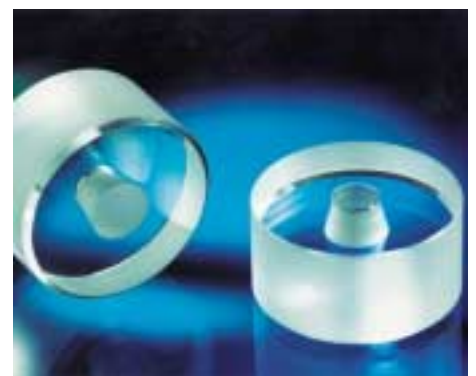




Fraunhofer Institut
Lasertechnik

Performance and Results Annual Report 2002



Annual Report
Fraunhofer Institute
for Laser Technology ILT
2002

Foreword



As Scottish journalist B. C. Forbes once said: »Ideas are the raw material of progress«. This could easily stand as the motto of the Fraunhofer ILT, for whom furthering the progress of science and technology forms an integral part of its mission. So here we look back at the innovations achieved in 2002 with a certain satisfaction.

Continuous progress has been made in work on the SLAB laser. Its focusing accuracy at 1 kW output has been proven in laboratory tests to be 2 times superior to the best CO₂ lasers. The market for diode-pumped solid-state lasers, a key area of our R&D activities, is on a consistent upward trend. While we freely admit that there is room for improvement in the long-term stability of such systems, especially when operating in pulsed mode, it is also true that significant progress has been made in this respect.

The close association between laser research and applications has enabled us to widen our horizons on many occasions. The selective laser melting process developed by the ILT, with its variable geometry factors, can be used to manufacture complex components. Its use in medical engineering, for the production of dental implants, is already beginning to make headway: a prime example of mass customization.

Members of the ILT staff are helping to spread the word about this and many other innovations at industrial and scientific forums. At the AKL'02 laser technology colloquium in Aachen, for example, more than 60 R&D projects were featured in 'live' presentations. The AKL colloquium has grown far beyond its original intentions, and the 2002 event, which was extremely well received, encompassed 35 specialist technical lectures, 11 marketing papers, 30 exhibitors and 400 guests. We would therefore like to repeat our thanks to the participants, and most especially our sponsors.

We are also proud to announce that the ILT quality management system has obtained ISO 9001:2000 certification. This places us in an excellent position to attack the upcoming challenges in 2003, with our core competences and a highly motivated team - despite a drop in basic funding imposed by the government's cost-cutting measures. I wish our partners a successful and creative year 2003.

Aachen, February 2003

Prof. Dr. rer. nat. Reinhart Poprawe M.A.



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Short profile

ILT - for the last fifteen years, this abbreviation has stood for extensive know-how in laser technology. Innovative solutions for manufacturing and production problems, development of new technical components, competent advice and training, highly-qualified personnel, the latest technologies and an international reputation: these are the guarantors for long-term business relations. The numerous customers of the Fraunhofer Institute for Laser Technology ILT belong to various sectors like automobile industry, mechanical engineering, chemical and electrical engineering, steel construction, precision mechanics and optics.

With more than 230 employees and 10.000 m² of usable floor space the Fraunhofer Institute for Laser Technology is world-wide one of the most important development and contract research institutes of its specific field. The four business areas cover a wide range of actual and vertical integrated topics. In the business area »laser and plasma sources« development activities are concentrated on innovative diode and solid state lasers for industrial use as well as compact EUV-sources for lithographic use in semiconductor production. The business area »laser material processing« offers solutions in cutting, ablation, drilling, welding, soldering, surface treatment and micro processing. The activities cover a wide range of applications from macro processing via nano structuring to biophotonics.



In the business area »laser plant and system technology« prototypes are developed, built up and installed on site. Process monitoring and control as well as system components and control software are part of the activities. In the business area »laser measurement and testing technology« processes and systems for inspection of surfaces, for chemical analysis, for testing the accuracy of dimensions and geometry of workpieces as well as for analysis of static and dynamic deformations are developed.

The comprehensive offer of services of the Fraunhofer Institute for Laser Technology ranges from research and development as well as system construction and quality assurance to advice and training. Industrial laser systems from various manufacturers as well as an extensive infrastructure are available for the work on research and development projects.

In the Laser User Centre of the Fraunhofer Institute for Laser Technology guest companies work in their own separated laboratories and offices. The basis of this special form of technology transfer is a long-term cooperation agreement with the institute in the field of research and development. The surplus value lies in the use of the technical infrastructure and in the information exchange with ILT's experts. Already 10 companies profit from the advantages of the Laser User Centre. Besides subsidiaries of leading laser manufacturers and innovative laser users, new entrepreneurs from the areas of special machine production, laser processing and laser measurement find a suitable frame to realize their ideas on an industrial scale.

Declaration of Principles

Mission

We occupy an international top position in transferring laser technology to industrial application.

We continually expand the knowledge base and know-how in our sector and make significant contributions to the ongoing development of science and technology.

Working with our partners in industry, science and government, we create innovations on the basis of new beam sources and new applications.

Cousters

The customers needs are the focus of our work.

Discretion, fairness and a spirit of partnership are top priorities in our customer relationships. Our customers can rely on us.

We tailor solutions and their cost-effective implementation to the demands and expectations of our customers, with the objective of creating a competitive advantage.

We support industry's needs for new specialists and managerial staff through project-based partnerships with our customers.

We want our customers to be satisfied - because we want them to return.

Chances

We strategically expand our knowledge base across the network.



Fascination: Laser

The unique characteristics of laser light and the resulting diversity of applications, are a constant source of inspiration and fascination.

Staff

Teamwork between the individual and the group is the foundation of our success.

Strengths

Our broad spectrum of resources enables us to offer one-stop solutions.

Management style

Cooperative, demanding and supportive. Knowing the value of our staff as individuals and the value of their know-how and their commitment forms the basis of our management philosophy. We involve our staff in the formulation of goals and the decision-making process. We place a high value on effective communication, goal-oriented and efficient work and clear decisions.

Position

We work within vertical structures, from research to application.

Our expertise extends from beam source, machining and measuring techniques, to application, through to integration of systems into the customer's production line.

Business Area »Laser and Plasma Sources«

This business area encompasses the development of diode laser modules and systems as well as diode-pumped solid-state lasers, the design of new diode laser structures, the microassembly of diode lasers and optical components, and the development of plasma systems. Outstanding project results, which have been successfully transferred to practical applications in close cooperation with industrial partners, include the transversally diode-pumped 5 kW solid-state laser and diode laser modules for joining plastic components. In cooperation with the Fraunhofer IAF new structures are being designed which permit the manufacture of diode lasers demonstrating higher beam quality. The business area continues to enjoy a unique reputation in the assembly of high-power diode lasers and in particular the installation of partially automated assembly facilities. Work in the plasma technology sphere focuses on the development of EUV beam sources for semiconductor lithography. The main target markets for the business area as a whole are laser machining, medical engineering and metrology, along with the component market for information and communications technology.



Business Area »Laser Material Processing«

Production processes addressed by this business area include cutting and joining techniques applying micro- and macro-technology, as well as surface engineering. The services provided extend from process development for the manufacture of sector-specific products and the integration of these processes in production lines, through simulation services for laser applications, to the production of samples in support of series production start-up. The strength of the business area is rooted in its extensive process know-how, which is tailored to specific customer requirements in each case. In addition to process development, the business area offers complete system solutions which utilize selected technology networks. Customers are offered laser-specific solutions that encompass design engineering, material specification, product design, production equipment and quality assurance. In addition to the target market of material processing, the business area also addresses customers in the medical engineering, biotechnology and chemical sectors.



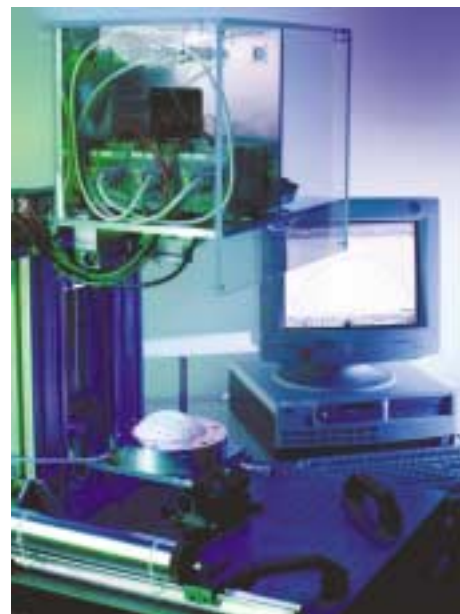
Business Area »Laser Plant and System Technology«

This business area focuses on the development of prototype equipment for laser and plasma-technology applications, as well as on laser systems engineering, particularly in the fields of automation and quality assurance. Areas of application embrace welding, cutting, hardening, repair coating, drilling and micro-joining. The system technology offered provides complete solutions for process monitoring, components and control systems for precision machining, laser-specific CAD/CAM technology modules, as well as software for measurement, open- and closed-loop control and testing. For its work in process monitoring in particular the business area can draw on extensive and, where required, patent-protected know-how. In this sector numerous systems have already been licensed for companies. Target markets include laser equipment and component manufacture as well as all sectors of production industry which deploy lasers in their manufacturing activity or intend to do so.



Business Area »Laser Measurement and Testing Technology«

The services provided by this business area include the development of measurement and testing processes and related equipment for material analysis and for geometric testing and surface inspection. The requisite measurement and testing software is tailored to customer-specific problem areas. Material analysis is based on the deployment of laser-spectroscopic processes, focusing on the analysis of metallic materials, identification testing of high-alloy steels, rapid recognition of plastics and analysis of process waste gases. Special electronic components are developed for the parallel processing of detector signals of high bandwidth. The business area has recently become involved in the new subject area of biophotonics. Projects are being conducted jointly with other institutes to systematically gather expertise in highly sensitive fluorescence detection for protein chips. As part of the area's work on geometric testing and surface inspection components, devices and equipment are being developed for obtaining 1 to 3D information about the geometry or surface properties of workpieces. These include processes and special systems for testing the topology of bar and strip products, devices for the 1D to 2D scanning of unit goods, and electronic components for laser triangulation and laser split-beam sensors. Target markets include all sectors of production industry which conduct measurement and testing requiring high reliability.



Committees

Board & Committees

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:

Ch. Schneider Dr.-Ing.
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Kanzler der RWTH Aachen

R. Wollermann-Windgasse Dr. rer. nat.
Trumpf Lasertechnik GmbH

The eighteenth Board of Trustees meeting was held on September 18, 2002 at the Fraunhofer ILT in Aachen.

Directors' Committee
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. Dr. R. Poprawe, Dr. P. Loosen, Dipl.-Ing. Wolfgang Oesterling (until 30.04.02), B.-O. Großmann (since 01.05.02), Dr. E.W. Kreutz, Dipl.-Phys. A. Bauer, Dr. K. Boucke, Dr. A. Gillner, Dipl.-Ing. H.-D. Hoffmann Dr. S. Kaierle, Dr. W. Neff, Dr. R. Noll, Dr. D. Petring, Priv.-Doz. Dr. W. Schulz, Dr. B. Weikl, Dr. K. Wissenbach, Dipl.-Phys. G. Vittr, Dr. J. Gottmann.

Health & Safety Committee
The Health & Safety Committee is responsible for all aspects of safety and laser safety at the Fraunhofer ILT. Members of this committee are: Dipl.-Ing. Wolfgang Oesterling (until 30.04.02), B.-O. Großmann (since 01.05.02), M. Brankers, Dr. E.-W. Kreutz, A. Lennertz, Dr. W. Neff, B. Theisen, K.-H. Ulfing, Dipl.-Ing. F. Voigt, Dipl.-Ing. N. Wolf, Dr. G. Kotitschke, Berufsgenossenschaftlicher Arbeitsmedizinischer Dienst (BAD).

Science & Technology Council
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 the ILT are: Prof. Dr. R. Poprawe, Dipl.-Phys. G. Vittr, Brigitte Theisen.

Department of Laser Technology at the RWTH Aachen
The Fraunhofer ILT is home to most of the Department of Laser Technology. This means that a close scientific relationship between the Fraunhofer ILT and the Department of Laser Technology has built up, based on a contract of cooperation. Prof. Dr. rer. nat. Reinhart Poprawe M.A. is Director of the Department of Laser Technology, Dr. E. W. Kreutz is Academic Director.

Contacts



Prof. Dr. rer. nat.
Reinhart Poprawe M.A. (-110)
Director



Dr. Peter Loosen (-162)
Vice director



Dr. Dirk Petring (-210)
Cutting and Joining



Dipl.-Phys. Axel Bauer (-194)
Marketing and Communication



Dr. Konstantin Boucke (-132)
Laser components



Dr. Konrad Wissenbach (-147)
Surface treatment



Bernd-O. Großmann (-185)
Administration



Dipl.-Ing. Dieter Hoffmann (-206)
Solid state and diode lasers



Dr. Arnold Gillner (-148)
Micro technology



Dr. Bruno Weikl (-134)
IT-Management



Dr. Reinhard Noll (-138)
Laser measurement
and testing technology



Dr. Stefan Kaierle (-212)
System technology



Dr. Alexander Drenker (-223)
Quality management



Dr. Willi Neff (-142)
Plasma technology



Priv.-Doz. Dr. W. Schulz (-204)
Modelling and Simulation

Core areas

Laser components

Dr. Konstantin Boucke (-132)

- active and passive cooling of diode lasers
- mounting of diode laser bars
- electro-optical characterization of diode lasers
- simulation of new diode laser structures
- micromachining techniques
- automation of micromachining techniques

Solid state and diode lasers

Dipl.-Ing. Dieter Hoffmann (-206)

- development of solid state and diode lasers
- methods and components for frequency doubling
- forming of diode laser beams
- development of diode laser modules and systems
- design and characterization of micro-optical components
- development of components for solid state and diode lasers

Laser measurement and testing technology

Dr. Reinhard Noll (-138)

- development, construction and testing of laser measurement and testing equipment
- chemical analysis of solid, liquid and gaseous substances with laser spectroscopy
- fluorescence spectroscopy
- measurement of geometrical quantities
- inspection of surfaces
- non-destructive test procedures
- real time operation and automation

Plasma technology

Dr. Willi Neff (-142)

- excitation systems for plasma technology
- low and high pressure plasmas for cleaning processes and sterilisation
- plasma based EUV and soft X-ray sources as well as X-ray technology
- short time measurement techniques
- photo and plasma chemistry

Cutting and Joining

Dr. Dirk Petring (-210)

- high speed processing
- thick section processing
- cutting and joining of special materials
- removal (drilling, caving, perforating, graving)
- 3D-applications
- welding with additional material
- hybrid techniques
- design of processing nozzles and optics
- sensor based process control
- computer supported simulation and optimization of processes
- multimedia qualification and information systems

Surface Treatment

Dr. Konrad Wissenbach (-147)

- transformation hardening, remelting, cladding, alloying and dispersing for the production of load orientated layers
- development of powder feeding systems
- polishing of glass and metals
- cleaning and modification of surfaces such as burr removing, activation and structuring
- rapid prototyping and rapid manufacturing for production of metallic parts, tools and implants

Micro technology

Dr. Arnold Gillner (-148)

- laser micro soldering and micro welding
- laser supported bending and adjustment
- precision cutting and drilling of metals, ceramics, semiconductors and diamonds
- micro structuring with excimer and Nd:YAG-lasers
- micro punching and stamping
- marking and lettering
- laser CVD and PVD, laser-galvanizing
- cutting and perforating of paper, plastics and composite materials
- welding of thermoplasts and thermo-plastic elastomers

Modelling and Simulation

Priv.-Doz. Dr. W. Schulz (-132)

- Design of hollow cathode discharge for generation of EUV-radiation
- Design of optical resonators for gas, solid state, and high power diode lasers
- Optimisation of beam guidance in optical systems
- Analysis of radiation transfer in process gases during processing
- Sub- and supersonic gas flow of assist and process gases
- Analysis of melt flow, heat transport, and movement of phase boundaries
- Dynamical models of cutting, welding and drilling
- Data evaluation algorithms
- Programming of graphical user surfaces for simulation of the models and visualisation of data using commercial graphic-servers like OpenGL®
- Numerical methods and codes, such as Cluster-In-Cell Code (CIC), adaptive meshing domains with moving boundaries (Hierarchical Basis), finite elements and finite volume methods on time dependent domains (Level-Set Method)
- Process monitoring using spatial and temporal resolved detectors like commercial CCD- and CMOS-camera systems
- Control of processing

System technology

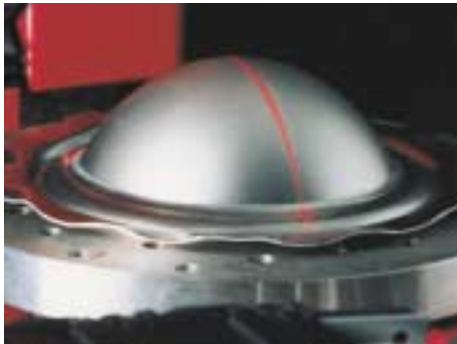
Dr. Stefan Kaierle (-212)

- pilot plants
- integration of laser technology into manufacturing systems
- development of sensors and control systems
- development of power supply for diode lasers, of generators for EDM equipment and of high-voltage-pulse-generators
- small-lot applications
- concept and design of plants
- control technique for laser plants
- education and training

Services

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

- development of laser beam sources
- manufacturing and assembling technology
- pulsed power supplies and control technology
- beam guiding and forming
- development, set-up and testing of pilot plants
- process development
- process monitoring and control
- model and test series
- integration of laser technology into already existing production plants
- X-ray and plasma systems



Cooperations with R&D-partners

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

- Realization of bilateral, company specific R&D-projects with and without public support (contract for work and services)
- participation of companies in public-funded cooperative projects (cofinancing contract)
- Production of test, pilot and prototype series by Fraunhofer ILT to determine the reliability of the process and minimize the starting risk (contract for work and services)
- companies with guest status at Fraunhofer ILT (special cooperation contracts)

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

During the implementation phase of new laser processes and products, companies can acquire 'guest status' at the Fraunhofer Institute for Laser Technology and use the equipment, infrastructure and know-how of the institute as well as install their own systems.

Facilities

The usable floor space at the Fraunhofer Institute for Laser Technology ILT amounts to more than 10,000 m².

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 Fraunhofer ILT also has a video conference room and a computer network.

Scientific infrastructure

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

Equipment

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

- CO₂-lasers up to 20 kW
- Nd:YAG-lasers up to 5 kW
- diode laser systems up to 3 kW
- diode-pumped solid state lasers up to 5 kW
- excimer lasers
- fibre lasers
- five-axis gantry systems
- three-axis processing stations
- beam guiding systems
- robot systems

- sensors for process control in laser material processing
- direct-writing and laser-PVD stations
- clean rooms for assembly of diode lasers, diode laser systems and diode pumped solid state lasers
- devices for process diagnostics and high speed video analysis
- laser spectroscopic systems for the chemical analysis of materials
- laser triangulation sensors for distance and contour measurement
- laser coordinate measuring machine
- devices for holographic vibration analysis and Speckle interferometry

Fraunhofer ILT abroad

Since its foundation, Fraunhofer ILT has been involved in many international cooperations. The objective of these cooperations is to recognize new trends and current developments and to acquire further know-how. The customers of Fraunhofer ILT can directly benefit from this. Fraunhofer ILT carries out bilateral projects as well as international cooperative projects with foreign companies and subsidiaries of German companies abroad. These companies can also contact Fraunhofer ILT through:

- international subsidiaries of Fraunhofer ILT
- foreign cooperation partners of Fraunhofer ILT
- liaison offices of the Fraunhofer Society abroad

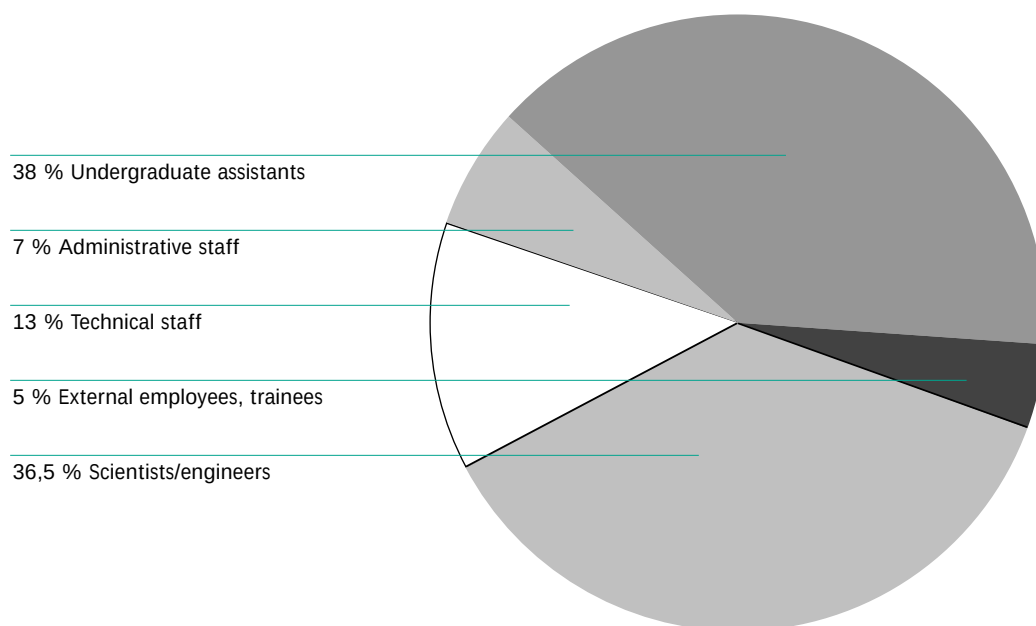
© AVIA-Luftbild, Aachen
Dipl.-Ing. Martin Jochum



Employees

Employees at the Fraunhofer ILT 2002	number
Personnel	140
- Scientists and engineers	91
- Delegated scientists	-
- Technical staff	33
- Administrative staff	16
Other employees	109
- Undergraduate assistants	98
- External employees	8
- Trainees	3
Total number of employees at the Fraunhofer ILT	249

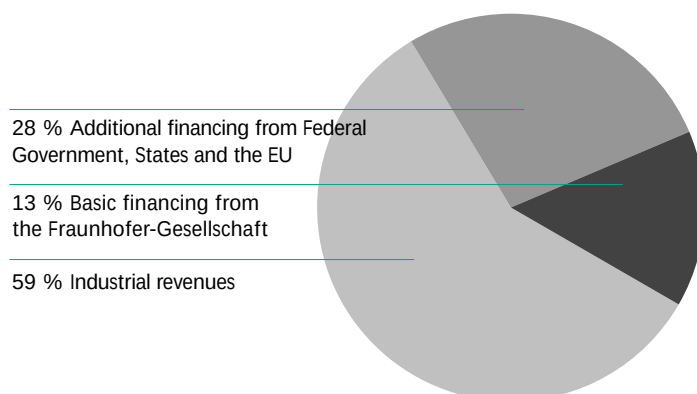
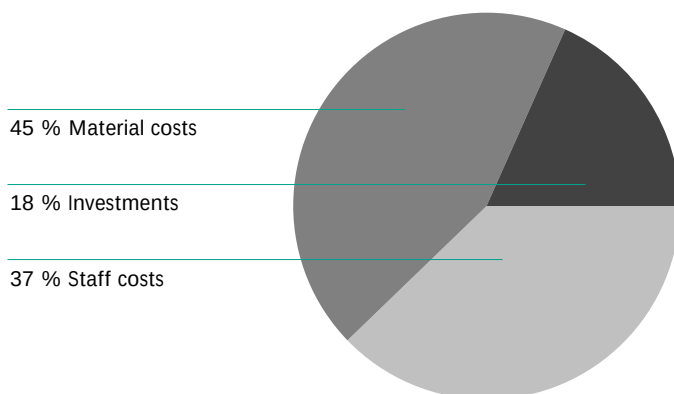
- 5 members of staff completed their doctorates
- 21 undergraduates carried out their final year projects at the Fraunhofer ILT



Revenues and Expenses (provisional)

Expenses 2002	Mill. EUR
Operating budget	17.1
- Staff costs	7.8
- Material costs	9,3
Investments	3.8

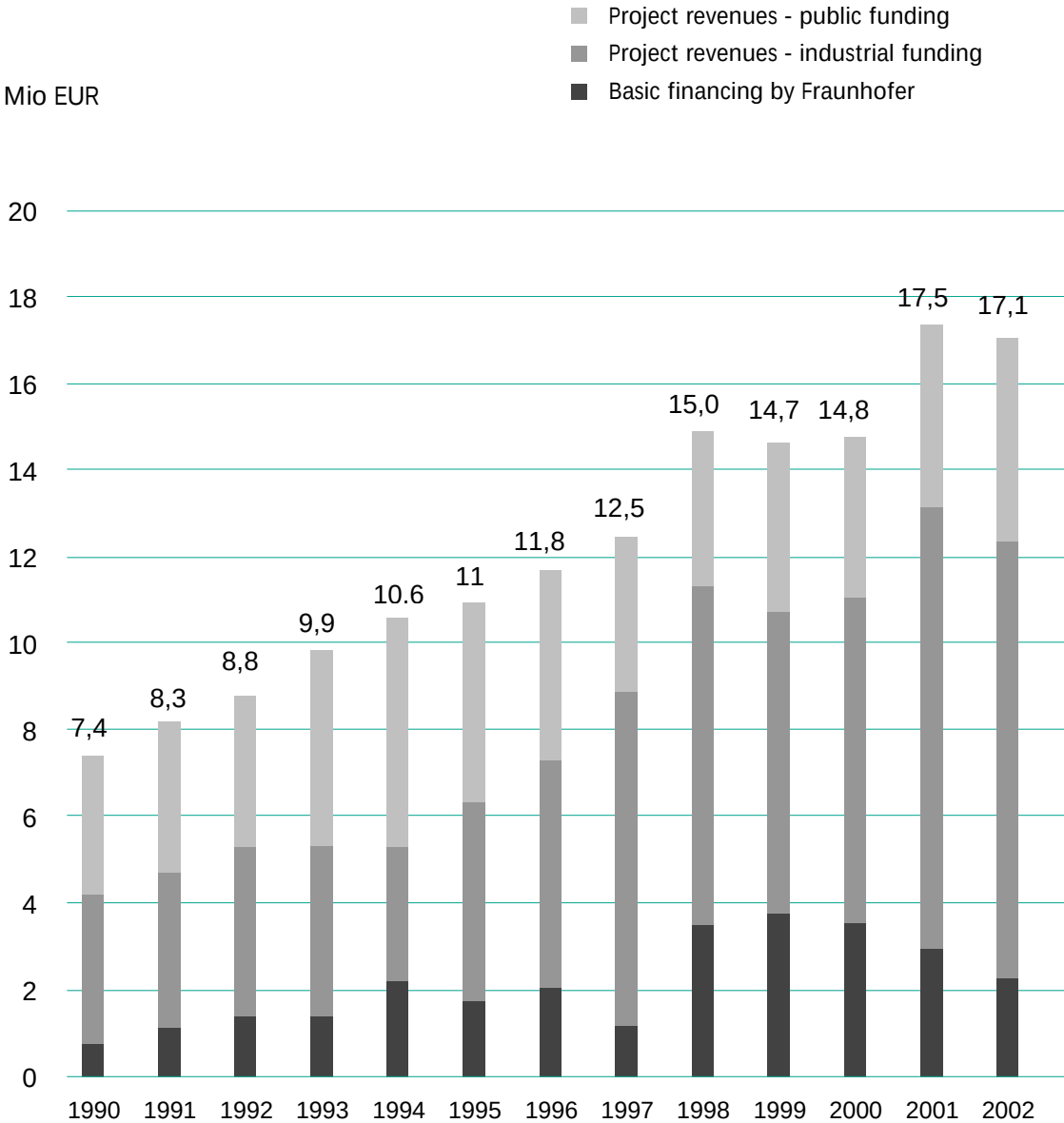
Revenues 2002	Mill. EUR
- Industrial revenues	10.1
- Additional financing from Federal Government, States and the EU	4.7
- Basic financing from the Fraunhofer-Gesellschaft	2,3
Total revenues	17.1
- Revenues from projects abroad (already included in total)	1.9





Budget growth

The following graph illustrates the budget trend over the last 14 years.



