institutes in Germany and abroad. For only a lively exchange of ideas makes innovative developments possible.

The Fraunhofer network: infrastructure and expertise
More than 60 Fraunhofer Institutes are engaged in developing components, systems and methods, right up to their practical application. This makes the Fraunhofer-Gesellschaft a leader in application-oriented research. Thanks to this close cooperation, our clients can profit from the expertise and skills of all the institutes. In questions of patents and contracts, too, our common infrastructure means that processing is fast and uncomplicated.

Universities and R&D centers: research in its finest form
Our close ties with the various chairs and research areas of the RWTH Aachen University, one of Europe's top technical universities, ensures we have access to a broad range of basic knowledge. In matters of an interdisciplinary nature, we cooperate closely with a wide variety of international research and development centers so as to be able to offer our clients solutions from a single source.

Innovation clusters: stronger in a team
Our customers can benefit from the competitive advantages offered by our project-specific networks. The Fraunhofer ILT maintains a range of contacts to national and international innovation clusters, associations and funders of research projects. We are able to coordinate cooperative projects and ensure they are brought to a successful conclusion. We can also incorporate public funding, as the case may be.

International partners: knowledge branches out worldwide
Sophisticated R&D projects connect us to foreign partners from industry and science. For example, Fraunhofer ILT is participating in the Franco-German satellite mission MERLIN on the development of a future laser platform for LIDAR supported climate research. In production technology, international companies use processes and systems as well as basic knowledge of Fraunhofer ILT. Since the institute networks with other R&D facilities worldwide, we have a global overview in our own specialized disciplines.

A selection of our customer references:

• AG der Dillinger Hüttenwerke • Airbus Deutschland GmbH • Aurubis AG • Bartels Mikrotechnik GmbH • BEGO Medical GmbH • Berlin Heart GmbH
• BMW Group • Braun GmbH • Concept Laser GmbH • DILAS Diodenlaser GmbH • Evonik Degussa GmbH • FEV Motorentechnik GmbH • Förster Technik GmbH
• Heidelberg Instruments Mikrotechnik GmbH • Heraeus Noblelight GmbH • Huf Tools GmbH • IMA Klessmann GmbH • INOVAN GmbH & Co. KG
• JENOPTIK Laser, Optik, Systeme GmbH • KARCOMA Armaturen GmbH • Kistler Instrumente AG • LASAG AG • Laserline GmbH • Leyer & Kiwus GmbH
• MAN Diesel & Turbo SE • manroland AG • Marquardt GmbH • Maschinenfabrik Karl H. Arnold GmbH & Co. KG • Philips Licht GmbH • Precitec GmbH & Co. KG
• Radium Lampenwerk GmbH • Robert Bosch GmbH • ROFIN-SINAR Laser GmbH • Rolls-Royce Deutschland Ltd. & Co. KG • Stork Gears & Services
• Tesat-Spacecom GmbH & Co. KG • TRUMPF Laser- und Systemtechnik GmbH • Valeo Schalter und Sensoren GmbH • voestalpine Stahl GmbH • Zwiesel Kristallglas AG

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