References

ABB ALSTOM
POWER

BAASEL
LASERTECH

BRAUN



BOSCH

DILLINGER HÜTTE

DILAS
Diodenlaser GmbH



HEIDELBERG INSTRUMENTS

Heraeus

HufTools

INOVAN



JENOPTIK
JENA
LASERDIODE

LAMBDA PHYSIK

LASAG
INDUSTRIAL LASERS



LEYER & KIWUS
LEITFACHEN & LASERTECHNIK



MARQUARDT

MicroLaserTec GmbH

MESSER
Igne Schweißtechnik

Mubea
ENGINEERING FOR MOBILITY

MULTEK

NAU



PROMETEC

Radium
Die Lichtmarke



Raufoss

ROFIN Sinar
LASER



Siemens Automation

INSTITUT FÜR METALLFORSCHUNG
AN DER UNIVERSITÄT DUISBURG ESSEN



Thyssen Laser Technik Aachen



VYCON
Engineering for Medical Products

WILDEN

Zinser

ZUMTOBEL STAFF
DAS LICHT

February 2003

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The companies listed here represent a selection of the Fraunhofer ILT's many clients.

Fraunhofer USA Center for Laser Technology CLT

Short profile

The Fraunhofer Center for Laser Technology CLT, located in Plymouth, Michigan, has a new 1250 m² development center housing \$9 million worth of the most varied, leading edge laser equipment in North America. This area has established itself as the center for laser production, system integration and industrial users in the USA.

The on-going goals are:

- Integration in scientific and industrial development in the USA
- Growth in know-how by faster recognition of trends in the field of laser and production technology
- Accelerated use of R&D and work methods, in which the USA is the leader
- Know-how growth through close cooperation with Wayne State University
- Strengthening position in the R&D market
- Increase of industrial return from the USA
- Increase of motivation and qualification level of employees

The central philosophy of Fraunhofer USA is the creation of a German-American joint venture where give and take occur in harmony. The win-win situation is an essential prerequisite for both sides. The Fraunhofer Gesellschaft is always interested in considering and trying to develop relationships on the American side that strengthen mutually.

As first commercial partner of the Center »Visotek« has been founded in January 2001. Aim is the fast commercialization of Fraunhofer technology and the common work on research projects. First prototypes of welding optics with integrated process and beam control have been delivered. The research on fibre coupled diode lasers with high power is intensively carried out.

The American partners' interest concentrates on:

- Using the competence of the Fraunhofer ILT for American companies
- Using the experience of the Fraunhofer ILT in the introduction of new technologies
- Providing the connection between industry and university
- Providing practical training for students and graduate students

Services

The CLT Michigan offers services in the field of laser processing. This covers the entire spectrum from education and feasibility studies, process development to pre-series development and system integration. As an independent institution small and mid-sized companies are given the opportunity to develop and test their processes on Fraunhofer machines with the help of Fraunhofer personnel. It is also possible to develop and test complete systems at the CLT. Our customers come from the automobile industry, construction industry, ship building and medical engineering.



Employees

Both Germans and Americans are employed at the CLT. The goal is to rotate German employees so that the collected experience can be brought over to the parent institutes and to offer German employees the opportunity to become further qualified during their stay in the USA. Furthermore, students from the Technical University in Aachen write their diploma thesis in the USA.

Equipment

Current equipment at the CLT consists of CO₂ lasers with 6 kW power pulsed Nd:YAG lasers from 1 kW to 4.4 kW, diode lasers from 30 W to 4 kW, a number of special and hybrid optics as well as a series of 3.5 and 6 axes systems.

'Laserspot' is a work group initiated and organized by the CLT that provides support by state-of-the-art laser systems to a wide array of laser users. CLT customers profit from the fact that the CLT has no special allegiance to any one laser manufacturer. This provides a unique view into the best laser practices and the opportunity to advise customers about the best laser equipment for the job.

References

- Alcan
- Borg Warner
- Coherent Semiconductor Group
- DaimlerChrysler
- Dana Corporation
- Ford Motor Company
- General Motors
- JMC Technology Group
- Johnson Controls
- Kuka
- LASAG
- Nuvonyx
- Parker Hannifin
- Praxair Surface Technologies, Inc.
- PRC Lasers
- Rofin Sinar
- Soudronic
- Spectra Physics
- Trumpf
- Tailor Steel
- T&H Lemont
- Valeo
- Visteon

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Operating budget 2002*

	Mio. US\$
Operating budget	3.1
- Staff costs	1.05
- Material costs	2.05

*Post-calculation has not occurred yet



Short profile

The Fraunhofer Institute for Laser Technology has been in successful cooperation with the CLFA in Paris for five years now working with leading French research institutions. In the infrastructure installed by the French partners (CEA, CNRS and DGA) in Arcueil near Paris interdisciplinary teams of experts from Germany and France work together to transfer laser supported manufacturing processes into the European Industry.

The on-going goals of the CLFA are:

- Integration into scientific and industrial development in France
- Growth in know-how by faster recognition of trends in the fields of European laser and production technology
- Strengthening the position in the R&D market
- Assembly of a European competence center for laser technology
- Increase of mobility and qualification level of employees

The CLFA is a result of increasing link of application oriented research and development in the field of laser technology in Europe. The cooperation of the Fraunhofer ILT with the French partners contributes to the improvement of the presence of the Fraunhofer Gesellschaft in Europe with the advantages for the French and German sides equally taken into consideration. On an international scale this cooperation further strengthens the leading position of European industry in the laser supported manufacturing process.

The French partners' interests concentrate on:

- Using the competence of the Fraunhofer ILT for French companies
- Using the experience of the Fraunhofer ILT in the introduction of new technologies
- Providing the connection between industry and university with practical training for students and graduate students

Services

The CLFA offers services in the field of laser material processing. This covers the entire spectrum from application oriented fundamental research and training, feasibility studies and process development to pre-series development and system integration. Small and mid-sized companies have the opportunity here to get to know and test laser technology in an independent system. The open development platform allows the French customers to test and qualify new laser supported manufacturing processes.

Employees

At the CLFA employees from France and Germany work together. A mutual exchange of personnel occurs between Aachen and Paris for joint projects. The employees therefore have the opportunity to improve their competence especially with regard to mobility and international project management.

Equipment

The infrastructure of the CLFA in Arcueil on a total area of 3000 m² consists of CO₂, Nd:YAG, and Excimer lasers with different power classes as well as the corresponding handling systems. These are complementary to the systems at the Fraunhofer ILT and are intensively used by customers in all fields of French industry.

Sales and Customer Spectrum

Turnover for the business year 2001 at the CLFA was about 2 million Euro. CLFA customers come from all areas of French industry: automobile industry, aerospace engineering, off-shore industry and nuclear technology as well as relevant suppliers. The integration of the CLFA within European-wide joint projects is being successfully pushed forward

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The Fraunhofer-Gesellschaft at a glance

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration. The organization also accepts commissions and funding from German federal and Länder ministries and government departments to participate in future-oriented research projects with the aim of finding innovative solutions to issues concerning the industrial economy and demands faced by society in general.

By developing technological innovations and novel systems solutions for their customers, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. Through their work, they aim to promote the economic development of industrial society, paying particular regard to social and environmental concerns.

As an employer, the Fraunhofer-Gesellschaft offers a platform that enables its staff to acquire the necessary professional and personal qualifications to assume positions of responsibility within their Institute, in industry and in other scientific domains.

At present, the Fraunhofer-Gesellschaft maintains roughly 80 research units, including 57 Fraunhofer Institutes, at over 40 different locations in Germany. A staff of some 13,000, predominantly qualified scientists and engineers, work with an annual research budget of around one billion euros. Of this sum, approximately 900 million EUR is generated through contract research. Roughly two thirds of the Fraunhofer-Gesellschaft's contract research revenue

is derived from contracts with industry and from publicly financed research projects. The remaining one third is contributed by the German federal and Länder governments, as a means of enabling the Institutes to pursue more fundamental research in areas that are likely to become relevant to industry and society in five or ten years' time.

Affiliated Research Centers and Liaison Offices in Europe, the USA and Asia provide contact with the regions of greatest importance to future scientific progress and economic development.

The Fraunhofer-Gesellschaft was founded in 1949 and is a recognized non-profit organization. Its members include well-known companies and private patrons who help to shape the Fraunhofer-Gesellschaft's research policy and strategic development.

The organization takes its name from Joseph von Fraunhofer (1787-1826), the illustrious Munich researcher, inventor and entrepreneur.

Fields of research

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

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

Target groups

The Fraunhofer-Gesellschaft is committed to working for the economy as a whole, for individual businesses and for society. The targets and beneficiaries of our research activities are:

- The Economy: Small, medium-sized and large companies from industry and service sectors can all benefit from contract research. The Fraunhofer-Gesellschaft develops concrete, practical and innovative solutions and furthers the application of new technologies. The Fraunhofer-Gesellschaft is an important 'supplier' of innovative know-how to small and medium-sized companies (SMEs) not equipped with their own R&D department.
- Country and society: Strategic research projects are carried out at federal and state level, promoting key technologies or innovations in fields of particular public interest, e.g. environmental protection, energy technologies and preventative health care. The Fraunhofer-Gesellschaft also participates in technology programs initiated by the European Union.

Range of services

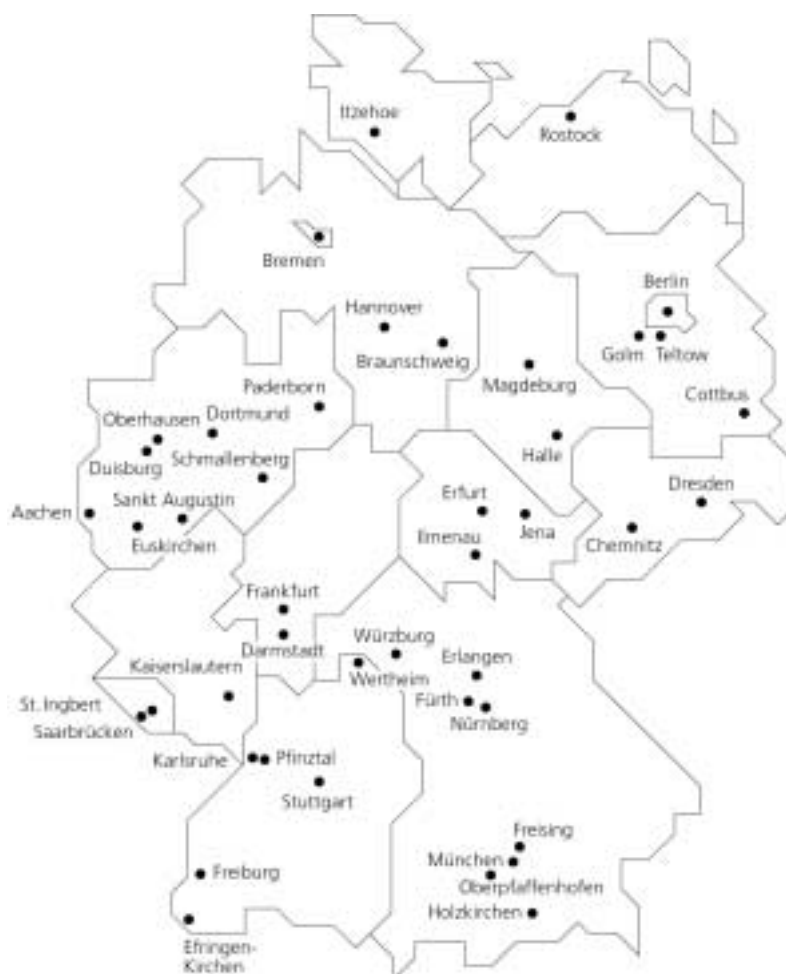
The Fraunhofer-Gesellschaft develops products and services to full maturity. We work closely with our clients to create individual solutions, combining the efforts of several Fraunhofer institutes if necessary, in order to develop more complex system solutions. The services provided by the Fraunhofer-Gesellschaft are:

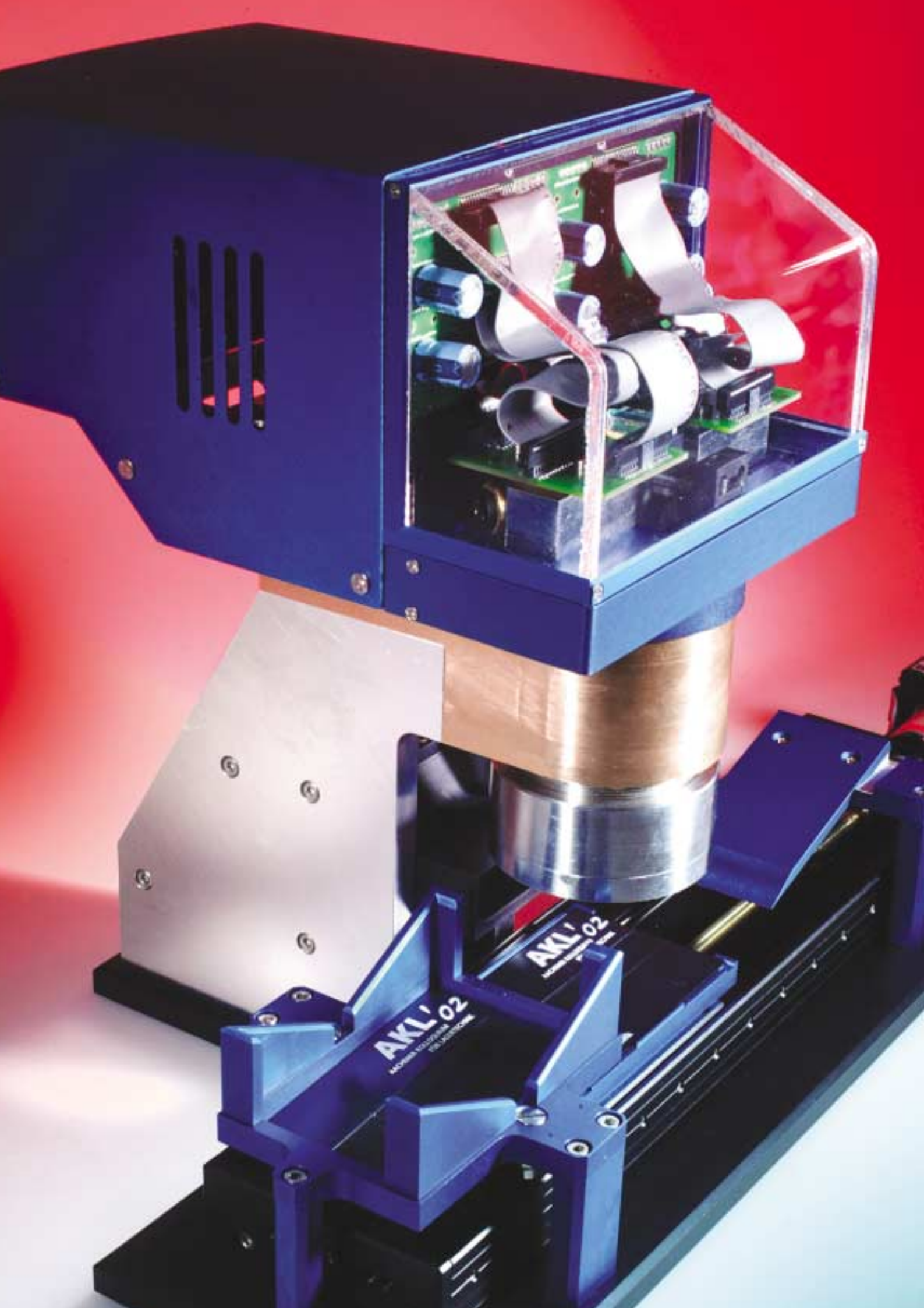
- Product optimization and development through to prototype manufacture
- Optimization and development of technologies and production processes
- Support for the introduction of new technologies via:
 - Testing in demonstration centers using highly advanced equipment
 - In-house training for the staff involved
 - On-going support, also subsequent to the introduction of new processes and products
- Assistance in assessing new technologies via:
 - Feasibility studies
 - Market analyses
 - Trend analyses
 - Life cycle analyses
 - Evaluation of cost-effectiveness
- Supplementary services, e.g.:
 - Advice on funding, especially for SMEs
 - Testing services and quality validation

The Advantages of Contract Research

Cooperation between all the Fraunhofer institutes means that our clients have access to a large number of experts covering a wide range of competencies. Thanks to common quality standards and professional project management, the Fraunhofer institutes ensure that research projects achieve results that can be relied on. Our institutes are equipped with up-to-date laboratory technology, making them attractive to companies of all sizes and from all industrial sectors. As a strong community, we can provide our partners with reliability and economic benefits: the Fraunhofer-Gesellschaft can bring the knowledge already gained from cost-intensive preliminary research into joint projects.

Research Facilities in Germany





Business Area Laser and Plasma Sources

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Demonstration device
for individually addressable
high-power diode lasers

Note from Institute Director
We would like to point out that the publication
of the following industry projects has been
coordinated with our customers. In principle,
industry projects are subject to the strictest
obligation to maintain secrecy. We would like
to take this time to thank our industrial partners
for their willingness to have their reports listed
published.

Demonstration device for individually addressable high-power diode lasers

Task

Usually all emitters in a diode laser bar are connected in parallel. But if individually contacted, each emitter can be controlled independently. Therefore, an individually addressable diode laser represents a source that can be modulated temporally and spatially. Our aim was to construct a demonstration device for this type of source with which to demonstrate the capacity of individually addressable diode lasers, combined with the ability to generate complex patterns at high speed.

Method

A diode laser bar with 48 emitters was chosen as the source. To compensate for variations in power or even the complete failure of one or more emitters, two diode laser bars were operated in parallel. They were coupled by a polarization beam splitter. The two diode laser bars were arranged to form one column of a label, with each emitter representing one line in the column. The pixel diameter was about 100 microns. We tested the experimental setup by using it to write a label on a special polymer film. A strip of film was

incorporated in an aluminum plate the size of a business card. To generate the lines of the label, the card was mounted on a fast translation stage, allowing the card to be moved under the static laser source. A card magazine and an extraction device were added to speed up the labeling process.

Results and Applications

The demonstration device is presently under construction. Preliminary tests have proved that it is possible to generate labels at a resolution of 200 dpi.

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Short-pulse power supply for high-power diode lasers

Task

The ability to determine the short-pulse wavelength of diode lasers is key to analyzing the thermal behavior of packaged diode lasers. Diode laser wavelength is highly temperature-sensitive ($> 0.2 \text{ nm/K}$), allowing the diode laser's thermal load to be derived from the wavelength shift. In this case, the short-pulse wavelength acts as a reference wavelength under non-thermal loading conditions. To make this determination, the diode laser must be driven by pulses of extremely short duration ($< 1 \mu\text{s}$). This requires a power source capable of generating more than 100 amps of power at a maximum pulse duration of $1 \mu\text{s}$.

Method

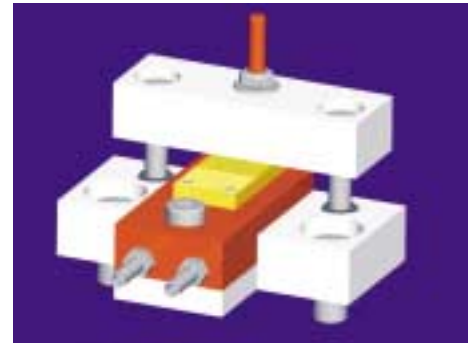
The power supply is being developed largely on the basis of off-the-shelf components in order to keep costs to a minimum. A pulse generator creates the desired pulses which are converted by a driver module into high-intensity pulses at peak current/voltage of $120 \text{ A} / 20 \text{ V}$. The driver module is designed to be able to generate pulses of variable duration, from $< 1 \mu\text{s}$ to cw (continuous wave). In order to achieve short pulse durations, the self-inductance of the circuit must be minimized. This is accomplished by designing the diode-laser mounting bracket such that the distance between the current-carrying components is as short as possible in order to reduce induction. In addition, special ribbon cables are employed.

Results and Applications

With the specially developed mounting bracket and ribbon cables, measurements have shown that the power supply can generate pulse durations of less than $1 \mu\text{s}$ at more than 50 amps of power. The power supply can also achieve pulse durations of less than $1 \mu\text{s}$ at 100 amps with a stack consisting of seven series-connected diode lasers. The power supply will be employed in the characterization of pulse-operated diode lasers and to determine short-pulse wavelengths.

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Diode laser system for cutting applications

Task

One of the aims of the BMBF-funded project »Modular Diode Laser Systems (MDS)« is to develop and test laser systems that derive benefit from the specific features and advantages of diode lasers. Our task was to create a compact high-radiance diode laser system for cutting sheet metal with a thickness of up to 1 mm.

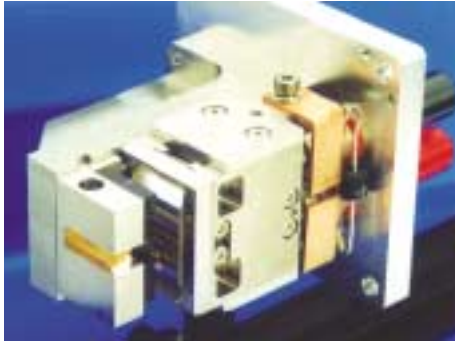
Method

To obtain the required radiance for cutting processes, six linear polarized diode laser bars of 3 different wavelengths are superimposed. The wavelength and polarization-multiplexing is realized with a cemented component consisting of edge filters, a $\lambda/4$ retardation plate and a polarization beam splitter. The linear shaped beam of the six superimposed diode laser bars is symmetrized by step mirror beam shaping technology. The beam is then focused on the workpiece through an optical microscope system.

Results and Applications

The optical output power amounts to 155 W at 55 A with a beam parameter product of about 22 mm mrad. This leads to a radiance of approximately $2 \times 10^6 \text{ W cm}^{-2} \text{ sr}^{-1}$.

Cutting edges free of burrs have been demonstrated on sheet thicknesses of 0.8 mm at feed rates of 5 m / min., optical output power of 125 W and a focus diameter of 0.3 mm.



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Diode laser line cutter

Task

As part of a BMBF-funded project »Modular Diode Laser Systems (MDS)«, our task was to develop a diode laser system of high power density for simultaneous cutting of thin metal sheets with a width of up to 40 mm. Homogeneity and linearity of the focal intensity distribution are most important for the quality of the cutting process.

Method

The system is based on four diode laser stacks, each consisting of six bars. The homogeneity of the laser radiation along the slow axis is assured by the use of a waveguide. The slow axis is imaged onto the processing zone by means of a special optical unit. The desired line width is 40 mm. The fast axis is focused by a focal length of 30 mm on a line of 0.2 mm.

Results and Applications

The requirements with respect to homogeneity and linearity of the line focus are met. The focus dimensions amount to 40 mm x 0.2 mm. The edge steepness of the intensity distribution

reaches less than 5 % of the line width, while the homogeneity achieves more than 90 % respectively.

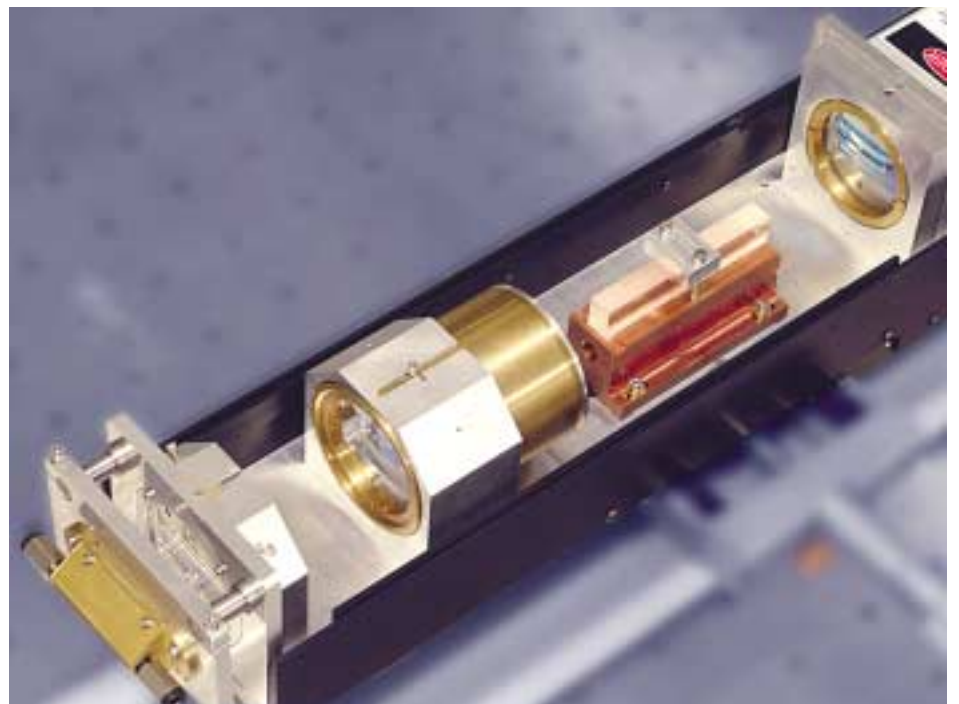
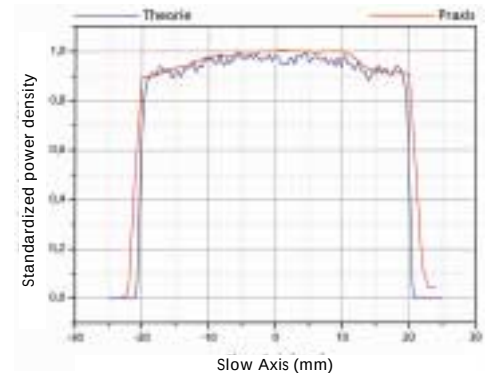
The overall efficiency of the optical system amounts to 78 % with a focal laser power of 680 W.

The modularity of the optical concept allows the intensity distribution to be easily scaled up or down for different applications.

The laser unit will be integrated in a special application system. First cutting experiments have demonstrated the functionality of the system and the feasibility of the process.

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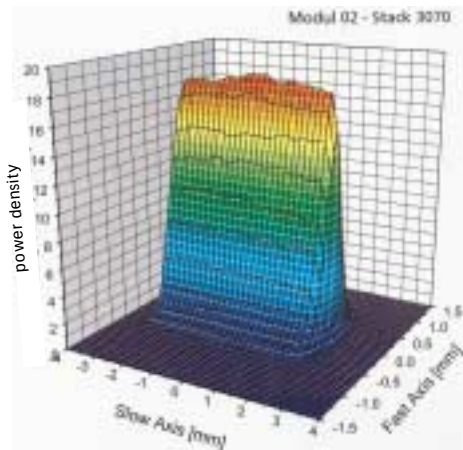
Modular diode laser system for hardening of metals

Task

As part of a BMBF-funded project »Modular Diode Laser Systems (MDS)« we constructed five diode laser modules for the hardening of metallic surfaces. The requirements on homogeneity of the focal intensity distribution of the process as well as its conformity over all modules call for a special technique in beam shaping.

Method

The optical components of the beam shaper and the link to a pyrometer are integrated in an industrial-grade housing. The output of the diode-laser stack is homogenized along the slow axis by means of a waveguide. The design of the optical system was verified by means of 3D ray tracing tests performed on the prototype. Once the prototype had been accepted, four identical modules were produced.



Results and Applications

The requirements with respect to homogeneity and conformity of the focal beam distribution were met by all modules. With an efficiency of more than 80 % over all optical components, the output power amounts to 450 W on the workpiece. The beam dimensions are less than 5 mm x 0.8 mm, at a power density of 20 kW/cm². The slope of the intensity profile (< 5 % of the full length) and the homogeneity of the slow axis (> 90 %) fulfilled highest requirements. First experiments on hardening of steel have been carried out successfully.

The high power density of the optical system and the facility with which it can be adjusted to process parameters, together with the top-hat-shaped intensity distribution, allow the system to be employed in a wide range of other materials processing applications, including polymer welding and cutting processes.

The modularity of the optical design also allows the beam profile to be adapted to specific applications.

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Directly diode-pumped femtosecond laser system

Task

Ultrashort pulses in the femtosecond range are required e.g. for the laser generation of x-ray radiation and in high precision micromachining of biological tissue. The necessary pulse energies of $> 10 \mu\text{J}$ can only be generated in oscillator-amplifier setups. Commercially available Ti:sapphire oscillator-amplifier systems of CPA type (chirped pulse amplification) are complex and expensive. This is mainly due to the necessary pulse stretcher which demands precise adjustment and due to the elaborate q-switched and frequency-doubled pumping laser. Thus the range of possible commercial applications is limited.

Method

The use of colquiriite crystals as lasing medium allows efficient, compact diode lasers to be employed as the pumping source. This simplifies the structure of the apparatus. A pumping module consisting of beam-shaped, thermoelectrically cooled, red diode laser bars ($\lambda = 685 \text{ nm}$) has been developed and successfully tested. This pumping module is used to end-pump two thermoelectrically cooled laser crystals inside the resonator of a regenerative amplifier. Currently available CPA (chirped pulse amplification)-systems require a setup consisting of a pulse stretcher before amplification and a following pulse compressor. In the Fraunhofer ILT's regenerative amplifier, the pulse stretcher is omitted. This leads to a particularly simple and stable compensation of dispersion. The laser pulses are sufficiently stretched by the dispersion of intracavity elements

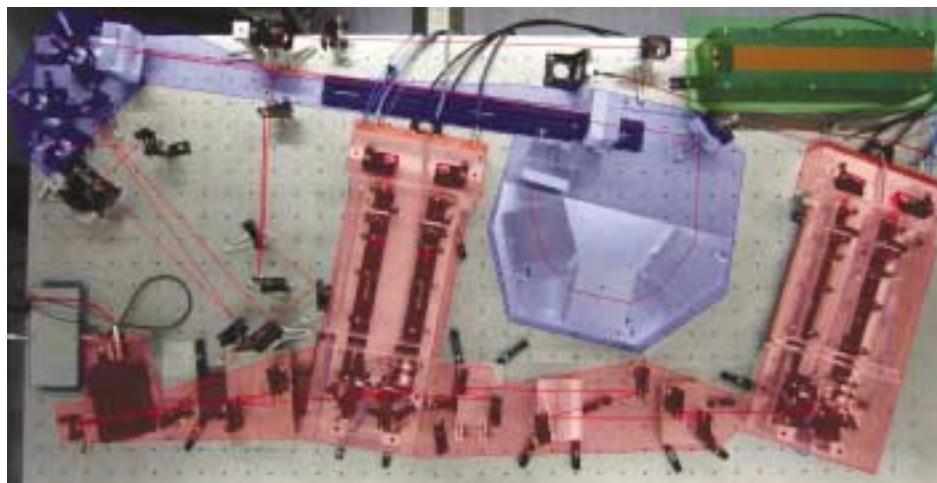
as to avoid any damage of resonator components and are compressed with a combination of a prism compressor and chirped mirrors to sub100-fs pulse lengths.

Results and Applications

The system delivers pulse lengths of 75 fs with pulse energies of $115 \mu\text{J}$ at a repetition rate of 2.5 kHz. This is the highest pulse energy from a directly diode-pumped amplifier system and the shortest pulse duration out of a colquiriit CPA system. The total power consumption of the system including cooling is only 400 W. The system has been successfully used for microstructuring of ear bones.

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Widely tunable laser with nanosecond pulses

Task

Secondary neutral mass spectrometry with resonant laser post-ionization (laser SNMS) is the most sensitive measuring method for spatially resolved surface analysis. This requires lasers with a relatively wide tuning range (190 nm – 1000 nm), narrow laser linewidth (less than 10 GHz) and millijoule pulses with a pulse duration of around 10 ns. Most research laboratories today use dye-laser-based systems for high-throughput screening. There is a need for compact, low-maintenance, high-repetition-rate, all-solid-state laser systems to replace them.

Method

The required tuning range and laser linewidth can be generated by nonlinear optical frequency conversion of a Ti:sapphire laser.

The absorption band of Ti:sapphire spreads over the blue and green regions of the visual spectrum. The lifetime of the upper laser level is relatively short (3.2 μ s). Therefore a frequency-doubled Nd:YAG q-switched laser is used for pumping. Wavelength selection is performed by prisms inside the laser cavity. An etalon is used for narrowing of the laser linewidth.

Results and Applications

The first step was to develop a Ti:sapphire laser which is tunable from 675 nm to 1030 nm. At 10 W pump power and 1 kHz pulse repetition rate, 0.8 mJ to 2.8 mJ output energy per pulse has been demonstrated. The pulse duration is less than 10 ns within a wide wavelength range and rises up to 60 ns at the tails of the tuning range. Beam quality is better than $M^2 = 1.5$. In a later development stage, nonlinear optical frequency conversion of the Ti:sapphire laser will make the short wavelength region of the required spectrum available.

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High-power short-pulse MOPA system with kW average power

Task

The increasing component density of lithographically produced structures in microchips requires new kinds of lithography radiation sources.

Laser-based EUV lithography with a wavelength of $\lambda = 13.4$ nm demands the development of high-power laser systems with a pulse power in the MW range, average power in the kW range and high beam quality.

A Nd:YAG master-oscillator-power-amplifier (MOPA) system with pulse durations below 10 nanoseconds, repetition rates of several kilohertz and an average power in the kilowatt range with a beam quality of $M^2 < 10$ is being developed on behalf of Xtreme technologies.

Method

The amplifier system is based on commercial diode-pumped Nd:YAG laser modules, which have been developed in cooperation with Rofin Sinar during the last few years for application in high-power cw lasers. The modules are continuously transversely pumped.

To achieve the required high beam quality, suitable optics are being developed to compensate for the negative effects on beam quality that occur when Nd:YAG rods are operated at high average power.

Results and Applications

So far the MOPA arrangement has been operated with up to 10 kilohertz repetition rate and a pulse duration between 7 and 20 nanoseconds.

A setup based on an industrial laser with four laser modules has been developed and realized. At 10 kilohertz, the system delivers an average power of 400 watts.

With an optimized MOPA arrangement containing eight laser modules, an average power output of 2 kilowatts with a repetition rate of 20 kilohertz is expected.

Apart from its use in EUV lithography, the laser system could be of interest for high-speed precision machining processes such as percussion drilling, surface structuring or pulsed laser deposition.



Prototype of the MOPA system with connected EUV-plasma-chamber (photo: Xtreme technologies)

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Diode end-pumped high-power slab laser

Task

By comparison with lamps, diode lasers are more suitable for pumping solid-state lasers because of their spatial and spectral emission characteristics. In diode-pumped rod laser systems which are widely used in practice, the diode laser radiation is focused on the crystal via fibers through the rod end. This technique provides the optimum overlap between pump volume and mode volume achieved. The scalability of this pump arrangement is, however, limited by the small pump area and thus the high thermal load on the laser crystal.

The aim of this investigation into diode-pumped slab lasers is to scale up the output power into the 1 kW range with a beam quality of $M^2 < 10$ for high speed precision processing.

Method

The laser medium in the slab laser concept shown in the diagram is plate-shaped rather than rod-shaped and is end-pumped by a diode laser stack. The pumped volume has a rectangular cross-section with an aspect ratio of > 10 and the total slab volume is only partially filled by the pump radiation. The slab is contact-cooled across

its larger surface. A hybrid resonator is used to obtain a high beam quality, the resonator is stable in the plane of the small dimension and off-axis unstable in the plane of the large dimension of the gain cross-section.

Due to the unstable resonator, the intensity distribution at the focus shows sidelobes. To reduce the power content of the sidelobes in this direction, mirrors with a variable reflectivity profile were used. The profile was optimized using a numerical code.

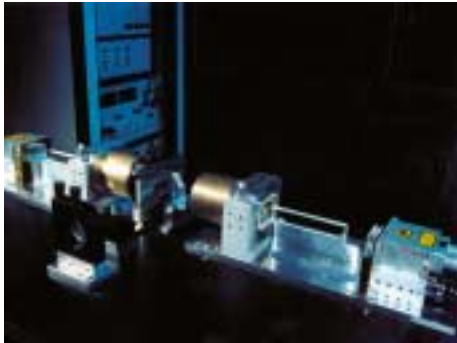
Results and Applications

Pumped with a stack consisting of 6 diode laser bars, an output power of 80 W ($M^2 < 1.5$) was obtained. In q-switched mode at a repetition rate of 1 kHz, the pulse energy was 6 mJ and the pulse length 15 ns.

A maximum output power of 982 W was obtained in cw mode, with a beam quality of less than $M^2 = 7$ over the whole power range.

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Continuous on-line atmospheric plasma process

Task

The aim of the project is to develop a continuous on-line atmospheric-pressure plasma process (speed 600 m/min; width of treatment up to 2m) for the surface treatment of various materials (papers, fibers, plastics, textiles). The objectives are to obtain better products (adhesion, wettability, ink-ability), to improve process outcome, consume less energy and harmful chemicals, reduce contamination on the final products and environmental burden, reduce waste to dispose.

Method

The consortium is composed of eleven partners from six European countries. Six research centers (three specialized in plasma, one in paper, one in composite fibers, one in material sterilization) and five industrial companies (one manufacturer of plasma equipment, one paper producer, one glass fiber producer, two textile manufacturers) participate. The ILT focuses on development of the plasma devices.

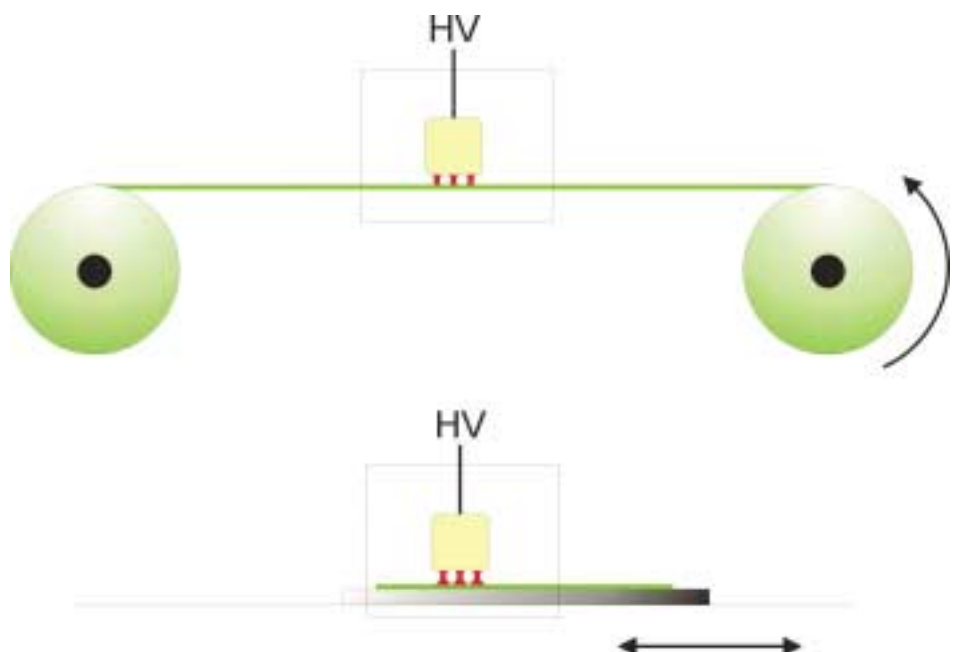
Results and Applications

Possible applications are to be found wherever plasma-chemical surface modification under high-speed conditions is required.

The project is being funded by the European Commission under the project code G1RD-CT-2002-00747.

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Atmospheric-pressure plasmas for sterilization of packaging

Task

Sterility is an essential aspect of the materials used for the packaging of food or medical products – often plastic films made of PET, PE or PP. The most common techniques used at present in aseptic packaging are chemical processes such as sterilization by hydrogen peroxide or hot steam. These techniques have certain disadvantages with respect to environmental compatibility and machinability. The aim of this project is to develop sustainable and efficient sterilization processes which can be applied in an industrial environment.

Method

Plasmas at atmospheric pressure – as they occur in a dielectric barrier discharge – can be used to sterilize packaging material. Such plasmas emit UV light which has a bactericidal effect. Additionally, the production of oxygen free radicals increases the sterilization effect. In collaboration with the Fraunhofer Institute for Process Engineering and Packaging (IVV), well-defined samples (loaded with spores of *Bacillus subtilis* and *Aspergillus niger* respectively) are treated in different discharge setups at the Fraunhofer ILT and the number of survivors is determined with the so-called count reduction method.

Results and Applications

The project has demonstrated the theoretical feasibility of plasma sterilization. It has been shown that there are no efficiency losses in spore reduction when the packaging material is moving at a speed of up to 30 m/min through the barrier discharge. Significant enhancements have been achieved in the efficiency of spore reduction through the development of new types of discharge setup. With the so-called cascaded barrier discharge, a spore reduction by five orders of magnitude on continuous film is feasible now in a few seconds. A portable setup that makes use of this concept has been built (see photograph). This equipment can be used for end point tests in a sterile environment.

This work was sponsored by the BMBF under contract code 13N7602.

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Atmospheric-pressure plasma produced by a dielectric barrier discharge

Plasma reactors for reducing pollutants in exhaust gases

Task

Many everyday activities contribute to or are affected by air pollution, which is subject to strict concentration limits. A typical example is the exhaust emissions from road vehicles and industrial plant, which often contain volatile organic compounds (VOCs). Most of the available treatment technologies are complex to install and maintain. One low-maintenance, easy-to-install alternative is the generation of atmospheric-pressure plasmas through processes such as barrier discharge.

Method

Barrier discharge, also known as dielectric barrier discharge, is the most suitable method for generating non-thermal plasmas under ambient pressure.

Barrier discharge creates oxidative and reductive free radicals when high-energy electrons collide with gas molecules under atmospheric pressure and at relatively low ambient temperatures. The radicals subsequently react with and reduce the level of pollutants in the exhaust gas, influencing its interaction with an immediately following catalytic converter.

The influence of the plasma characteristics, additives and catalysts are key factors in the reduction of exhaust gas pollutants. With the help of a comprehensive gas analysis, various reaction mechanisms can be set up which allow plasma processes to be customized for any application.

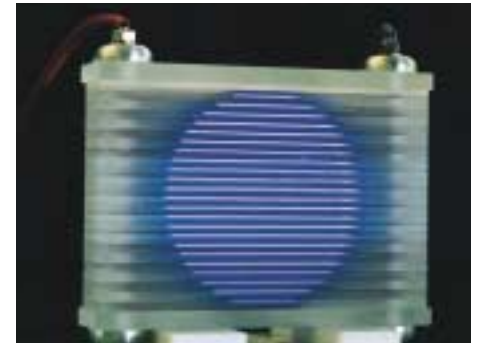
Results and Applications

Whereas our earlier plasma reactors were constructed from quartz glass, we have now succeeded in taking the first step toward low-cost mass production by using ceramic-based reactors. By further reducing the dimensions, we can now install the reactor in the vehicle's exhaust system. Its use in combination with a catalytic converter and additives further increases the efficiency of the process.

In order to assess the viability of plasma processes, the ILT has the facilities to perform in-house feasibility studies. Customer-specific reactor designs are available on request as well as process and technical support during testing. In addition, the ILT can supply electrical controls, electrical measuring instruments and PC-based controls for the entire system.

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Quartz glass
plasma reactor

XUV light as a measuring tool in nanoanalysis

Task

Light in the spectral range of extreme ultraviolet radiation (XUV) has unique properties. Large cross-sections when interacting with material and short wavelengths from approximately 1 up to 50 nm allow microstructure investigations at penetration depths in the nanometer to micrometer range and spatial resolutions well beyond those of light microscopy.

Because of the lack of suitable compact light sources and efficient optical components, the industrial use of XUV light has not yet been possible. In the meantime, an EUV radiation source is commercially available from AIXUV GmbH. The gas-discharge-based plasma source was developed at the Fraunhofer ILT and emits radiation at wavelengths of 10 to 20 nm. Furthermore, the Fraunhofer IWS and the Fraunhofer IOF have developed highly sophisticated coating processes for the production of precise multilayer systems, which are essential for highly reflective mirror optics. The three institutes have therefore pooled their resources to develop and integrate the single components that are required for the construction of different demonstrators.

Method

At the Fraunhofer ILT, an experimental setup is currently being tested that allows the detection of spectrally resolved light, transmitted or reflected from defined specimens. The information content can be filtered to determine, e.g., layer thickness, material structure and chemical composition of the specimens. Inside the analytical instrument, two identical light beams are obtained from the EUV source spot. One of them interacts with the specimen and one serves as a reference signal. In order to obtain spatial resolutions in the submicrometer range, suitable Schwarzschild-objectives are being developed at the Fraunhofer IOF and IWS.

Results and Applications

Possible applications related to EUV lithography are the characterization of optics, masks and photoresist. The determination of low Z-contamination and layer thickness can be used in semiconductor quality assurance. Potential applications in materials science include measurements of surface roughness or the chemical composition of near-surface layers. In the life sciences, the XUV light can be used in the microscopy of living cells.

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Hollow cathode discharge simulation by means of particle-in-cell coding

Task

The capacity of processors and memory chips doubles every 1 - 2 years. One of the main contributory factors is the continuing reduction in the size of structural features on the chips. In order to advance a step further in reducing the size of structures, there is a need for powerful light sources in the extreme ultraviolet (EUV) range, operating at a wavelength of 13.5 nm. One promising candidate for the generation of EUV-light is the method of hollow cathode discharge. In order to optimize these sources, the ignition phase of the discharge needs to be well understood. Calculations performed using numerical models are a useful supplement to experimental investigations.

Method

Owing to the low gas pressures, so-called particle codes are used. The motion of the charge-carriers in the electric field is calculated by numerical integration of the equations of motion. The electric field is derived self-consistently from the density of charge-carriers and the boundary conditions on a grid. The intersections of the grid form cells, hence the name of the particle-in-cell method. The collisions of the electrons and ions respectively are simulated using pseudo random numbers.

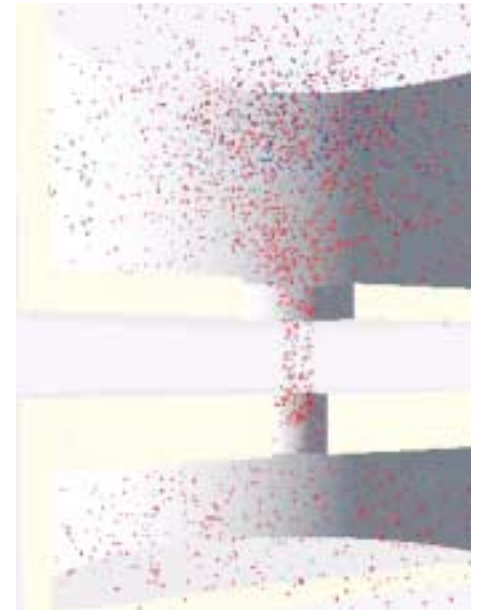
Results and Applications

One of the main results of the simulation calculations is the time elapsing between application of the discharge voltage and triggering of the discharge, after which the primary current of approx. 15 kA flows through the discharge, and the desired EUV radiation is generated. As well as determining the resolidification time of the discharge, this time also determines the maximum pulse frequency and thus the upper mean beam power limit.

Particle codes can be used to advantage in all cases where it is not possible to describe processes in terms of continuum mechanics.

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Discharge geometry showing some of the particles used in the calculation. Electrons are shown in blue, ions in red.

Business area
laser material processing





Business area laser material processing

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Task

Existing parameters for conventional laser drilling are inadequate when precision drillings of a few μm in diameter are to be produced in metallic components. Deviation of the beam cross-section from an ideal circle, for example, must be compensated. In contrast to drilling within the mm range, the result is affected by the polarisation direction of the laser radiation.

Method

In order to achieve a drilling geometry independent of the beam cross-section, the so-called spiral drilling method is used. In this process, the laser beam rotates relative to the component and removal of the material takes place in several stages by erosion. The laser beam at the same time rotates in itself, so that a reconciliation of the polarisation direction is reached. In addition to cylindrical drilling, conical drillings can also be produced by tilting the laser beam relative to the component.

Results and Applications

Using the spiral drilling procedure, circular holes of 30 μm in diameter can be produced.

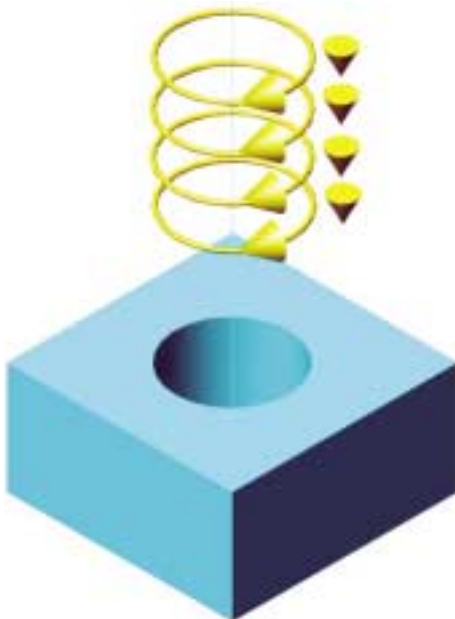
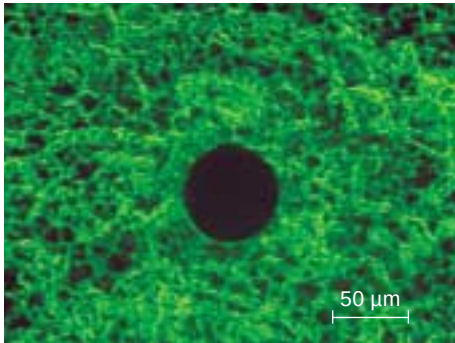
For conical drilling, expansions of up to 1 : 2.5 are possible.

Investigations have thus far involved tool and high-grade steels with a material thickness of up to 2 mm.

Possible applications can be found in cases where drillings of this geometry and precision can only be achieved at substantial expense if conventional methods are employed. Injection nozzles in the automobile industry or starting hole drillings for EDM procedures are concrete examples of such applications.

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Laser beam perforation of elastomeric belts for spinning machines

Task

Elastomeric belts are used to conflate fibres in spinning processes. In a new type of spinning machine, these belts are perforated with round and elliptical holes. A vacuum suction force is applied to the raw fibres through these holes to bring them together as tightly as possible before spinning. The perforation edges must be sufficiently smooth to prevent fibres being caught by the holes.

Method

Laser beam perforation proves to be the best method to achieve the required smoothness. Thanks to the material's good absorption characteristics, a CO₂-laser was selected as the laser beam source.

Following qualification of the method in a feasibility study, an optical system was developed which produces two cutting beams. These work independently of each other and allow two belts to be produced simultaneously. Both beams are fed by the same laser beam source using a beam splitting optical device.

Results and Applications

It has been shown that the polymer belts can be perforated in consistently high quality with a CO₂-laser. Dependent on the size of the belts, 70 to 100 holes of less than 1 mm in diameter are produced within 1 hour.

The emissions generated during perforation of the belts with the laser beams, can be highly pungent and a health hazard depending on the belt material. A filtering unit must therefore be employed to capture and clean all exhaust air from the production process.

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By courtesy of
Zinser Textilmaschinen GmbH.



Laser bonding of micro-optical components

Task

In the assembly of micro-optical components, lenses, optical fibres and other optical elements are generally mounted using manual adhesive joining techniques. In response to the call for increasing automation and improvement of product characteristics, there is a need for technologies that can be integrated into assembly lines and do not require any bonding additives.

Method

A new technology has been developed for the material combination of silicon and glass. Glass components such as lenses, optical fibres and micro mirrors are positioned onto a silicon substrate subsequent to their being specially prepared, whereby appropriate metrological techniques are used to identify and compensate for any dimensional inconsistencies in these parts. These are then pressed onto the silicon and heated through the transparent glass by a Nd:YAG laser. A very strong oxide bond, comparable in durability to that achieved with anodic bonding, is formed within fractions of a second at the interface of the two materials.

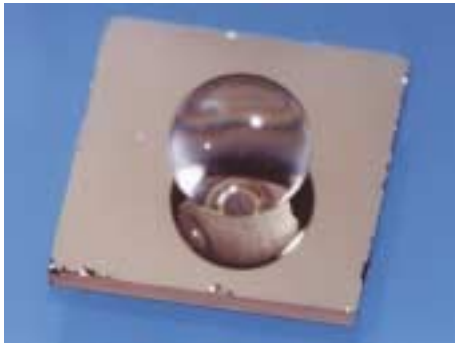
Results and Applications

The laser bonding process allows lenses, optical fibres and mirrors to be mounted directly onto silicon substrates without any additional material. Laser power requirements lie in the range of $P < 50 \text{ W}$ and bonding takes less than 1 second. Although similar to silicon fusion bonding, the new process is not limited to certain glass varieties which are adapted to the expansion coefficient of silicon, but can be used on standard high-temperature glass and quartz.

The new technology allows the aligned joining of micro optical components in highly automated production lines, including the manufacture of optoelectronic components, wavelength multiplexers, fibre couplers and optical switches.

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Above: laser bonded lens
Below: laser bonded glass fibre

Simultaneous laser beam micro-welding with diode lasers

Task

The ability to shorten processing times and minimize investment costs are both key factors in the manufacture of micro mechanical components.

Although laser beam micro welding is already established, process times are frequently too long for mass production because movement of the laser beam or workpiece as a rule dictate that the process proceeds in sequentially.

Method

Processing times for laser beam micro welding could be reduced if several diode lasers, each with a line focus of 2 mm x 0.2 mm, are used simultaneously. Furthermore, technical equipment can also be simplified by eliminating the movement apparatus.

In developing the simultaneous laser beam micro welding process, welds were produced in 1.4301 stainless steel with a thickness of 1 mm. Only one diode laser was used for workpieces with a flat surface. Three diode lasers were used to create a ring seam for industrial applications. The beams of these lasers were overlaid to create a common focal point measuring 5.5 mm x 0.2 mm. The cross-section and longitudinal axis geometry of the welding seam was compared with numerical simulations.

Results and Applications

Due to the large beam diameter in the lateral direction, evaporation temperature is already reached at laser intensities of 104 W/cm^2 , resulting in uneven seam depths. Uniform seams up to welding depths of 500 μm can be produced using simultaneous laser beam micro welding, whereby the ratio of seam depth to seam width is 0.5 to 1.

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Laser beam micro-welding of watch components

Task

The methods employed to connect components in the manufacture of watches must be flexible and efficient, without distorting the shape of the parts or creating unwanted residues. On the one hand present connecting techniques such as flanging or press fitting apply mechanical forces with distortion of their shape, so that only low mechanical tolerances can be maintained. On the other hand, gluing watch components together is very time consuming, since normally all parts must be pre-treated. The need to maintain a constant process environment and to handle small amounts of adhesive means that gluing techniques can only be considered in mass production involving extensive equipment outlays. Furthermore, the methods employed must be suitable to form a bond between dissimilar metals.

Method

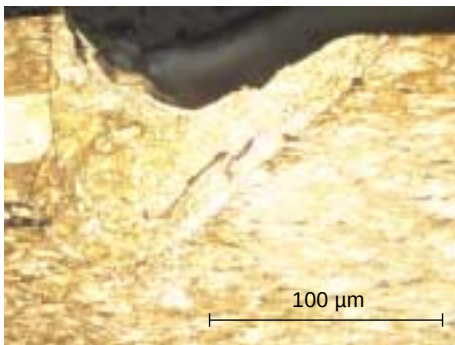
Micro-welding of watch components using pulsed Nd:YAG laser beams, in particular the so-called SHADOW technique, shortens processing time. Since no mechanical contact is involved, this method can easily be adapted to changes in geometry or material. The ability to vary the power and duration of pulsed laser sources makes it possible to adjust energy deposition to ensure uniform depth and width over the entire length of the weld seam.

Results and Applications

The example shows a day indicator made of the brass alloy Ms61Pb. A single laser pulse is moved across the workpiece at a high feed rate of $v_f = 40 \text{ m/min}$ and generates a large ring-shaped weld seam of 13.5 mm in length. The low energy deposition in this continuous process can be used to join together micro-scale components, materials with poor welding properties or material combinations such as steel and brass. For joining steel parts in SHADOW-technique a very high feed rate can be obtained only limited by physical effects such as humping. Weld seams with a length up to 25 mm can be generated depending on material and geometry. The SHADOW technique is suited for linear welds as well as for rotationally symmetric parts.

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Above: Day indicator produced using the SHADOW technique

Below: Cross-section of a day indicator welded using a laser beam

Laser-assisted deep drawing

Task

Micro technical applications have created a growing need for new technologies to manufacture the small metal parts involved, which are becoming more complex and precise. While sheet metal forming is an economical answer, the process is limited by the degree of deformation that can be attained. This can be improved, however, by applying heat to specific areas of the workpiece.

This heat is generated by a laser beam that is guided through a transparent tooling part directly onto the workpiece during the forming process. The resulting temperature profile of the workpiece enhances drawing qualities and extends drawing limit ratios.

Method

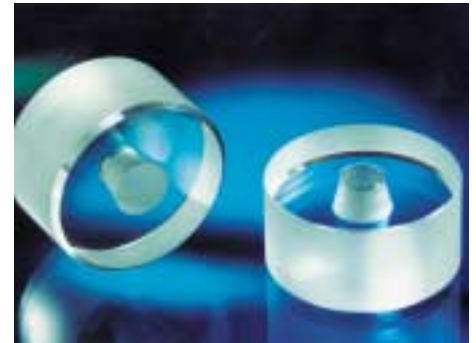
Using transparent materials such as sapphire or diamond for the tooling part, the laser beam can heat up the workpiece during the forming process itself. The laser beam is adapted to the contours of the workpiece, so that temperatures are increased where forming takes place, while no heat is applied to areas that serve its tensile strength.

Fibre-coupled solid state lasers or diode lasers are used, since this facilitates integration of laser beam optics into the material forming tool. Special optics allow the laser beam to be adapted to the different areas of the workpiece that are to be warmed up.

Results and Applications

The process of laser-assisted sheet metal forming was implemented in the deep drawing process for a rotationally symmetrical cup. A drawing die made of sapphire enabled the collar region of the cup to be heated by a ring-shaped laser beam. Grade 1.4301 steel sheet of 150 μm thickness was drawn with a drawing punch of 4 mm diameter in the first draw without heat and then with 150 J laser pulse energy.

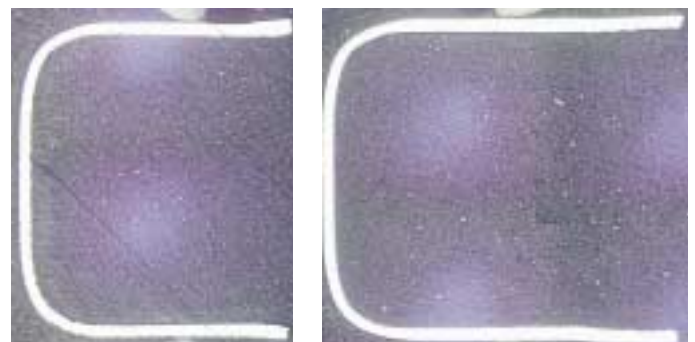
The heat applied extended the drawing limit ratio by 10 %, from 2.0 to 2.2. Possible applications can be seen in particular in the production of small metallic parts, where shaping must be completed in the first draw without intermittent heat treatment in order to meet the prerequisites for mass production.



Above: Sapphire drawing rings for laser-assisted deep drawing of rotationally symmetrical cups
Below: Cross-section of a rotationally symmetrical cup
1. Deep drawing without heat. Drawing limit ratio: $\beta = 2,0$.
2. Deep drawing with 150 J laser pulse energy. Drawing limit ratio: $\beta = 2,2$.

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Laser beam soldering of thick-film circuits

Task

In the automotive industry, preference is given to circuits built on a ceramic base, for electronic sensors and control systems. This base material demonstrates excellent characteristics in being able to cope with conditions prevailing in the engine compartment. When mounted on active or passive heat sinks these electronic systems reliably prove to be enduringly resistant to high thermal loads. Yet it is precisely this combination with heat sinks that makes final assembly of the electronic module extremely difficult. Electrical or mechanical connections between contacts on the module housing and corresponding contact points on the ceramic base call for an exceptional degree of technical sophistication.

Method

Based on the controlled and locally restricted heat input laser beam soldering provides ideal requirements for this kind of soldering tasks.

Combining standard diode laser systems with precise positioning systems based on galvanometer scanners, this soldering process is able to consistently produce product-specific interconnections at high throughput rates.

Results and Applications

The advantages of laser beam soldering have been impressively demonstrated in several applications. High quality interconnections can be manufactured by laser beam soldering with small, locally limited thermal load for the product. Depending on the individual structure and dimensions of each soldering area the beam on time is in the range of a few 100 milliseconds and the optical output power of the laser system is up to 200 W.

The use of low priced diode laser systems has made laser beam soldering economically competitive when compared with other industrially established techniques.

Laser beam soldering also represents an outstanding solution for automated manufacturing thanks to the further option of controlling on-line the temperature at the interaction zone, through the use of intelligent sensors.

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Ceramic circuit with
laser beam soldered
contacts

Alignment structures for laser-beam microforming

Task

The positioning and alignment of individual components is an important element in assembly and interconnect techniques for micro assembly. Laser-beam microforming provides a means of separating the mounting and alignment operations, thus reducing assembly effort. Alignment structures integrated in the components allow the components to be brought into their final position, with an accuracy in the submicron range, by applying a controlled dose of laser energy after the initial, low-cost, mechanical pre-assembly stage.

Method

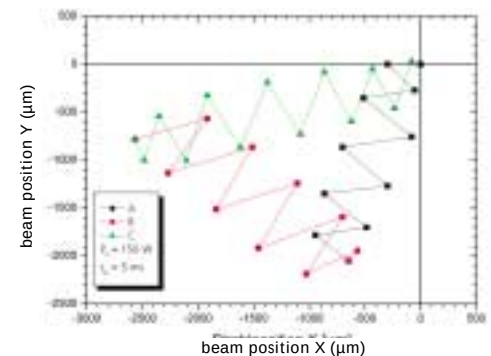
Cylindrical actuators with integrated alignment elements replace external mechanical positioning elements for position verification. The distribution of alignment elements on the cylinder walls allows it to be tilted freely around three axes, enabling the two end faces of the actuator to be positioned precisely in relation to one another. Alignment is achieved using a pulsed Nd:YAG laser. Each pulse produces a deformation in the structure, causing the end face to turn around one axis. The deformation action is based on the mechanism of laser-induced compression.

Results and Applications

The shortening of one double bridge results a tilting motion around an axis defined by the other two bridges. Low pulse energies of 0.75 J lead to tilting movements of 4.5 mrad. All positions on the end face of the cylinder are reached by processing the various double bridges sequentially.

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Above: Movement of the end face of a cylindrical alignment actuator
Below: Cylindrical alignment actuator0



Micromachining of ceramics with a Nd:YAG laser beam

Task

Ceramic components are used in tool technology for moulding and embossing, for electronic devices and in medical products. Since conventional grinding and milling techniques can not be used to produce geometries $< 100 \mu\text{m}$, alternative methods are required to meet the demands of industrial use.

The gaussian mode laser beam of a solid-state Nd:YAG laser can be used to shape complex structures, such as convex and concave forms, to drill wafers made of ceramic materials such as sapphire, and to create recesses or cavities in various types of ceramic and other brittle materials, such as silicon.

Method

Two different types of laser have been used for micro structuring applications: diode-pumped 3w-Nd:YAG lasers at high repetition rates, and lamp-pumped base wavelength Nd:YAG lasers. The 3w-Nd:YAG laser beam is focused on the surface of the workpiece via a galvanometer scanner providing high speed scanning with speeds up to 1000 mm/s . By slicing the desired geometry complex 3-dimensional parts can be realized.

Cutting of sapphire and silicon has been performed by using Nd:YAG-lasers and high precision positioning stages.

Results and Applications

For use in tool technology three-dimensional structures in Al_2O_3 have been made as embossing tools. The quality achieved for the ablated surface was $R_a < 1 \mu\text{m}$ at machining speeds of several 100 mm/s .

Using Nd:YAG laser radiation of high beam quality, through holes of $650 \mu\text{m}$ in diameter have been machined in a sapphire wafer with a thickness of 2 mm at drilling rates of 300 holes/hour . Through holes of $30 \mu\text{m}$ in diameter have been produced in thin sapphire disks of $500 \mu\text{m}$ maximum thickness, using frequency trippled Nd:YAG lasers at a wavelength of $\lambda = 355 \text{ nm}$.

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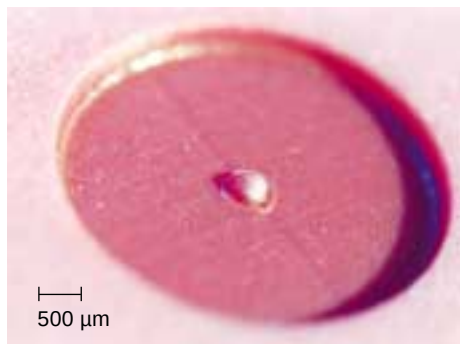
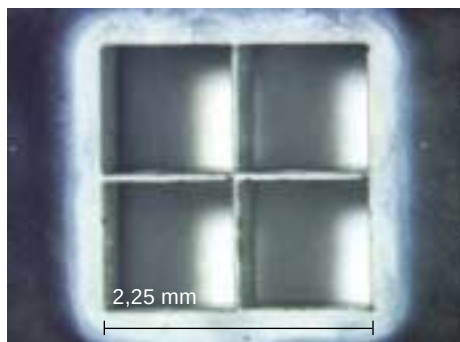


Fig.1: Embossing tool
in Al_2O_3
Fig.2: Laser drilled holes
in sapphire wafer
Fig.3: Hollowed out
silicon structure



VUV micro processing of high performance materials

Task

Recent developments in biotechnology and combinatorial chemistry have created a demand for chemically inert surfaces. The majority of relevant applications are still in an early testing phase, whereby the need for cost-effective prototypes can not be met using conventional manufacturing techniques. Unfortunately, existing laser technology is not suitable for processing well-known materials like Teflon™ or quartz glass in the desired quality.

Furthermore, medical and surgical products like catheters and polymer covers of implants require precisely drilled orifices which can serve for drug delivery or as micro-pores to induce proliferation of tissue for a durable fixation.

Method

Precise structuring of glass and materials similar to Teflon™ can be accomplished using very deep ultra-violet (VUV) radiation at a wavelength of 157 nm. The structures are formed by a laser ablation process that features unsurpassed edge definition and minute recesses in the heat-treated zone.

The following objectives have been defined to develop the appropriate manufacturing tool:

- construction of a versatile VUV-laser tool
- validation of optical components
- 157 nm process development
- fabrication of prototypes from fluorinated polymers and glass
- proof of biocompatibility of the laser process

Process capabilities are to be demonstrated in selected applications and characterized with respect to requirements and functionality.

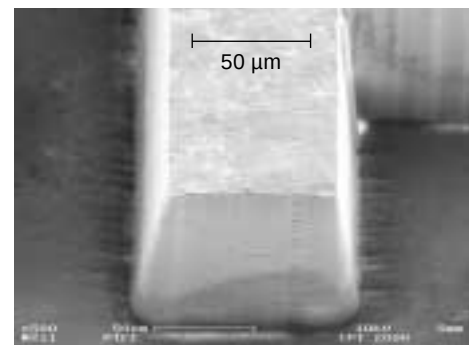
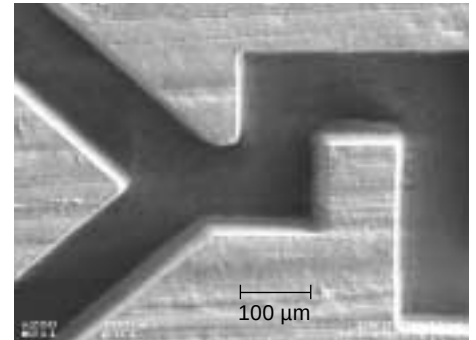
Results and Applications

Initial samples confirm the outstanding quality achieved when machining structures in Teflon™ with the VUV tool. Screening tests on soda lime glass have verified virtually crack-free processing.

Once final modifications have been made to the VUV laser system, a broad based trial is to be carried out in the prototype production of micro-fluidic devices, micro-reactors and implants.

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Above: Fluid structure
in Teflon™
Below: Detail of the
structure

Laser-assisted anastomosis

Task

In microsurgery, the anastomosis of small tubular structures (inner diameter of 0.1 to 0.75 mm) is a time consuming task. It is usually carried out with magnifying lenses (2 to 6-fold magnification) or microscopes. A prime example of this technique is the re-anastomosis of the vas deferens (spermatic duct) following a previous vasectomy. This operation can take up to 2 hours due to the large number of stitches involved and accompanying problems that often arise through initial leakage, tissue granulation or foreign-body granuloma.

In a joint effort with the Clinic for Urology at the Aachen University hospital, the Institute of Technical Chemistry and Macromolecular Chemistry, and the Institute of Plastics Processing at RWTH Aachen, development of a laser-assisted procedure is being pursued with the aim of shortening operation times and improving short-term results.



Above: Laser anastomosis of spermatic duct (rat model)
Below: Test sample following tensile strength test

Method

A bio-resorbable micro-stent (micro-tubing) is inserted into the lumen to keep both ends of the vessel (end-to-end anastomosis) in the right position, and prevent the special tissue solder from clogging the inside of the tube. Then albumin solder, doped with a chromophore (ICG) to enhance its absorption properties, is applied and cured by radiation from a diode laser.

In-vitro tests have been performed to optimize processing parameters. This is to be followed by animal tests to investigate wound healing and to improve the operation technique.

Results and Applications

In-vitro tests determined the processing window with respect to laser power, irradiance, irradiation time, and the composition and application of the solder. A tensile strength of up to 50 % compared with natural tissue has been achieved through laser-assisted anastomosis. In addition, a prototype laser applicator has been built for use in upcoming animal tests.

Successful demonstration of the technique will hopefully lead to its extended use for other micro-surgery operations.

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Cleavage of a photolinker with laser radiation

Task

Linker systems that are only cleavable under special conditions are of interest for applications in solid phase organic chemistry (SPOS) and molecular biology for performing complex synthesis steps on a solid support. At the end of the procedure the target molecule can be easily cleaved off the solid support and is obtained with high purity.

Beyond this in the field of bioanalytics peptides and proteins have to be released from chip surfaces after successful detection.

Method

The photocleavage of linker systems is an elegant approach for the selective release of molecules from surfaces. Photocleavable linkers are usually resistant against acidic or alkaline reaction conditions. But they decompose when photons of a suited wavelength are applied.

In cooperation with the Chair for Organic Chemistry of the RWTH Aachen a linker system based on triazenes has been developed that can be cleaved with radiation of a frequency tripled Nd:YAG laser.

Results and Applications

The resin bound triazene group absorbs UV radiation in the range of 300 to 360 nm dependent on the substitution.

In basic experiments the laser parameters (wavelength, intensity, duration of irradiation) and suited solvents etc. have been investigated. The aim was to achieve high yields and purities of the cleaved product.

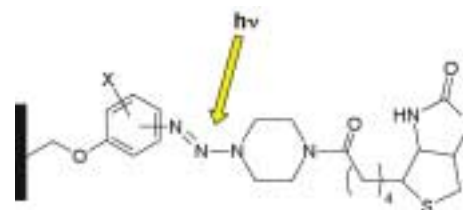
In further studies the triazene linker system should be transferred from polymer resins to glass or polymer slides as substrates. Biomolecules like biotin immobilized via the triazene linker can be released from the slide by means of laser irradiation with the advantage of high spatial resolution.

Applications for this technology can be found in the field of proteomics for screening systems like biochips etc.

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Above: Photocleavage of triazene linker
Below: Irradiation of a reaction mixture in a cuvette

Microstructures for guided cell growth

Task

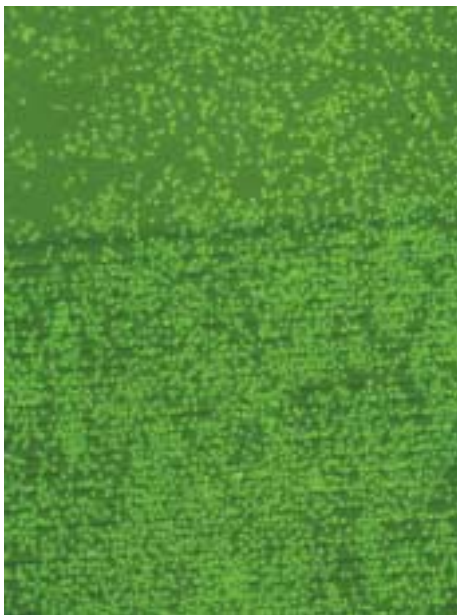
In the fields of medical technology and biotechnology the need for tailored surfaces is increasing. Modifications for special applications have to be carried out. For medical implants the coupling of artificial material to the tissue has to be optimized. Cells should grow on the surface or proliferate into certain areas to build a tight contact between implant and tissue – called biomimetic matrix. For the engineering of suited surfaces different methods are under investigation.



Method

For the fabrication of biomedical devices laser processes have been developed to generate defined microstructures on polymer surfaces. Therefore excimer laser radiation of 193 nm wavelength has been employed. The surfaces were scanned with a shaped beam to produce regular microstructures like ripples. Beneath the topographical changes chemical surface modifications occur.

The characterization of the modified surfaces is carried out by contact angle measurement and cell seeding experiments.



Above: Cells growing along 40 mm wide stripes on PDMS
Below: Enhanced cell density on laser treated zone (below, PC)

Results and Applications

Numerous different polymers - which are already used as biomaterials - were laser treated to form surface topographies like ripples, scales, wells or pillars with the particular aim to change wetting properties. The polymers can be divided into two groups: hydrophilic polymers like PEEK become more hydrophilic and on the other hand hydrophobic materials e.g. PDMS become »super«-hydrophobic (lotus-effect). The increase of roughness is responsible for enhancement of the wetting properties.

Cell seeding experiments using L929 cells reveal that cell behavior is different on laser treated polymer surfaces. Cell density as well as adherence can be increased e.g. on PDMS. Even cell guidance along laser generated grooves has been shown.

The applications for such tailored surfaces where hydrophilic / hydrophobic or rough / flat zones alternate with high spatial resolution are still under investigation in cooperation with the Institute for Pathology of the University Hospital Aachen. This technology seems to be promising for improved implants or tissue engineering.

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Fluidic cell for bioanalytic applications

Task

The department for laser measurement and testing at the ILT has developed a system for applications in bioanalytics. It is used for the detection of single protein-pairs in water. Elements of the system include a fluidic-cell with an integrated protein-chip, a confocal measurement system and a desorption laser to release the protein-pair from the biochip. The fluidic-cell is clipped into a special cartridge which acts as a connection to the precision x-y-positioning table.

The fluidic-cell has to meet the following specifications:

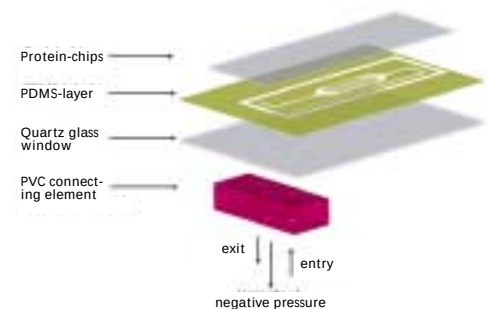
- Minimal fluidic volume
- Uniform and laminar flow
- No dead water zones
- Materials must be chemically and biologically compatible.

Since the fluorescence stimulation and the observation of the protein pairs is made through the bottom of the fluidic-cell, it must demonstrate exceptional mechanical, optical and thermal properties.

Method

The base of the fluidic-cell is a high-quality quartz glass of 1 mm thickness. Using a cast process, a 200-micrometer thick PDMS* layer was deposited on the surface of the glass. This was followed by creating micro channels 450 micrometers in width into this layer by means of an excimer laser ($\lambda = 193 \text{ nm}$) and a mask imaging system.

* PDMS = Polydimethylsiloxane



Above: Schematic diagram of the fluidic cell
Below: Picture of the fluidic cell

Results and Applications

The technique proves efficient in being able to generate high quality microstructures in a PDMS layer on the surface of quartz glass substrates. In order to fix and seal up the protein-chip at the top of the fluidic-cell, a rectangular duct was created around the micro channels. Applying a negative pressure of about 40 mm Hg to this duct is sufficient to fix the protein chip and seal up the micro channels.

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Simultaneous laser beam welding of thermoplastics

Task

Laser beam welding of thermoplastics has meanwhile established itself as an alternative to conventional joining methods. However, the usual technique of sequential laser beam scanning of the joint contour is often too slow for applications in mass production.

Method

Simultaneous laser welding is made possible through the compact and modular set up of high power diode lasers. The entire weld seam is irradiated as a whole and welded with one single laser pulse. Apart from short process times, simultaneous welding allows more moderate irradiation at lower intensities resulting in higher gap bridging capability and joint strength.

Results and Applications

A prototype system has been set up involving six high power diode laser modules. Each has a maximum output power of 15 W and is focused to evenly irradiate the surface being welded along a straight line (20 x 1 mm²). The six modules are arranged to create a rectangular weld seam (20 x 40 mm²). The laser system is able to control and monitor each module individually. Forming and guiding the beam in order to adapt the power-density distribution to specific weld seam geometries represents a particular challenge of the process. Welding results have not only confirmed that process times are shorter compared with contour

welding, the simultaneous method also results in improved bridging capabilities, higher weld strength and wider process windows. Since the entire weld seam is plasticized simultaneously, part tolerances can be compensated, although this depends on the design of the weld seam and the surrounding area. In the welding of polyamide samples, a total laser output power of 80 W and an irradiation time of 1 second produced a seam that was subsequently able to withstand burst pressure of 16 bars. Any commercial evaluation of the simultaneous welding process should take into account factors such as the size of the weld seam, the laser power required and cycle times. When applying higher laser power, irradiation (time) can be further reduced.

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Microtom-cut samples of simultaneously welded PA
Above: Adhesion
Middle: Good welding seam
Below: Holes showing up in the welding seam

Process monitoring and control in the simultaneous laser beam welding of thermoplastics

Task

Applying simultaneous laser beam welding of thermoplastics it is advantageous for process control to monitor the entire weld seam contour at once. Corresponding to the process performance a spatially dissolved, process related signal over the entire welding area is necessary.

Method

During irradiation of the overlapping thermoplastics, temperatures within the welded area rise through absorption of laser radiation. Heat radiation from the weld seam is recorded as a process-related signal by an IR-camera that generates a locally resolved picture of the weld seam. In the picture opposite, a rectangular sample was irradiated simultaneously by six diode laser modules. The IR-camera image shows the heat radiation emitted from the weld seam the moment the lasers were switched off.

Results and Applications

This technology can be used to support the individual adjustment of the laser modules to the seam contour, to measure temperature distribution over the welding area during the process, as well as to identify defective welds resulting from melt burr, attributable to gaps or overheating.

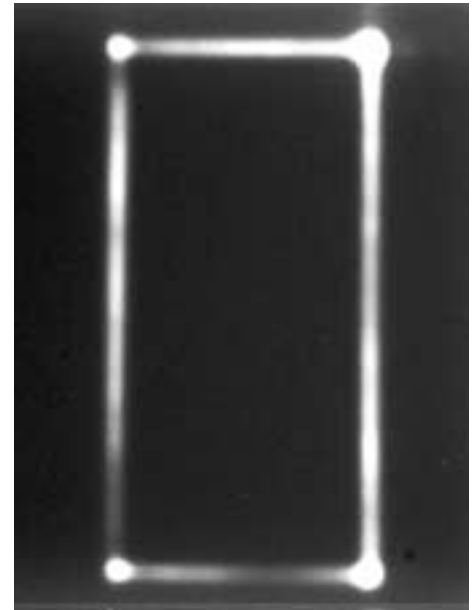
Even small changes in the physical properties of the thermoplastics, or a gap between them, make it necessary to adjust process parameters. Comparing the signal obtained with a reference signal, adjustments can be made to either the irradiation time or laser power, allowing control of the welding process and ensuring consistently high weld quality. The reference signal is determined by systematic investigation of proven welding parameters or results.

The process adapted software of the IR-camera system provides rapid processing of relevant data and supports sophisticated on-line process control and post process inspection.

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IR-camera image of a simultaneously irradiated rectangular weld seam contour (20 x 40 mm²).

Optical diode laser cutting-plotter

Task

New diode laser devices are being developed and tested as part of the BMBF-funded project »Modular Diode Laser Systems (MDS)«. This has led to the development of a diode laser for cutting applications that provides a power density of about $2 \times 10^5 \text{ W/cm}^2$. The system superimposes the radiation of six diode bars on a common axis. The average beam quality of the unit is 20 mm mrad at an optical power of approx. 100 W. This »optical cutting plotter« is to be tested on different metallic and organic materials.

Method

The diode laser device was equipped with a cutting head and installed on a triaxial handling system. Numerous cutting experiments using different processing parameters and sample materials have been performed.

For comparative cutting examinations a commercial diode-pumped Nd:YAG laser with a beam quality of 15 mm mrad was used.

Results and Applications

Applying laser power of 100 W at the workpiece, diode laser burning and fusion cuts in 0,5 mm thick mild steel were achieved at speeds of 5.75 m/min and 0.5 m/min respectively.

At the same laser power, the maximum cutting speeds for fusion cuts in stainless steel samples with thicknesses of 0.5 mm and 0.1 mm were 1.2 m/min and 9 m/min respectively.

It has also been demonstrated that organic materials such as leather, paper, pasteboard and cotton fabric can be cut with the diode laser.

Compared with the diode laser, the beam quality of the Nd:YAG laser is 25 % higher and its focus is 10 % smaller.

Using this equipment with a laser power of 100 W on mild and stainless steel of 0.5 mm in thickness, cutting speeds were on average 20 % higher than those achieved with the optical cutting plotter. However, compared with Nd:YAG lasers, diode lasers possess the advantage of being up to 10 times more compact in size and around five times more efficient.

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Diode laser cutting of 0,5 mm thick stainless steel

Welding of high strength stainless steel in the construction of railway vehicles

Task

High strength stainless steel is increasingly being used in the production of structural components for the automotive sector and in railway vehicle construction. In terms of sheet thickness, the strength of this type of steel is equivalent to thicker varieties, enabling it to be used in much the same way as aluminium for lightweight construction. It has the advantage of being easy to weld, particularly using techniques such as laser beam welding.

Method

Lasers were used to weld samples of structural body components for precision assembly, whereby strict tolerance of dimensional accuracy and shape distortion are to be observed. The bushings were welded into the profiles using a CO₂ laser without filler wire. The holes for the bushings were prepared by laser cutting. A laser was also used to weld together profiles and shaped parts.

CO₂ lasers and diode-pumped Nd:YAG lasers were employed alternatively depending on sheet thickness and welding speed.

Results and Applications

The welded parts were assembled and examined in static and dynamic load tests. The results of the tests show no failure in welded joints. Further investigations involving other vehicle components and various welding joint configurations are currently underway. Close cooperation between the design engineers and laser experts promises to lead to significant improvements in lightweight railway construction.

This project »eSIE.CAR« is supported by BMBF under the overall management of Siemens Transportation.

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Robust and efficient applications of laser-arc hybrid welding

Task

The essential benefit derived from the combination of laser and arc arises from the simultaneous application of a deep-penetration welding beam and an arc process, which generates heat as well as molten filler metal with a high degree of efficiency. This combination creates a robust, gap-tolerant, flexibly controllable and effective process, enabling the high-quality welding of components so far considered to be unsuited for laser welding or other welding techniques. The patented welding head design and correct process settings ensure full exploitation of all the advantages of hybrid welding.

Method

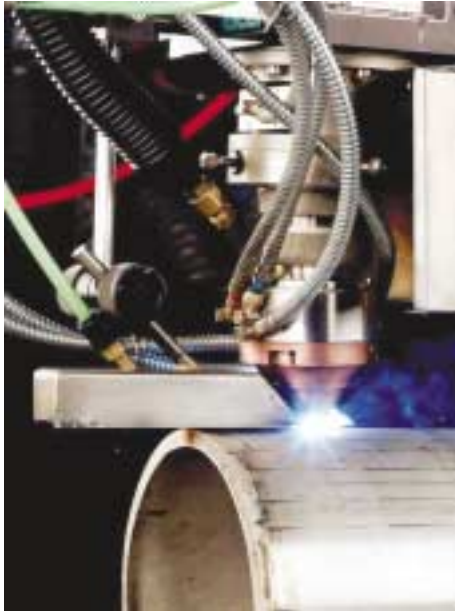
The patented hybrid welding head designed by Fraunhofer ILT features a compact, water-cooled nozzle device with an annular gas channel and an integrated, easily replaceable contact tube. The nozzle encloses both the laser beam and arc, allowing both to be combined in the most effective way within the smallest possible physical dimensions, and ensuring a homogeneous process gas flow without any contamination. The ILT's hybrid head combines CO₂ and Nd:YAG laser systems with commercial arc sources. This technology has been qualified for steel and aluminum applications.

Results and Applications

The world's first Laser-MIG / MAG hybrid welding system to be used in series production was put into operation by Fraunhofer ILT in 2000. It is used by a container manufacturer in the welding of oil tanks. The process has been certified to comply with German TÜV standards. Hybrid welding is meanwhile being used in ship building, the automotive industry and in the manufacture of storage containers, as well as in production processing of pipes and profiles. In 2002, the ILT's hybrid welding technology was certified by Lloyd's Register for a pipe manufacturer, concerning the longitudinal joining of stainless steel tubes of a wall thickness between 2.4 and 14.4 mm. Another laser-TIG hybrid welding technique patented by the ILT is being used by a supplier to the automotive industry in the production of non-linear tailored blanks. Forthcoming applications will additionally benefit from a novel modulation technique, further extensions to laser-arc brazing methods and an »integrated hybrid nozzle« specially tailored to complex 3D structures.

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Increasing welding depth in aluminum with a High Power Diode Laser (HPDL)

Task

The steadily rising use of aluminum alloys in aerospace and car body construction, coupled with progressive improvement in the beam quality of diode lasers, have heightened interest in HPDL for welding applications on aluminum. Due to the comparatively low power density of HPDL and the high thermal conductivity of aluminum, only heat conduction welding has thus far been performed successfully. Welding results can, however, be optimized by adapting the size of the beam spot and by applying high-absorption coatings on the target material.

Method

In order to investigate the influence of beam spot sizes while welding 6 mm thick AlMg-alloy, working distances were varied; the laser beam was defocused in the range of 0 mm to 20 mm, while the feed rate and laser power (2.5 kW) were held constant. All welds were performed without melt pool support and root protection.

In another test series, an enhanced absorption graphite coating was applied to 2 mm thick AlMg-alloy and then welded with a focused laser beam. The welds generated in this case were compared with analogous welds in non-coated material.

Results and Applications

In heat conduction welding, larger spot sizes can cause deeper fusion penetration if the feed rate is sufficiently low. With decreasing feed rates, there is a shift to higher values for optimum defocusing in respect of the welding depth that can be achieved. The width of the weld increases proportionately to the growing beam spot according to the selected defocusing value.

Through the application of a graphite coating, the rate of thermal absorption of an AlMg-alloy in cold state can be increased to approx. 90 %. Due to increased absorption of laser radiation, feed rates can be increased three to fourfold, while the cross sectional welding results are similar in dimension to those of welds performed on non-coated material.

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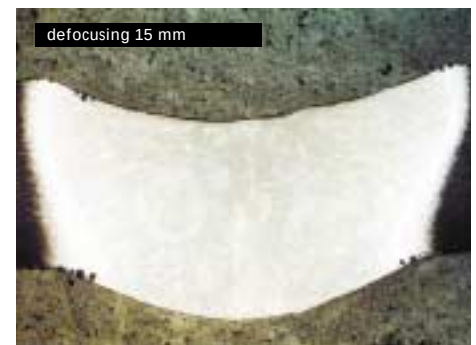
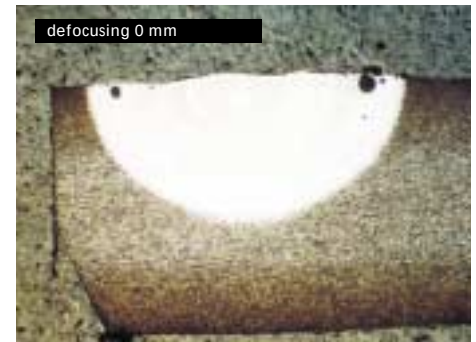


Fig. 1 and 2 from above:
Weld seams in 6 mm AlMg-
alloy, $v = 150 \text{ mm/min}$.
Fig. 3 and 4: Weld seams
in 2 mm AlMg-alloy with
graphik layer.

New joining technologies using an annular diode laser beam

Task

Within the scope of the Modular Diode Laser Systems (MDS) project supported by the German Federal Ministry for Education and Research (BMBF), a diode laser with an annular beam geometry was developed and implemented at the ILT. This device provides multifaceted applications in the field of joining technologies, such as single-shot spotwelding of overlap joints or distortion-free single-shot welding of annular seams on cylindrical components. Furthermore, filler wire or powder can be fed to the welding or soldering process along the same axis through the central aperture. The system offers the potential to create a laser-laser hybrid process when combined with a coaxial Nd:YAG or CO₂ laser beam.

Method

Welds in stainless steel and mild steel with single-shot welding technology (i.e. without relative movement of workpiece and laser beam) were performed with the annular diode laser beam. The median diameter of the annular beam spot is 5 mm on average and its total power output is rated at 2 kW. The irradiation time was varied according to the machining task and varied thickness of the sheet.

Results and Applications

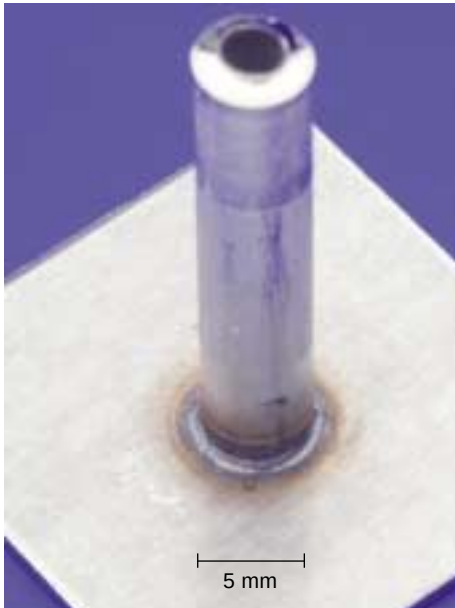
The full penetration weld time for 1 mm thick stainless steel and mild steel sheets was rated at close to 400 ms.

Sturdy overlap spotwelds on two 1 mm thick stainless steel sheets were achieved at irradiation times of 1 second. At irradiation times over 1.5 seconds, the joint weld penetrates a thickness of 2 mm. The same results apply for 0.8 mm thick mild steel sheets.

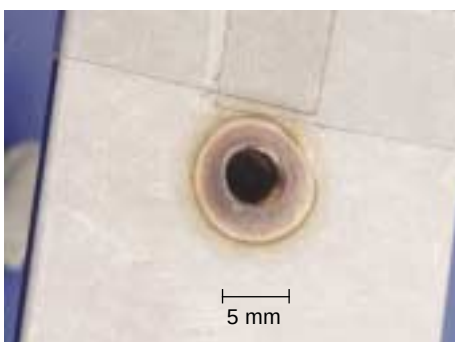
A stainless steel tube with an external diameter of 5 mm and a wall thickness of 1 mm was single-shot welded to a 1 mm thick stainless steel sheet. In doing so, an annular fillet weld was generated on the component side with the tube in 250 ms. Due to the laser's short active beam time of interaction and a uniformly distributed irradiation all around the workpiece, the resulting joint showed no distortion.

If an overlap weld were to be performed on the component side, facing away from the tube, than a distortion-free joint could be achieved within an irradiation time of 1 second.

The examples described above represent only a small portion of the multifaceted welding, soldering and hybrid processing possibilities offered by the new diode laser design.



Stainless steel tube-sheet-joint, wall thickness 1 mm, welding time 250 ms.



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Laser cladding in the repair of aero engine components

Task

In order to improve the specific efficiency of the low and high pressure compressors (LPC and HPC) of the latest aero engines, increasing use is being made of blade integrated disks (BLISKs) made of nickel and titanium based alloys. Should these become damaged, through impacts with foreign bodies, for example, the individual but fully integrated blades can not be repaired or replaced (figure 1).

Laser cladding with powder additive materials represents a promising repair technique.

Method

In a first step, suitable processing parameters and strategies are determined on mock-ups which have the same geometry and material composition as the damaged areas of the original standard milled component.

Based on the results of the first step the processing parameters and strategies are adapted to the real component.

The processing parameters and strategies are converted into NC commands by CAD/CAM modules.

A closed-center process chain is implemented through the subsequent processing and transfer of the generated NC commands to the handling system.

Results and Applications

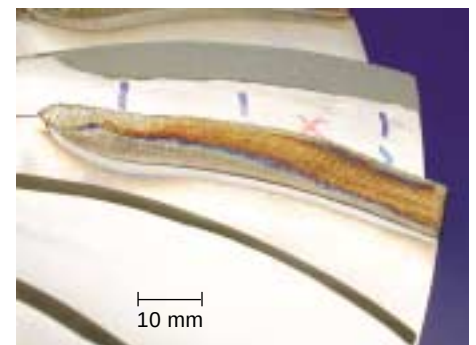
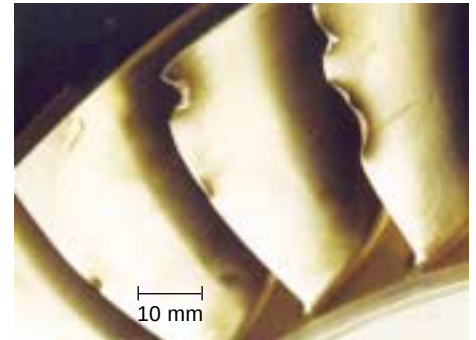
A closed-center process chain is available for the repair of BLISKs made of nickel (e. g. Inconel 718) and titanium (e. g. Ti 6Al 4V) based alloys, which enables laser cladding to the following specifications:

- generated layers free of pores, cracks and bonding defects
- oxide-free laser cladding without a processing gas chamber
- minimal thermal input resulting in minimal distortion of the components

The repaired leading edge of a BLISK blade made of Ti 6Al 4V is shown in figure 2.

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Above: BLISK blades damaged through impacts with foreign bodies
Below: Repaired leading edge of a BLISK blades made of Ti6AL4V

Process monitoring during laser cladding

Task

Laser cladding has been developed for series production in the last few years. Due to the specific benefits it offers when compared with conventional cladding methods, such as low heat input, a low degree of dilution, highly precise built-up of the layers and weldability of practically all metallic alloys, this technology has qualified itself for the repair and modification of expensive machine components such as precision tools (injection moulds, diecasting moulds and forming tools, etc.), turbine components (turbine blades, seals, housing parts, etc.) and the cladding of series produced parts (valve seats).

A monitoring system based on the emitted heat radiation has been developed to ensure that the layers are of consistent quality, particularly when there are changes to the geometrical dimensions of the part to be cladded or when consideration must be given to the heat load during the process.

Monitoring should also encompass the condition of several components of the processing head, such as the powder feeding nozzle tip and protective glass.

Method

A pyrometer was integrated into the processing head for Nd:YAG laser radiation to detect, on the same axis, the heat radiation emitted from the cladding zone. A coaxial powder-feed nozzle was also developed and integrated.

In this configuration, cladding and monitoring can be carried out independent of the processing direction.

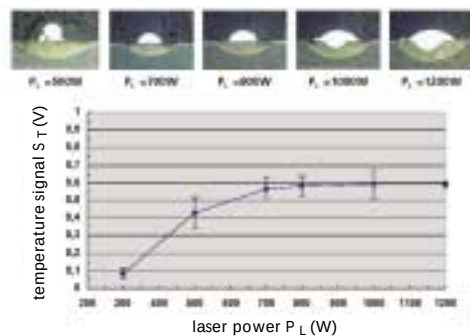
Results and Applications

The processing head was successfully tested during laser cladding. Integrated sensors were used to monitor the emitted heat radiation, the irradiated laser power, the reflected laser power, the temperature of the protective glass and of the nozzle tip. Further experimental work is required to correlate the detected signals with the cladding results (e. g. the degree of dilution, see figure 2), in order to enable the use of the processing head, including its process monitoring system, in industrial applications.

The processing head was developed in cooperation with Precitec KG. The work was supported by the »PROINNO« programme, launched by the German Federal Ministry for Economics and Industry (BMWi).

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Above: Measured temperature signal during laser cladding of stainless steel on Vergütungsstahl in dependence of laser power and corresponding cross-sections.

Below: Processing head with integrated sensor and coaxial powder-feed nozzle.

Manufacturing of aluminum parts using Laser Melting (LM)

Task

The Selective Laser Melting process has been developed as a new manufacturing process to generate parts of virtually any shape or geometrical complexity. So far, processing has been limited mainly to steel and titanium alloys. The aim was to enhance the LM process for the processing of aluminum alloys.

Method

Different aluminum alloys are under investigation in terms of their suitability for processing with LM. The objective is to determine the effect of the composition and relative proportion of the alloying elements on the LM process. Principle investigations are carried out to determine the absorptivity, process parameters and scan strategies for different aluminum alloys. The practical suitability of LM was assessed in terms of density and occurrence of cracks.

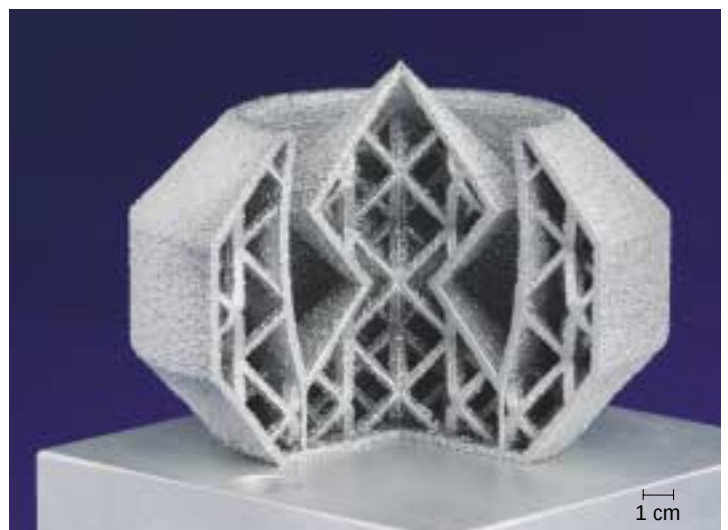
Results and Applications

Parts made of different aluminum alloys can be manufactured without cracks at a density of close to 100 %. This has been demonstrated by the generation of sample parts made of AlSi25 and AlSi10Mg. Other alloys are currently being investigated.

In addition to the rapid prototyping of functional parts, LM exhibits the potential to be used in manufacturing processes for parts with an individual geometry. The sample part shown below, featuring a complex internal structure, was manufactured from AlSi10Mg to demonstrate the application potential of LM for ultra light weight parts.

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GridGen2D: Graphical software for the definition of domains used in FEM / FVM calculations

Task

Within the context of a remote computing concept, the aim was to design a graphics-based software that would allow less experienced users to define and manipulate calculation domains at their workplace PC. Software packages are available for the numerical solution – based on the methods of finite elements and volumes – of problems in continuum physics, such as gas flow, melt flow and heat transfer. As a rule, these programs can only process definitions of the domains and conditions relating to the problem in an ASCII file format. Generating this file is very difficult and prone to errors, calling for substantial experience and specialist knowledge on the part of the user. The new intuitive software interactively assists the user by direct displaying the changes they have made. It comprises all necessary steps leading to the statement of the given problem, which can then be transferred to numerical software. This transfer takes place via intranet or internet.

Method

The platform-independent Java™ - programme GridGen2D allows the definition and manipulation of two dimensional domains. The program displays the domains using the graphics standard OpenGL™ and allows the creation, deletion, movement and transformation of domains. The properties of the domains (meshing, coupling to neighbouring domains) and their boundaries (boundary conditions and

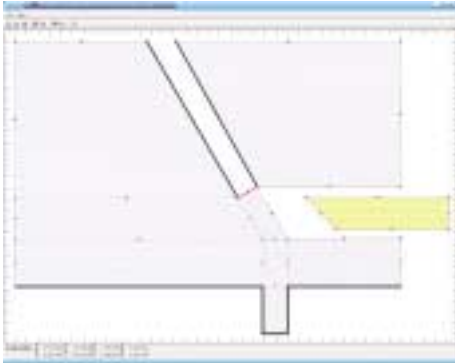
boundary values) can be edited. Rapid familiarity with the software is facilitated by a user interface based on concepts used in vector graphics programs. Once the problem has been defined, GridGen2D is able to start calculation of the problem via a TCP / IP-protocol link to numerical software running on a powerful remote computer system.

Results and Applications

GridGen2D has been successfully used to define two dimensional domains for the simulated flow of cutting gas in laser beam cutting through the numerical calculation of finite volumes. GridGen2D also makes it possible to solve problems generated by the finite element method. A non-cartesian meshing of the domains and the consideration of curved boundaries is possible.

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Parallel high-performance computing on a Linux cluster

Task

Numerical finite element and volume calculation methods have proven to be useful in solving problems relating to melt flow and heat transport. Familiarity with and understanding of the appropriate numerical software is essential to the successful application of these methods and the visualization of results. But even less experienced users should be given the possibility to use these numerical methods to investigate their problems. This not only calls for a uniform user interface but also for sufficient computing power to process large problems in as short a time as possible.

Method

The GridGen2D program, based on platform-independent Java™-OpenGL™ was designed to enable the definition of two dimensional domains and their respective boundary conditions. This software allows the processing of the domains from a standard PC and is based on well-known concepts from vector graphics software. The problem defined by GridGen2D is transferred to a Linux cluster via a TCP/IP communication protocol link to the intranet or the internet. An efficient numerical package calculates the given problem on the cluster using a predefined number of processors and the parallel coupling libraries MPI and MPCCI. Transfer of the resulting data to the platform-independent Java™-program Visualization takes place over a TCP/IP protocol link even while the numerical

calculation proceeds. Visualization uses the OpenGL™ graphics standard to display the results, and users are also able to interact with the running calculation on the cluster system.

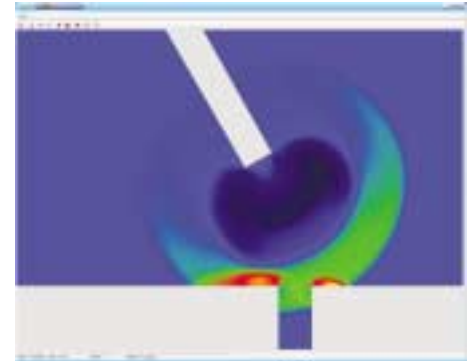
Results and Applications

The method allows less experienced users to initiate simulations of complex problems from their workplace PC using a remote powerful cluster system featuring standard hardware.

The method gives new groups of users access to numerical calculations.

Available applications cover

- dynamic simulations of the cutting gas in laser beam cutting
- application of high power diode lasers in laser welding (heat conduction in solid materials)
- dynamic simulations of charged particles in a hollow cathode by means of the Monte-Carlo method



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Ablation of metal pins: simulation of gas flow

Task

Metal pins fixed in a glass body are ablated up to a depth of 2 mm by a pulsed laser in an oxidation process together with oxygen. Due to an insufficient supply of oxygen inside the drilling hole, maximum drilling depths of only 1 mm could be achieved. The flow of oxygen was simulated in the search for appropriate parameters for the process.

Method

The flow of oxygen is simulated by a spatial two dimensional time-dependent Euler equation using the method of Godunov finite volumes. Riemann problems for the calculation of the numerical flows at the cell boundaries are solved by a modified Harten-Lax-Leer method. The intake flow of oxygen in the calculation domain is predetermined by the stationary solution of the thread flow inside the gas nozzle.

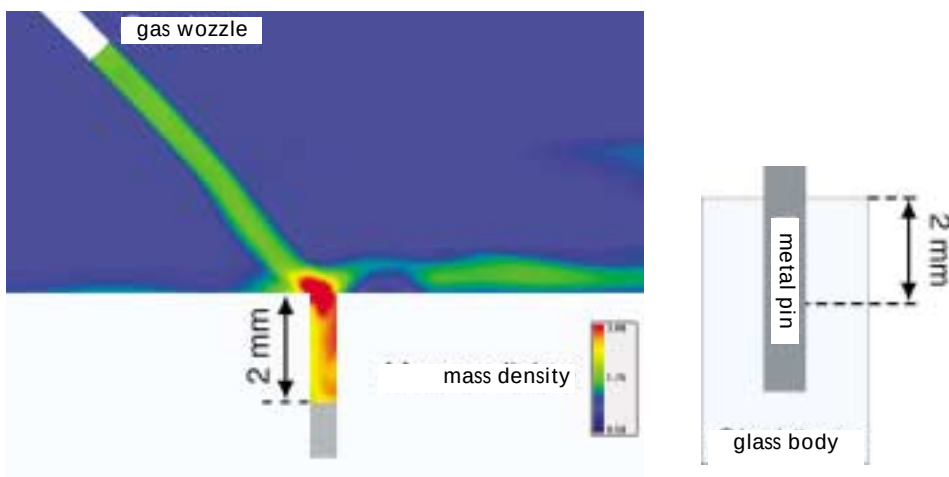
With this simulation the influence of positioning (angle, distance, orientation), type (conical, Laval) and process parameters (pressure at the nozzle, velocity) of the gas nozzle have been investigated. Visualization of the distribution of pressure, density, Mach number, velocity and their gradients inside the gas flow were presented through an interactive graphical user interface.

Results and Applications

A specially configured Laval nozzle was correspondingly selected to provide the supply with oxygen. This produced a sufficient drilling depth of at least 2 mm. A computer animation was used to visually demonstrate to the customer just how closely process results are dependent on the type and position of the nozzle.

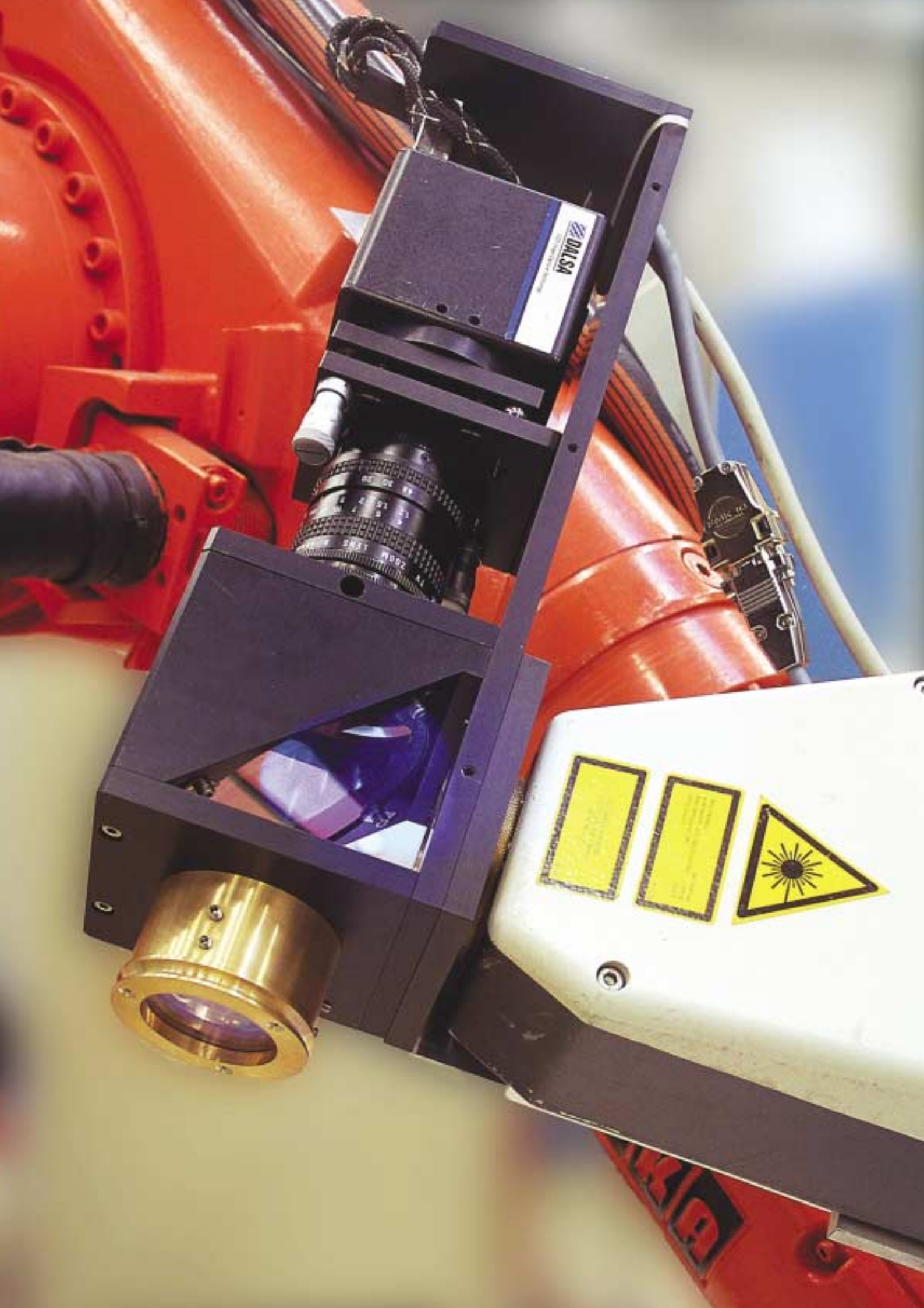
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Business Area
Laser Plant and System
Technology





Business Area Laser Plant and System Technology

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Note from Institute Director
We would like to point out that the publication of the following industry projects has been coordinated with our customers. In principle, industry projects are subject to the strictest obligation to maintain secrecy. We would like to take this time to thank our industrial partners for their willingness to have their reports listed published.

Coaxial process control (CPC)
for high power diode laser.

Laser drilling machine for main voltage halogen capsules

Task

The new generation of halogen lamps translates the advantages of a low voltage halogen lamp - compact size with high volume output and a long lifetime - in 230 V and 240 V applications.

During their manufacture, a molybdenum pin has to be removed from the capsule. The development objective was to design and construct a unit for the automated cutting and drilling of that pin.

Method

Extensive feasibility and validation studies resulted in a parameter window for the drilling process. The unit was thereafter designed and constructed in accordance with functional specifications and the customer's requirements.

Results and Applications

The machine operates fully automatically with manual loading and unloading of the capsules to be processed. Besides the loading unit, it comprises two units for cutting and drilling of the pin as well as a sorter to extract rejected parts.

The capsules are processed by means of a pulsed Nd:YAG laser with fiber outputs. The pin is cut with a single pulse. The positioning of the laser beam for the subsequent drilling is realised by means of a galvanometer scanning system with an integrated image processing unit. Drilling with oxygen support is the key production step in defining the quality of the product and the output of the unit. The unit works in 3-shift-operation.

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laser drilling machine to
remove the middle pole of
halogen capsules

Laser beam welding of glass ampoules for medical applications

Task

The sealing of medical glass ampoules is usually done by hot gas flames. Certain demands concerning particle-free filling and sealing can not be fulfilled with this method. Alternatively, the closure process could be carried out using a laser beam.

Method

Depending on the wavelength, laser radiation is absorbed by glass and converted into heat. A sufficient rise of the temperature leads to melting of the glass. An opportunity thus exists to seal ampoules with a laser beam and an adapted ampoule handling unit.

Results and Applications

Within the framework of an industrial project, a laser-based unit to seal medical glass ampoules was integrated into a commercial ampoule filling and sealing line. Melting of the ampoule head is done by CO₂ laser radiation instead of the flame heating previously used. First experiments and testing revealed requirements to be met in terms of mechanical stability, the laser beam parameters and the possibility to adjust the beam path. These requirements were fulfilled by modifying the laser source and adapting

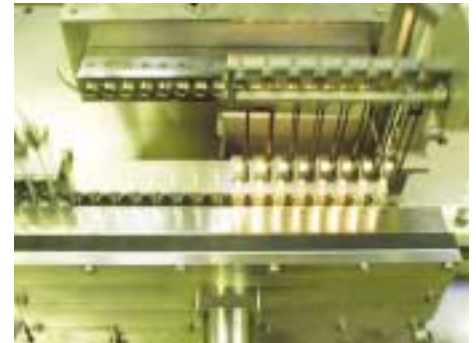
the mechanical setup. The laser sealing unit was integrated within two ampoule lines, containing cleaning, sterilisation, filling and sealing sections. In the sealing zone eight ampoules are pre-heated and sealed per cycle at an output rate of 400 ampoules / min.

Heat pollution of the sealing zone, as it appears with the traditional hot gas sealing method, is significantly reduced. Particle-free sealing is also achieved since the transfer of energy to the ampoules takes place via radiation.

By courtesy of Bosch,
Packaging Technology

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Laser beam welding of quick connectors for the automotive industry

Task

During the production of clutch and brake lines made of glass fiber reinforced polyamide (PA 12), the pipe and Quick Connector have thus far been joined by friction welding. This has the undesirable effect that substantial residues of molten polymer remain on the inner side of the pipe. As an alternative, laser beam welding offers several process advantages. The energy deposited at the melt joint can be more precisely controlled in terms of time and spatial dimension. Furthermore the overlap welding process prevents molten material from reaching the inner surface of the tube.

Method

High power diode lasers can be used to weld polymers. Both the optical characteristics of the joining partners and their geometry were adapted to the process and product. Heat conduction and plastification are improved by the close fit of the joining partners, leading to weld seams of high quality.

Results and Applications

A systematic series of tests was conducted to determine the optimal process parameters for the connection. Bursting pressure investigations of clutch and brake lines welded with the laser beam resulted in pressure resistance of up to 250 bar. The seams welded with the help of a laser beam met the requirements of the automotive industry in terms of tightness, resistance to aging and temperature. The Fraunhofer ILT worked together with the customer to draw up a concept for a laser-based plant for the production of clutch and brake lines. The production unit concept and all laser components (radiation source, electrical supply, optics) for this welding station, which is currently being built, were supplied by ILT.

By courtesy of Agora bv, Netherlands.

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Mobile system for laser beam cladding

Task

Systems for laser beam cladding that require more than 1 kW power are designed for stationary use at the end user or at a job shop. These systems cannot be used for the treatment of components, which for technical (size) or economical reasons (down time), cannot be transported. This created the need for a mobile system that enables treatment on site. Working together with the company Schuler Held Lasertechnik, the Fraunhofer ILT developed and tested a mobile system that meets the requirements for 3D treatment, compact size, low weight, fast assembly / disassembly and sufficient robustness.

Method

Schuler Held Lasertechnik has designed and manufactured a handling system with three linear and two rotary axes. The Fraunhofer ILT provides a fiber coupled high power diode laser and a cladding head which enables 3D-cladding.

Results and Applications

Figure 1 shows the mobile system that fits into a space of $2 \times 2 \times 2,6 \text{ m}^3$ and weighs approx. 1.200 kg. The three linear axes are screwed to the frame and can be quickly assembled and disassembled. Each part of the system weighs no more than 220 kg. The transfer lengths of the linear axes are $x = 600 \text{ mm}$, $y = 600 \text{ mm}$ and $z = 700 \text{ mm}$. Inside the rotary axes the laser beam is deflected by mirrors. This provides high manoeuvrability of the cladding head because the fiber is not twisted during rotation. The laser

beam source is a high power diode laser with a maximum output power of 2 kW. Figure 2 shows the cladding head. The powder is delivered through a three-way nozzle. Three separate powder streams are fed into the operating point of the laser beam. This concept allows 3D-cladding. For overhead cladding (figure 2) a cross jet has to be integrated into the head to prevent contamination of the optics with powder particles. At present the mobile system is tested at the Fraunhofer ILT. In August 2003 an on site demonstration is planned. Potential applications are the on-site repair of large crankshafts (length $> 3 \text{ m}$), heavy forming tools (e. g. in car industry) or in the wear protection of heavy steam turbine components.

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Above: Mobile 5-axis-system (Schuler Held Lasertechnik)
Below: Overhead cladding with the three-way nozzle with integrated cross jet

Laser cleaning of high voltage pylons

Task

The large number of high voltage pylons maintained by power supply companies represent a high-value operating resource. In order to avoid serious corrosion damage, old protective coatings must be renewed in regular cycles. Depending on the condition of the old coating, the task of repair extends from de-rusting to cleaning and roughening of the surface, through to the complete removal of the old coating. In terms of environmental and economic factors, the aim is to avoid the need for cost-intensive protective housings in certain areas.

Method

The overall objective of the cooperating project partners, including RWE-Net, Clean-Lasersysteme, Peiniger RöRo and Fraunhofer ILT, is the development of a mobile laser cleaning system that is transportable with a truck. In a first step, a suitable laser source was selected for process development. Once this was completed, emission investigations of the ablation products were undertaken, which resulted in the design of a suction system with appropriate filter technology. Another aim of the project was to develop a lightweight hand-guided processing head that integrated the beam guiding and forming system and the suction feature. The laser beam is transported through an optical fibre from the laser to the processing head over a distance of 50 metres. A robust covering protects the fibre against breakage and damage. Development of the 450 W Nd:YAG laser source not only took into account the requirements

resulting from the preliminary investigations: concepts were also devised to fulfil the requirements for outdoor use (vibrations and climatic conditions).

Results and Applications

The resulting laser cleaning system, including all of its constituent components, was successfully tested on the pylons. Depending on the selected processing parameters, the protective coating on the pylon was either completely removed or the surface cleaned and roughened. Severe rust occurs where the paint coat has been chipped off. These areas can be thoroughly cleaned, through to the original metal surface. Further fields of application are bridges, ships, tanks or other metal structures. In order to achieve feed rates that would make the system economically viable, it would be necessary to increase the laser output power to 2 kW or more.

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Autonomous Production Cell for Laser-Beam Welding

Task

A demonstration plant for autonomous (3D) laser-beam welding was set up in connection with the public funded research project »autonomous production cells« (SFB 368).

Autonomous manufacturing cells are capable of carrying out complex production processes largely independently, reliably and fault-tolerantly over an extended period of time. For this reason, they need to have a high level of automation and a high degree of flexibility.

Method

The manufacturing cell consists of the components planning, machining, process monitoring, process control and process visualization.

It was constructed by modifying a 5-axis portal system to create a laser cell with a choice of OSACA open control or a commercial control system. A 4.4-kW diode-pumped Nd:YAG laser was employed as the beam source. A technology module allows CAD-supported line and process planning and feature-based generation of processing data. A console equipped with an ergonomic user interface is provided for visualization tasks and human-machine interaction. During processing, various sensors observe the process, allowing it to be monitored and regulated, and also replanned.

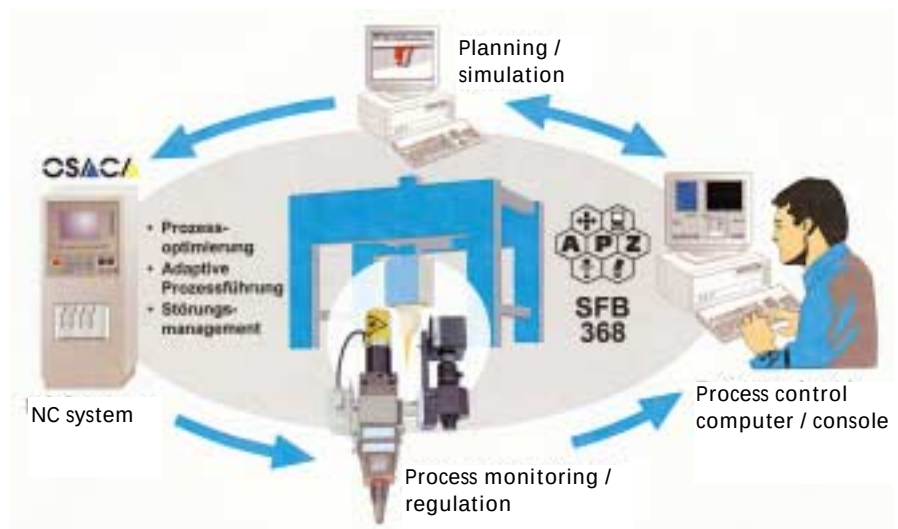
The sensor signals are recorded and processed by a process control computer, which serves as the central linking element between the networked modules of the manufacturing cell.

Results and Applications

The result of the modification work is a state-of-the-art 5-axis manufacturing unit optimized for laser processing. The progress of research project SFB 368 was judged positively in the end-of-year review (2002), and has now moved on to the fourth phase. The research work is being conducted in collaboration with the Chair for Laser Technology at RWTH Aachen.

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Cascaded Crossjet-Nozzle for High Power Diode Laser (HPDL)-Applications

Task

The lenses of HPDL devices have to be effectively protected against becoming soiled by fume deposition and splatters resulting from confined working space in the welding process. Moreover, the crossjet flow should not be allowed to interfere with the welding process. In meet these requirements for HPDL welding processes, a novel »cascaded crossjet nozzle“ was developed at the ILT.

Method

The development of the nozzle design took the following requirements into account:

- slim and compact structural shape
- to be mounted directly on the HPDL lens
- wide pass aperture
- wide compressed air stream that covers the width of the HPDL lens
- variable compressed air stream

A special feature is the so called »cascading« of the crossjet nozzle. The compressed air stream is generated by two parallel, narrow slits of different dimensions, generating two air jets with an accordingly different »cascaded« mass flow rate. The dimension of the slit closer to the workpiece is less than the dimension of the main slit close to the lens. The weaker calibrated air stream from the narrower slit supports the lens-protective function of the main stream. At the same time, it acts as a friction barrier between the main stream and the nearly dormant atmosphere above the workpiece. Interference with the weld zone should thus be kept to a minimum.

Furthermore, the cascaded crossjet distinguishes itself by its versatility. The slits are created using a partition piece in combination with the interior surfaces of the nozzle's top and bottom shells. Slit alignment and slit dimensions can be varied simply by exchanging the partition piece.

Results and Applications

The crossjet nozzle has proved itself in application during extensive welding tests with various materials (stainless steel, mild steel, aluminum) within a confined working space. In comparison to previous solutions, cascading of the compressed air stream results in a significantly more effective deflection of splatters and thereby ensures that protection of the lens is substantially improved. This could in particular be verified while welding zinc-coated steel sheets.

Fluidic analyses with various partition pieces could reveal further potential towards optimization of the crossjet nozzle.

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Coaxial Process Control (CPC) for High Power Diode Laser (HPDL)

Task

The CPC system serves the purpose of recording secondary radiation (temperature radiation, possibly plasma-evoked radiation) of welding processes with HPDL. During the process, the interaction zone of laser beam and workpiece is to be monitored through the HPDL's lens by a CCD camera which is aligned coaxially with the laser beam. The objectives are to obtain insight into the melt pool's movements and the dynamics of secondary radiation during the welding process.

Method

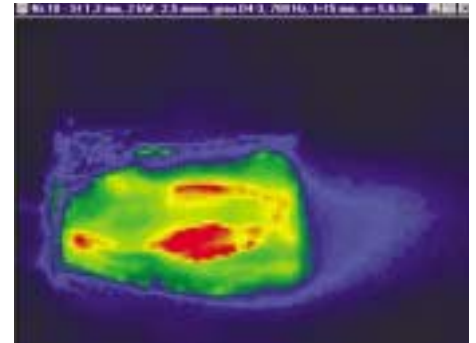
A dichroitic reflector with high image quality reflects the HPDL's laser radiation by 90° while enabling the transmission of other wavelengths that permit coaxial monitoring of the interaction zone with the camera. The laser radiation is then focused on the surface of the workpiece. To achieve optimum focus as well as a distortion-free image of a large image area (max. 12 x 12 mm²) and an effective correction of the image area's flexion, a specially adapted focusing lens was designed for the CPC system. The desired size of the image area can be set on the CCD camera's zoom lens. The camera's signal (max. 735 frames /s) is visualized and analyzed by a PC with appropriate software.

Results and Applications

First test recordings of welding processes on stainless steel, mild steel and aluminum show the luminance distribution of the melt pool and of the trailing, cooling weld seam. A false-color display allows the differentiated inspection of gray tone ranges, which is of interest in the examination of flow movements of the melt. Quantitative analyses of recordings of welding processes are upcoming.

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Above: Screenshot
of the CPC software
Below: CPC on ROFIN
DL025

Task

The method of coaxial process control (CPC) was developed by the Fraunhofer ILT for the monitoring of manufacturing processes that use laser beams. It is fundamentally suitable for all forms of laser material processing. To date, the system has been most frequently employed in laser-beam welding operations. The images produced by the CPC system enable the operator to observe different states of the process, and also to directly determine major characteristic parameters, such as weld-in depth. To confirm the correlations previously determined empirically, a method was sought that would enable the processing operation to be visualized simultaneously with its observation by the CPC system.

Results and Applications

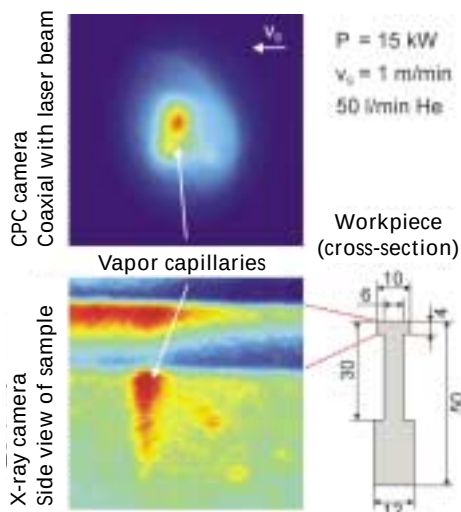
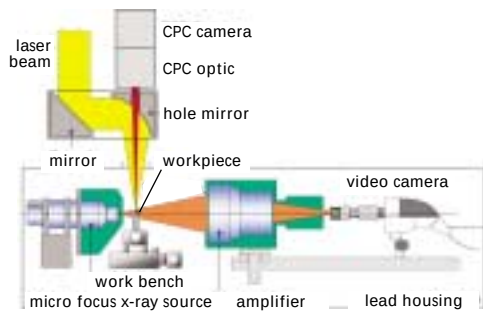
After a period of intensive preparation, the first joint experiments took place in Japan in November 2002. Welding operations were carried out using a 20-kW CO₂ laser and using a 2.5-kW Nd:YAG laser. The obtained extensive sample and data material is presently undergoing analysis. The first results are expected in summer 2003.

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Method

In order to solve this complex task, it was decided to use an x-ray technique for online visualization of the true weld seam geometry. Since the Fraunhofer ILT does not possess any suitable x-ray source, contact was taken up with the University of Osaka, which does have a source of this type, and with the Japanese research center AMPI, which maintains suitable laser systems in the vicinity of the University of Osaka. Both institutions showed an interest in the proposed research, and agreed to collaborate.



Above: Experimental setup
Below: Camera images
and workpiece geometry

Use of Coaxial Process Control (CPC) with Pulsed Lasers

Task

The Coaxial Process Control (CPC) is a measurement method developed by Fraunhofer ILT to observe on-line the interaction zone between laser beam and workpiece. Using an imaging detector (CCD or CMOS) it is possible to determine the quality of the treatment of the workpiece. The camera is coaxially aligned to the laser beam through the processing lens. This measurement method was tested on different cw laser beam applications in the laboratory and has been used successfully in industrial projects. The CPC-system was modified to meet the need for process control during work with a pulsed laser beam.

Method

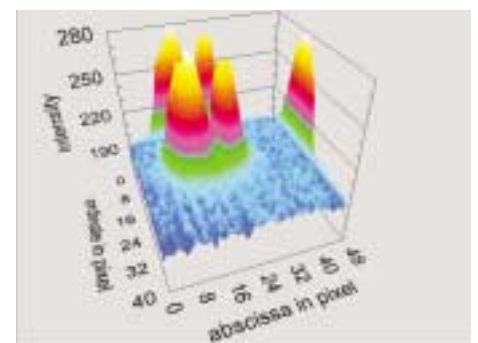
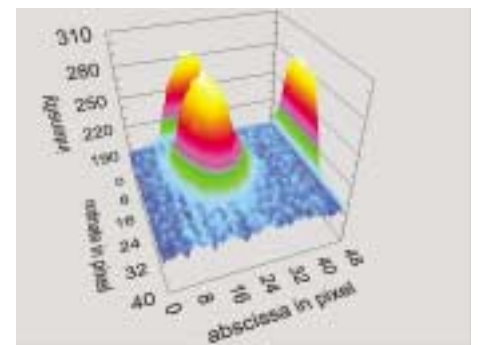
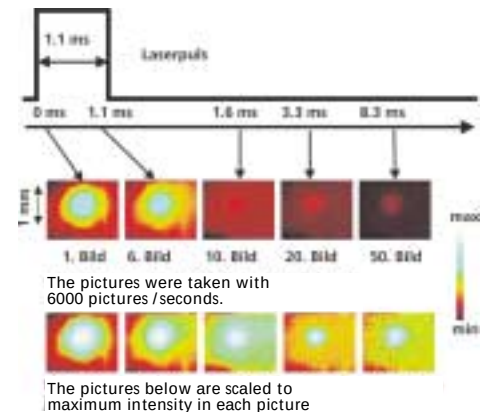
The CPC-system is based on a PC with frame grabber as processing unit and a camera as sensor. Thanks to the extremely flexible and extendable CPC-system, it was readily adapted from a continuous to a pulsed laser beam source. The C++ software already in use was modified to enable synchronisation of the recording with the incremental intensity of the laser pulse. It is thus not necessary to connect the laser with the CPC-system. Only the supplementary functions have been implemented in the existing CPC-software, so that the system is able to handle both pulsed laser beams and continuous beams. The recorded videos of the pulsed laser welding were analysed with algorithms developed under LabVIEW™. It is possible to detect gaps and different intensity distributions in the videos, as well as an image pattern that reveals good and bad results.

Results and Applications

Analysis of the videos enabled an observation of the cooling melt pool between the laser pulses. These pictures of the melt pool make it possible to detect geometrical seam errors, such as shifts in position, without an additional light source. The existing algorithms for continuous laser beam sources can of course also be used when the laser pulse is on.

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Above: Process pictures of the CPC with pulsed laser radiation
Middle: CPC-picture of a welded butt joint without gap
Below: CPC-picture of a butt joint with remaining gap

3D offline planning for laser-beam welding

Task

As part of the public funded research project on »autonomous production cells« (SFB 368), a feature-based 3D offline planning system for laser-beam welding has been developed.

The offline planning of laser processing operations enables the creation of a numerically controlled software program without blocking the production system. Through realistic simulation and modeling of the production tasks and equipment, the process can be planned under realistic manufacturing conditions.

Method

The core of the planning system is based on modeling the laser-beam processing task on the basis of processing objects referred to as features. The main advantage of the feature model is the combination of geometric data (CAD) with the physical parameters of the industrial process and the general workflow strategy.

The planning system was structured in such a way that there is a strict demarcation between the functional and presentation elements of the program. The result is an encapsulated core functionality with integrated technological know-how. The functional core can be utilized in one of three

modes: stand-alone, plug-in or server. The functional core is accessed via application-specific interfaces, allowing it to be easily integrated in other programs and offering greater flexibility in managing the planning data.

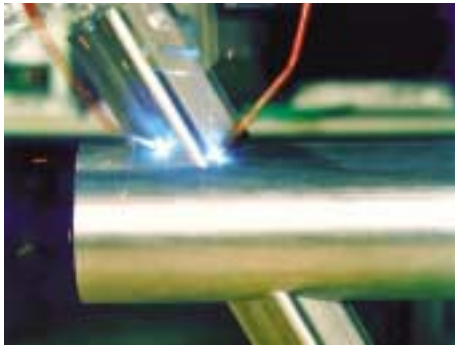
Results and Applications

The independent 3D planning system is a stand-alone solution. The system was developed on the basis of the functional core and is equipped with 3D presentation graphics and an industry-standard IGES interface for importing CAD models. As part of the project SFB 368, the functional core was also integrated into an operating console in a client-server environment. The CORBA standard was employed for communications between the functional core and the operating console.

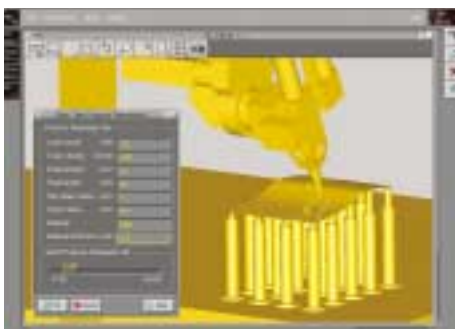
Project SFB 368 received a positive appraisal at the end of 2002 and will proceed with the fourth phase of development. The project is being conducted in conjunction with the Chair for Laser Technology at RWTH Aachen.

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Above: 5-axis laser-beam welding
Middle: Operating console display
Below: 3D planning system display



Fraunhofer testing and consulting center for laser technology

Task

The potential of laser technology as a highly flexible and universal tool in material processing, measuring techniques and medicine has not yet been fully exploited. Experience has shown that small and medium-sized enterprises (SME) in particular are open to new technologies and have a keen interest in using the possibilities offered by laser technology.

Method

In 1996, the ILT participated in a project launched by the German Federal Ministry for Education and Research (BMBF) which aimed to promote the introduction of laser technology to SMEs. The Fraunhofer ILT's testing and consulting center for laser technology coordinated the activities of the partners in the Land of North Rhine Westphalia (NRW). The nationwide network, involving more than 60 partners, provided SME's with independent and competent advice, as well as the opportunity to conduct application-specific trials relating to laser technology. Many thousand individual enquiries were successfully processed and hundreds of events organised during the 6-year project. Furthermore, the Internet portal www.lasernetz.de was set up and further developed during the project. It aims to serve as an information platform within the network and beyond.

Results and Applications

The second and final phase of the funded project came to as close in mid-2002. The concluding event also marked the continuation of the testing and consultation centers under independent management without public funding.

Those SME's interested in laser technology will continue to receive specialist advice and the opportunity to conduct test trials under much the same conditions as previously. In addition to its advisory service, the ILT has taken over the task of coordinating the cooperation of the centers in NRW.

The continuation of these services under own management, represents an enormous opportunity to successfully transfer this technology to SMEs with a minimum of bureaucracy, while at the same time providing solid evidence of the sustainability of the funding invested.

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VELI - Virtual European Laser Institute

Task

Europe has a world-wide leading position in laser research. But industry in general and small and medium sized enterprises (SMEs) in particular experience significant difficulties to exploit the enormous body of knowledge already existing in Europe and to transfer it into new laser applications and products. Objective of VELI is the improvement of the accessibility and use of the available European expertise and experience in laser technology.



Method

The Virtual European Laser Institute builds a European network providing local access to the knowledge dispersed in Europe.

Main tasks of VELI are:

- set-up of a database, containing know-how formerly dispersed at various laser research institutions
- operation of a virtual environment where supply and demand on knowledge can meet
- development of a framework for knowledge and technology transfer between research institutions and enterprises as well as between research institutions among each other.

Results and Applications

Led by Fraunhofer ILT, 15 leading European laser research institutions have founded the Virtual European Laser Institute midyear 2001. The network is open to additional partners. Objective is to integrate all relevant European research institutions into VELI.

Further information on the web site:
<http://www.veli.net>

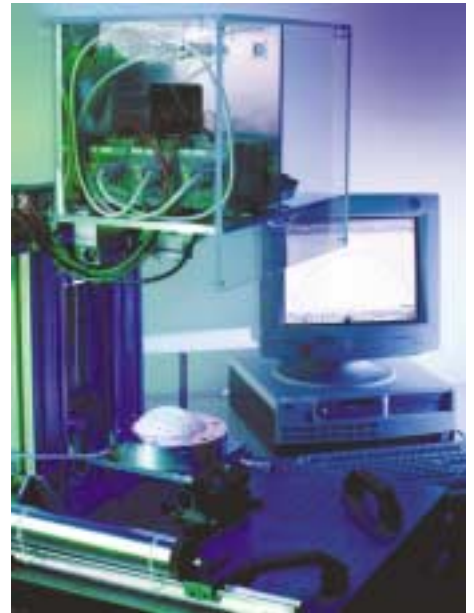
This work is funded by the European Union.

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Business area laser measurement and testing technology





Business area laser measurement and testing technology

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Note from Institute Director
We would like to point out that the publication of the following industry projects has been coordinated with our customers. In principle, industry projects are subject to the strictest obligation to maintain secrecy. We would like to take this time to thank our industrial partners for their willingness to have their reports listed published.

Demonstration set up for the online 3D-deformation analysis of sheet metal during bulge testing.

Online 3D-deformation analysis using laser light-section techniques

Task

The laser light section technique, which is based on the triangulation principle, is used for the non-contact determination of the geometrical profile of measuring objects at high measuring frequencies. Thus, it is particularly suited for industrial online measuring and testing applications.

One field of application is the 3D deformation analysis in the bulge-test, which is used to determine the deformability and strain hardening behaviour of sheet metals. As the bulge-test provides a fast and extensive characterisation of materials, it is used not only in the development of new metallic materials which demonstrate increasingly sophisticated properties, but also for the testing of sheet metals for quality assurance purposes.

Method

Within the scope of a joint ongoing R&D project, a demonstrator 3D laser sensor was set up and combined with a sheet metal testing machine. With this sensor, the deformation of the plates is detected online on two perpendicular planes with two light section sensors. An additional camera sensor traces individual spots on the metal surface. The measuring data is then used for calculating material characteristics such as flow and strain hardening behaviour.

Results and Applications

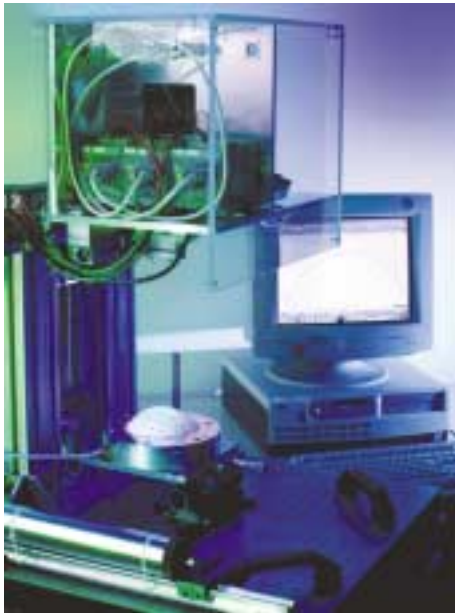
During the project, a demonstration set up was developed in which three individual optical sensors operate at three different wavelengths. This allows deformability to be measured during the testing procedure with all sensors simultaneously without disturbances from ambient or scattered light.

The sensor measures geometrical features of the deformed plates - such as the bulge height - with a precision of approx. 15 μm . In order to make the laser sensor system applicable for the deformation analysis of materials with strongly varying surface characteristics, an adaptive control of the light exposure of the sensors is to be developed in the next phase of the project.

The project is supported by small and medium-sized companies and by the German Federal Ministry for Education, Research and Technology under contract no. 13N8111.

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Demonstration set up for the online 3D-deformation analysis of sheet metal during bulge testing

Fast identification of light metal alloys for automatic sorting

Task

The recycling of solid waste material with high added value can often only be accomplished for material of a single type. This is especially true for light metals, which are increasingly being used in automotive engineering, for example. As conventional analysing and sorting techniques are not suitable for an economic separation of light metal alloys, a national R&D-project has been initiated in order to develop a new, laser-based classification technique.

The SILAS project, as it is known, is being carried out by an interdisciplinary consortium comprising five medium-sized companies, a university institute and the Fraunhofer ILT.

Method

The technological approach adopted for the rapid identification of the waste materials is based on a combination of fast image processing, laser-based geometry detection and laser-induced breakdown spectrometry.

After passing a particle singularisation unit, geometrical and optical features of the particles are detected and evaluated with image processing algorithms. Subsequently, the chemical composition of the individual particles is determined using laser laser-induced breakdown spectrometry. The waste particles are categorised by taking all measured values into account, and then separated accordingly into two or more fractions.

The goal of the project is to set up a demonstration system on a pilot plant scale, which allows the capabilities of the laser-based separation technique under realistic operating conditions to be evaluated.

Results and Applications

An economic separation of light metal alloys requires high measuring frequencies in the range of 100 Hz. In order to achieve these frequencies with laser-spectroscopy, a newly developed high-repetition laser system and a Paschen-Runge spectrometer with photomultiplier detection are to be integrated into the demonstrator.

During the first phase of the project, spectroscopic investigations were performed with different kinds of light metal alloys in order to determine which spectral lines are suitable for the laser-based alloy identification. A selection of 20 lines was made that enables several elements such as Al, Cu, Fe, Mg, Mn, Si and Zn to be analysed.

The project is supported by medium-sized companies and by the German Federal Ministry for Economics and Labour (BMWA) under contract no. 16IN0100.

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The sorting of light metal alloys helps to close the material cycle

Development of evaluation processes in the analysis of steel cleanness

Task

In order to determine the cleanness of steel, inclusions within the steel matrix have to be determined. Existing methods are either cost and time intensive and results can seldom be reproduced. Steel manufacturers have thus set out to determine standard values for the purity of steel with the help of spatially resolved multi-elemental analyses based on emission spectrometry employing laser or spark excitation. These standard values are not comparable on a European scale. The objective is to define a unified evaluation method in cooperation with partners of the European steel industry that provides comparable standard values for the steel cleanness even when different measuring systems are used.

Method

In a joint project involving partners in the European steel industry, tests with a defined set of samples are performed on-site with spark and laser optical emission spectrometers. The measuring data are stored in a uniform data format and are transferred to Fraunhofer ILT. The different algorithms for the determination of standard values for steel cleanness are to be tested and improved with respect to the various individual spectroscopic systems and in terms of accuracy.

The results of the different algorithms are to be made available to all project partners on a web server installed at Fraunhofer ILT. This allows all partners to make a rapid comparison and classification of the calculated standard values and thereby ensures that further development of the evaluation algorithms takes a targeted approach.

Results and Applications

A uniform data format for the different spectroscopic systems and a unified set of process parameters has been developed. Control procedures ensure consistency of the data.

Current developments are focused on server-based applications that are to replace existing evaluation programs used by the partners. This will provide all partners with access to the newest version of evaluation and visualization programs.

The work is funded by the European Coal and Steel Community (ECSC).

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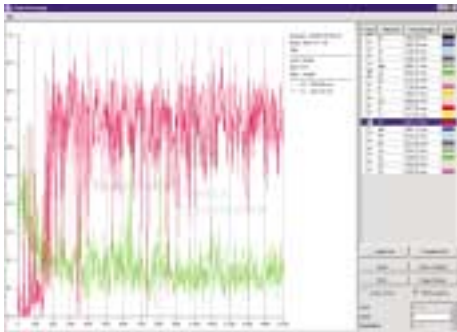


Fig 1: Display module for the visualization of measuring data within the scope of the project. Thanks to the uniform data format, the data sets of all partners can be displayed despite the fact that they use different analyzing systems.

Laser-based elemental analysis of production control samples with scale layers

Task

The elemental analysis of production control samples is an important application in on-site analysis at steel works. These steel and pig iron samples exhibit scale layers of up to 1 mm thickness, and this must be removed for a reliable analysis of the bulk material. Spark discharge spectrometry, combustion and X-ray fluorescence analysis are the methods used today. These necessitate sample preparation by mechanical milling or grinding of the samples, which is very time-consuming. Automatic sample preparation in on-site container laboratories is prone to failures and expensive. Hence the goal is to develop a method which allows reliable analysis following simplified sample preparation.

Method

A laser is used for the sample preparation. The scale layer is removed locally. In the following step the sample is analysed using laser induced breakdown spectrometry. In comparison to automatic milling or grinding, the contact-free laser works virtually without wear and maintenance.

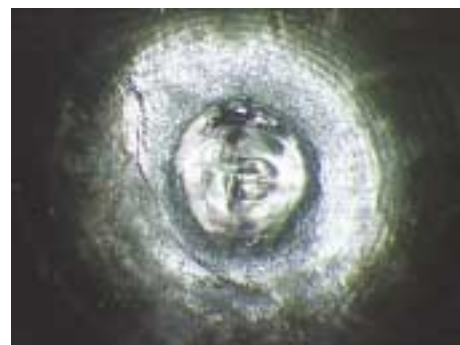
Results and Applications

It proved possible to improve the accuracy and precision of the analytical results at the scale layer through targeted control of the laser pulses. Comparison of the analysis results of the conventionally prepared side with the results of the laser-prepared scale side confirm a very close correlation for the majority of the elements.

The work is supported by funding from the European Coal and Steel Community (ECSC).

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Above: Example of a production control sample of pig iron.
Left: Sample prepared for conventional analysis.
Right: Sample without preparation showing a scale layer.
Below: Microscopic image of a crater after ablation and analysis with the laser

Online measurement of galvanized sheet metal

Task

The objective is to investigate and evaluate the effectiveness of employing an online measuring process to monitor characteristic parameters during the production of galvanized sheet metal. One of the key parameters is the thickness of the zinc layer which lies typically in the range of 2-20 μm .

Method

As part of a European R&D project, a measurement technique based on laser-induced breakdown spectrometry (LIBS) was investigated for the characterization of the zinc layer on a steel substrate and assessed in terms of its applicability in a production environment.

Results and Applications

The first phase of the project involved the design of the equipment components. Process parameters were tested on static sheet metal samples in the laboratory. Through a fine adjustment of the laser parameters, the crater depth could be markedly increased. This is an essential requirement for the measurement of sheet metal as it moves through a production line.

The project is being conducted with the financial support of the European Coal and Steel Community (ECSC).

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Sample of galvanized sheet metal



On-line elemental analysis of aerosols in the top gas of blast furnaces

Task

It is well known that alkalis, zinc and lead have a negative impact on blast furnace operation; they affect its degradation behaviour and can lead to higher coke consumption and accretions.

The task was to adapt and to test a laser based sensing system for the on-line and in-situ analysis of top gas dust at the top gas tube in order to assist the process control of the blast furnace.

Method

Within the scope of a European R & D project, a sensing system based on laser-induced breakdown (LIBS) was developed and tested at three different blast furnaces. Access to the top gas tube was performed by a 2.7 m long probe containing multi-fibre optics and focusing optics to detect the element-specific radiation of the laser induced plasma. It can be moved along the tube cross-section to enable spatially resolved measurements in a range of up to 800 mm.

Results and Applications

It has become possible for the first time to monitor, in-situ and on-line, the elements of top gas dust. Measuring campaigns at blast furnaces in Germany, Finland and Spain proved the practical viability of the sensing system.

It enabled the continuous and simultaneous monitoring of Na, K, Zn, Pb, C, N, O, H, Ca and Fe at gas velocities of 10 - 20 m/s, at gas temperatures of 115 - 180 °C and dust densities of 4 - 10 g / m³. The average concentration of the circulating materials ranged between 2.46 – 18.4 x 10⁻³ g / m³.

Measuring periods of up to 10 hours a day with 10 measuring values per second were recorded. The relative standard deviation of the measurements was element-specific and about 2.3 % up to 7 % for the circulating materials.

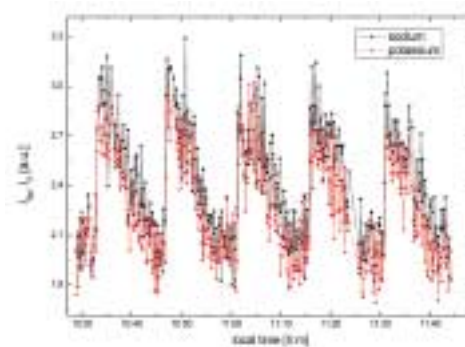
A correlation was identified between the measured element concentrations and operating parameters of the blast furnace like hot blast, differential pressure or charging period.

The top gas overpressure of 2 - 4 bar can lead to a decrease in measured radiation intensity attributable to collisional de-excitation processes of particles. A significant increase of the signal-to-background ratio was achieved by temporal modulation of the laser pulses, e.g. for nitrogen up to 65 %.

The work was funded by the European Coal and Steel Commission (ECSC).

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Section of a measuring period at atop gas tube of a German blast furnace. The periodical change of the elements natrium and calium reflects the charging process.

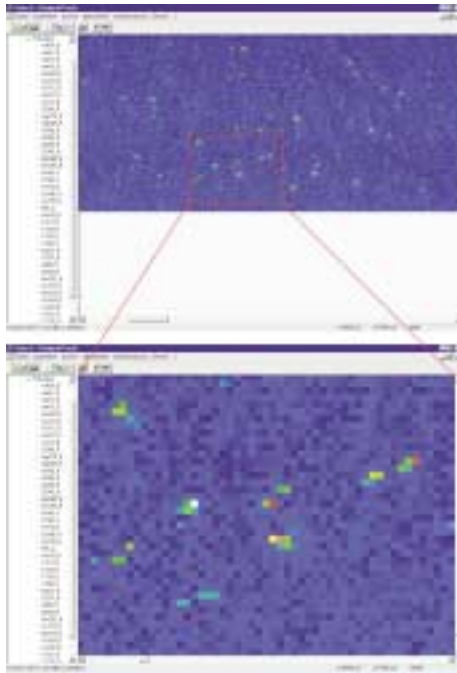
Measuring and visualisation software for the spatially resolved elemental analysis of solids

Task

The chemical mapping of the surface of solids at spatial resolutions below $20\text{ }\mu\text{m}$ enables assessment of the quality of many materials, such as of steels. Within the scope of a former project with an industrial partner, ILT has developed the analysing system SML, which is based on laser-induced breakdown spectrometry enabling a measuring frequency of up to 1 kHz .

Measuring parameters and measuring methods are selected with respect to the material properties and to the specific analysis problem.

The task is to develop software that features user friendly handling and management of measuring parameters and measuring methods for automated measuring sequences, as well as simple and rapid visualisation of the measured data sets.



Display of measuring data of the analysing system SML using the developed software. In the left part of the window a menu is shown, from which the element channels to be displayed can be selected. The measured signal levels are displayed in a colour-coded way.

Above: Display of the manganese distribution of a sample in an area of $4,28 \times 2,00\text{ mm}^2$. The coloured dots correspond to local manganese enrichments. Below: Detailed view of a part of the upper image enlarged by a factor 4. The small squares visible in this presentation correspond to an area of $20 \times 20\text{ }\mu\text{m}^2$ of the sample surface.

Method

The software was designed with a view to easy and intuitive operation. Standardised communication protocols are used to enable the possibility of remote operation and monitoring from a distant workstation.

Results and Applications

The software enables quick and efficient operation of the SML analysing system, which is used to generate chemical mappings of the surface of solid samples. With this software, the complexity of operational procedures are reduced significantly, increasing the potential sample throughput rate. The pictures on this page show how a data set is displayed. This gives users a rapid first impression of measuring results, so that they can for example decide in which regions further measurements are to be carried out.

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Analysis of small liquid droplets

Task

»Hyphenated Techniques« are analytical methods that combine a chromatographic separation stage with the sensitive detection of separated fractions. In an ongoing national joint project a new analytical technique is being developed combining micro-HPLC (high pressure liquid chromatography) separation with laser-induced breakdown spectrometry (LIBS) as the detection method. Speciation analysis of metal and metalloid species is foreseen as a key application.

Method

The eluate of a micro-HPLC column is transferred into a regular stream of small droplets using a piezoelectric pulsed nozzle. The droplets are irradiated, evaporated and transferred into a bright plasma by synchronised laser pulses. The plasma radiation is spectrally resolved and yields information about the elementary composition of the sample.

Results and Applications

The principal applicability of the described analytical method was demonstrated through a laboratory set up. Together with the project partners a demonstrator is being built to test possible fields of application for the novel analytical technique.

In order to achieve highly reproducible results for the analytical signal, it is essential that the activation of the laser and droplet generator are precisely timed. To trigger the laser at a defined time, a light barrier with a focused diode laser beam has been designed. Single droplets can be detected with an accuracy of better than one microsecond. Determination of trace element concentrations in the sub-ppm range calls for the highest possible sensitivity in detection of the plasma emission. An optical light collection system was therefore set up that is to be integrated into a Paschen-Runge-spectrometer. The spectrometer is provided by one of the project partners and is equipped with modern channeltron photomultipliers. In order to optimise the interaction of the laser pulse with the droplet and to maximise energy transfer into the liquid, the dynamics of the plasma generation at high temporal resolution (sub-nanosecond) is currently under investigation. An intensified CCD camera with exposure times in the picosecond range is used to analyse plasma dynamics. A Mach-Zehnder interferometer was built to visualise the shock front which develops subsequent to plasma generation.

The project is being funded by the BMBF under the reference 13N8039, by small and medium sized enterprises, and by the Fraunhofer Gesellschaft

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Mach-Zehnder interferometer to study the interaction of laser pulses with nanolitre droplets

Monitoring of conditions for protein crystallisation with laser light scattering

Task

Today X-ray diffraction analysis is the most important method for the determination of protein structures. Large and well ordered protein crystals are necessary for the diffraction analysis, yet they can only be grown under protein-specific conditions (pH, solvent, concentration and type of various precipitants). Lasers can help to simplify the search for optimised crystallisation conditions.

Method

Laser scattering techniques enable the analysis of protein - protein interactions before and during the crystallisation. The so-called second osmotic virial coefficient of dissolved molecules can be measured by static light scattering. This is a direct measure of the strength of attractive or repulsive forces between the molecules. Dynamic light scattering is sensitive to particle movements and enables the determination of the hydrodynamic Stokes radius. Changes in the diffusion caused by attractive or repulsive interactions and the aggregation of proteins can be observed long before the first microscopic precipitates or crystals show up.

The application of high throughput screening methods with an adaptive optimisation of crystallisation parameters is a promising start to speed up and to systemise the protein crystallisation. The corresponding »crystallisation window« can be found faster, consuming less valuable protein.

Results and Applications

Together with the Institute for Molecular Biotechnology (RWTH, Aachen) the application of laser light scattering for the monitoring and optimisation of crystallisation parameters is being investigated. In a laboratory experiment helium-neon and diode lasers and sensitive photomultipliers are used to count scattered photons. A specially designed optical set up has been employed with the aim of reducing the necessary sample volume for dynamic and static light scattering measurements down to less than one micro-litre. The goal is to enable measurements in modified microwell plates to make the system accessible for automated liquid handling systems. For this reason a strong reduction of light that is scattered at interfaces is important. A modified optical confocal set up for light scattering measurements has been developed.

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Protein crystal (glucose isomerase) for x-ray diffractometry

Micro-measuring and processing platform for life science applications

Task

The aim is to develop a universal, laser-based processing system for molecular biological models in aqueous solutions. Applications include the detection of single molecules in the field of life science and investigation of protein-protein interactions.

Method

A multi-axes system with a positioning accuracy of 1 μm for adjustment and scanning of biochips enables single molecules to be detected at high lateral resolution. The fluorescence, which is stimulated in a small probe volume by a tightly focused picosecond laser pulse, is detected using a confocal microscope set-up in conjunction with high sensitive avalanche photodiodes. A second laser is used to detach immobilised species at specified positions.

A two-dimensional detection of fluorescence can be carried out by use of a slow-scan camera of high sensitivity equipped with a microscope lens.

Results and Applications

A micro-measuring and processing platform for life science applications was developed. A modular software enables the components of the system to be controlled in a flexible manner thus enabling rapid adaptation to various applications.

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Figure: View of the micro-measuring and processing platform for life science applications

National	102 50 074.6 Verfahren zum Aufbau mikro-optischer Bauteile	Germany	Europe
102 26 724.3 Verfahren zum Montieren eines laseraktiven Materials mittels stoffschlüssigem Fügeverfahren	102 56 663.1 Gasentladungslampe für EUV-Strahlung	DE 195 32 105 C 2 Verfahren und Vorrichtung zur Behandlung von dreidimensionalen Werkstücken mit einer direkten Barrierenentladung sowie Verfahren zur Herstellung einer mit einer Barriere versehenen Elektrode für diese Barrierenentladung	EP 0 732 727 B 1 Vereinfachtes Verfahren zur Vorbehandlung und Beschichtung von Oberflächen
102 32 815.3 Verfahren zur Modifizierung von Materialeigenschaften	102 08 781.4 Verfahren und Vorrichtung zum Bestimmen der Intensitätsverteilung beim Auftreffen eines Laserstrahls auf eine Oberfläche	DE 197 51 716 C 2 Anordnung zur Formung und Führung von Strahlung	EP 0 855 095 B 1 Laseranordnung, vorzugsweise Hochleistungs-Gaslaseranordnung
102 07 692.8 Verfahren und Vorrichtung zur Prüfung der Qualität einer Haft- oder Klebeverbindung in einer Mehrschichtanordnung	International	DE 198 59 933 C 2 Verfahren zum Fügen eines Werkstückes aus zellularem Werkstoff	EP 0 889 769 B 1 Verfahren zum Fügen von Werkstücken mit Laserstrahlung
102 17 678.7 Verfahren und Vorrichtung für die Verbesserung der Laser-Materialbearbeitung mit hybriden Prozessen durch synchronisierte Pulsmodulation	PCT/DE02/00818 Verfahren zum Schneiden von zu fügenden Bauteilen mit Laserstrahlung	DE 100 17 845 C 1 Schweißdüsenanordnung und damit betriebenes Schweißverfahren	EP 0 879 494 B 1 Optisch gepumpter Verstärker, insbesondere ein Festkörperverstärker
102 28 743.0 Verfahren zum Glätten und Polieren von Oberflächen durch Bestrahlung mit energetischer Strahlung	PCT/DE02/01017 Verfahren und Vorrichtung zum Erzeugen von Extrem-Ultraviolettstrahlung/weicher Röntgenstrahlung	DE 199 57 808 C 2 Verfahren und Vorrichtung zur Bestimmung von Stoffkonzentrationen und/oder der Strömungsgeschwindigkeit in Gasen, Aerosolen und Stäuben	EP 1 036 488 B 1 Verfahren und Vorrichtung zur Erzeugung von Extrem-Ultraviolettstrahlung und weicher Röntgenstrahlung
102 09 374.1 Diodenlaseranordnung mit einer Mehrzahl von elektrisch in Reihe geschalteten Diodenlasern	PCT/DE02/01085 Maßnahmen zur Regelung der Leistungseinkopplung in eine Gasentladungsquelle für EUV-Strahlung	DE 100 27 149 C 2 Vorrichtung für die Röntgenradiografie mit relativ zu ihrer Partikelquelle bewegbarer Röntgenquelle und Verwendung derselben	EP 1 151 508 B 1 Resonatoranordnung mit mindestens zwei Faltungselementen
102 07 334.1 Verfahren und Vorrichtung zur Führung und Konvertierung der Strahlung aus optoelektronischen Bauteilen	PCT/EP02/08848 Schweißen mit gepulster Laserstrahlung	DE 101 09 750 C 2 Anordnung zur Detektion eines Glasbruchs einer Glasscheibe	EP 1 198 341 B 1 Vorrichtung und Verfahren zur Herstellung von Bauteilen aus einer Werkstoffkombination
102 53 515.9 Strahlungsführendes und/oder frequenzkonvertiertes optisches System sowie Verfahren zur Herstellung		DE 101 04 732 C 1 Verfahren und Vorrichtung zum selektiven Laser-Schmelzen von metallischen Werkstoffen	EP 1 181 754 B 1 Optische Verstärker-Anordnungen
102 38 096.1 Gasentladungslampe		DE 101 20 725 C 1 Koaxiale Pulverdüse zur Oberflächenbearbeitung mit einem Diffusor	EP 1 197 127 B 1 Extrem ultraviolette Strahlungsquelle auf Basis einer Gasentladung
102 29 498.4 Verfahren und Vorrichtung zur Durchführung der Plasmaemissions-spektrometrie			USA
102 48 207.1 Vorrichtung zum Scherschneiden und Verfahren dazu			US 6, 351, 477 B 1 Optically pumped intensifying agent, in particular a solid intensifying agent
			US 6, 365, 870 B 1 Method and device for treating workpieces with Laser radiation
			US 6, 389, 106 B 1 Method and Device for producing extreme ultraviolet and soft x-rays from a gaseous discharge
			US 6, 461, 409 B 1 Process and Device for Handling Streaming Gases

Wiedmann, N. - 29.01.2002
Hochleistungsdiodenlaser für
Hochtemperaturanwendungen

Weichenhain, R. - 16.04.2002
Einfluss von Pulsdauer und Wellen-
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bearbeitung von Keramiken

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von Silizium und Glas mit Laser

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Multifunktionale Bildverarbeitung
zur Tiefenmessung in der Mikro-
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Pfeiffer, Stefan
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Radenz, Ulf
Untersuchung zur Konzeptionierung
einer Hochgeschwindigkeitsschnitt-
stelle zum Datenaustausch zwischen
Hochleistungslaser und PC

Stier, Benoit
Verfeinerung des approximativen
Modells für das Schmelzschneiden
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Wawers, Welf
Kinematikanalyse verschiedener
Optikkonzepte für flexible Bauteil-
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Laserstrahlung

Zäck, Hans-Jürgen
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19.01.2002 - T. Kramer
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19.01.2002 - M. Talkenberg
UV laser-radiation-induced modification and microstructuring of glass (Invited Paper) Photonics West 2002, San Jose, CA

19.01.2002 - A. Olowinsky
Laser Beam Micro Welding in Watch Industry Photonics West 2002, San Jose, CA

02.02.2002 - C. Schnitzler
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27.02.2002 - A. Brysch
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27.02.2002 - L. Boeske
Automatisierte Strahlüberwachung und Fehlerdiagnose für die Materialbearbeitung mit Laserstrahlung Angewandte Informatik zur Füge-technik, Berlin

27.02.2002 - M. Dahmen
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27.02.2002 - M. Dahmen
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27.02.2002 - M. Dahmen
Vergleichende Studie zum Laserstrahlschweißen von Schiffbaustählen Fachmesse für Verbindungs- und Schweißtechnik, Stuttgart

27.02.2002 - M. Dahmen
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06.03.2002 - D. Petring
Laserstrahlschweißen - Fortschritte durch Hybridtechnik Laser-Optik 2002, Berlin

09.03.2002 - S. Kaierle
New Advances in Process Control for Automotive Laser Applications ALAW, Dearborn

11.03.2002 - C. Schnitzler
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21.03.2002 - J. Michel
Approximative Modellierung des Tiefschweißprozesses DPG-Frühjahrstagung, Bochum

21.03.2002 - B. Stier
Singularäre Störungstheorie im approximativen Modell für das Schneiden mit Laserstrahlung DPG-Frühjahrstagung, Bochum

21.03.2002 - S. Pfeiffer
Approximative Modellierung der Schmelzströmung beim Laserstrahlschweißen DPG-Frühjahrstagung, Bochum

21.03.2002 - W. Schulz
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21.03.2002 - K. Klages
Laserstrahlmikroschweißen ungleicher Metalle DPG-Frühjahrstagung, Bochum

11.04.2002 - P. Loosen
Neue Laser eröffnen neue Möglichkeiten Laser-Kolloquium IFSW, Stuttgart

20.04.2002 - N. Pirch
Theoretical investigations of laser induced crystallization and stress development in phase change electroceramic materials Fifth International Conference on Modeling and Simulation of Micro-systems, San Juan

28.04.2002 - A. Weisheit
Recent Developments in Laser Cladding and Selective Laser Melting International Symposium on Thermal Spray, Bombay

06.05.2002 - S. Kaierle
Virtual European Laser Institute Brüssel (VI Workshop)

15.05.2002 - S. Kaierle
New developments in process monitoring and control for laser beam welding LMPC, Beijing, China

17.05.2002 - S. Kaierle
Recent Developments and Trends in Lasertechnology Beijing Polytechnic University, China

18.05.2002 - C. Schnitzler
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19.05.2002 - P. Russbuehlt
Design of a Laser Diodepumped 100 µJ regenerative Cr:LiSGaF fs-Amplifier CLEO 2002, Kalifornien

20.05.2002 - S. Kaierle
Trends in Laser Source Development BIOET, Beijing, China

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Development of High-Brightness, High-Power Diode Lasers: The Z-Laser LAMP 2002, Osaka

25.05.2002 - M. Heise
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25.05.2002 - H.-D. Hoffmann
Development of highpower laser diode pumped solid state lasers LAMP 2002, Osaka

28.05.2002 - D. Petring
Macro-Processing with High Power Diode Lasers LAMP 2002, Osaka

14.06.2002 - E. W. Kreutz
Farbige Markierung von Gläsern mit Laserstrahlung ITWM, Scharnebeck

17.06.2002 - J. Gottmann
Fabrication of planar structures for optical waveguide applications by pulsed laser deposition and laser micro structuring E-MRS 2002, Strasbourg

25.06.2002 - A. Weisheit
Surface Technology, Protection, Rapid Prototyping, Manufacturing 1st. International Conference LASER, Barcelona

28.06.2002 - M. Dahmen
Research and Development
of Laser Materials Processing
for the Automotive Industries
Automotive Industries Development
Centre, Pretoria

28.06.2002 - P. Abels
Beleuchtungstechnik - von
der Beratung zur Laseranlage
Abschlussveranstaltung der Erpro-
bungs- und Beratungszentren,
Düsseldorf

23.08.2002 - E. W. Kreutz
Electroceraamics VIII, Rom

27.08.2002 - J. Gottmann
PLD of Perovskite Coatings for
Optoelectronics, Microelectronics
and Microtechnology
Electroceraamics, Rom

09.09.2002 - G. Schlaghecken
Absorption of plasma in the
pulsed laser deposition process
PSE 2002, Garmisch-Partenkirchen

09.09.2002 - S. Keutgen
Mikrostruktur einer laser-
behandelten AlSnZn-Legierung
und deren Korrelation mit
Verfahrensparametern und
Simulationsrechnungen
Abschlusskolloquium Kurzzeit-
metallurgie, Bremen

17.09.2002 - M. Röhner
Characterization device
for diode-laser-stack beam
propagation
Laser Beam and Optics
Characterization (LBOC), Colorado

18.09.2002 - E. W. Kreutz
Arbeitssicherheit für Laser in
der Materialbearbeitung
Seminar SBG, Markt Triefenstein
Lengfurt

19.09.2002 - S. Kaierle
Innovative Entwicklungen
in der Prozessüberwachung -
ein Überblick
AKL '02, Aachen

24.09.2002 - S. Kaierle
Laseranwendungen
im Automobilbau
IIS Konferenz Stuttgart

24.09.2002 - R. Noll
On-line detection of heavy
metals and brominated flame
retardants in technical polymers
with laser-induced breakdown
spectrometry
LIBS 2002, Orlando

29.09.2002 - A. Horn
Ultrafast pump & probe investi-
gations on the interaction of
femtosecond laser pulses with
glass
Konferenz HSPP, Beaune (F)

13.10.2002 - A. Horn
Time resolved optomechanical
investigations on the interaction
of laser radiation with glass in
the femto second regime
ICALEO, Phoenix Scottsdale (USA)

13.10.2002 - K. Du
Diode end-pumped high power
Nd:YV04 slab laser; efficient
second harmonic generation
of diode end pumped electro-
optically q-switched Nd:YV04
slab laser; Renaissance of slab
Photonics ASIA, Shanghai, Beijing
(China)

23.10.2002 - R. Wagner
Micro structuring of erbium
doped waveguides by femto
and pico second laser radiation
FemtoMat, Visegrad

24.10.2002 - J. Willach
Posterpräsentation »Shaping
of zirconia by laser radiation
for blow-out facilities of cooling
holes in turbine blades«
SHAPING II, Gent (Belgien)

25.10.2002 - M. Dahmen
Trends and Limits in Laser Micro
Processing
KIST (Korea Institute of Science
& Technology), Seoul, Kr

27.10.2002 - J. Gottmann
Fabrication of erbium doped
planar waveguides by pulsed
laser deposition and laser
micromachining
Photonics Fabrication Europe,
Brugge (Belgien)

14.11.2002 - M. Dahmen
Innovations in Laser Technology
for Small and Medium Sized
Enterprises
TWA Bijeenkomst »Modern
Producers« Aluminium centrum,
Houten (NL)

21.11.2002 - R. Noll
Industrielle Anwendungen
der Lasermesstechnik für Prozess-
führung und Qualitätssicherung
in der Produktion
VDI-Wissensforum, Magdeburg

25.11.2002 - D. Petring
CALCut: Making Laser Cutting
Calculable
TransLas-Workshop, CAMBRIDGE

25.11.2002 - M. Nießen
Numerische Simulation freier
Randwertaufgaben in der Laser-
materialbearbeitung
SIMPRO, IWM Freiburg

26.11.2002 - A. Bauer
Von der Vision zum Produkt -
Innovationsmanagement am
Fraunhofer-Institut für Laser-
technik ILT
Seminar des Marketing-Club
Aachen e. V., Aachen

27.02. - 01.03.2002
Stuttgart
Trade fair for connecting and wel-
ding technology

The Fraunhofer ILT was present at
the »welding technology« stand,
ILT topic: »Hybrid welding«.

15.04. - 20.04.2002
Hannover
HANNOVER FAIR 2002
International industry trade fair

The Fraunhofer ILT was present at
the »North Rhine-Westphalia micro
technology« stand, ILT topic:
»Lasers in packaging and assembly«.

The Fraunhofer ILT was present at
the VDI stand »Optical Technolo-
gies«, ILT topic: »Laser in medical
engineering at the example of sel-
ective laser melting for the manu-
facturing of implants«.

04.12. - 07.12.2002
Frankfurt
EUROMOLD
Trade fair for tool and die making

The surface treatment department
of the Fraunhofer ILT was present at
the stand of the Fraunhofer Allian-
ce »Rapid Prototyping«, ILT topic:
»Selective Laser Melting«.

Conventions and Conferences

17.01.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Dipl.-Ing. C. Schmid, Mobil Laser Tec GmbH, Wolfsburg
»Hand-guided laser systems for industrial applications«

17.01.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Dr. W. Barkhausen, CLEAN Lasersysteme, »Industrial applications - Hand-guided laser beam cleaning technology«

31.01.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Prof. Dr. R. Kassing, University of Kassel, »Manufacture of nanostructures - lithographic processes«

14.02.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Prof. Dr. K.-H. Zum Gahr, University of Karlsruhe, »Laser-assisted structuring and modification of metals, polymers and ceramics«

21.02.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Dipl.-Ing. T. Seefeld, Bremen Institute for Applied Laser Technology BIAS
»Direct laser beam joining of Ti/Al and Fe/Al alloys in thin metals«

11.04.2002, Aachen
Fraunhofer ILT Workshop
Lectures and discussions on the topic of »Laser metrology in manufacturing and quality assurance«

12.04.2002, Aachen
7th seminar of »Aix Laser People«
The Alumni Club of the Fraunhofer ILT and the Chair for Laser Technology with lectures by Oliver Steffens, GM, S&F NC-Systemtechnik GbR and Dr. Jens Biesenbach, DILAS Diodenlaser GmbH, Mainz on the topic of »Career challenges within a high tech company, DILAS case history« followed by a tour of AIX-TRON AG in Aachen conducted by Professor Heuken, VP Corporate Research & Development and Corporate Technology Transfer.

18.04.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Prof. Dr. M. Kohl-Bareis, University of Applied Sciences, Koblenz
»Optical spectroscopy of neurological tissues«

27.06.2002, Aachen
Fraunhofer ILT Open Day
Continuing education program for adults at RWTH Aachen with tours and lectures

28.06.2002, Handwerkskammer Düsseldorf
Final conference outlining the results of the VDI and BMBF sponsored project »Laser Technology Testing and Consulting Centers for Small to Medium Enterprises«. More than 80 participants from the North Rhine-Westphalia region were presented a wide range of topics in the area of laser technology.

04.07.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Dr. J. W. Tomm, Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin (MBI)
»Optical spectroscopy using diode laser technology«

11.07.2002, Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology
Dr. T. Lippert, Paul Scherrer Institute, Villingen, Switzerland, »Laser Ablation Applied for Direct Structuring«, »Thin Film Deposition and Emission Spectroscopy«

18 - 20.09.2002, Aachen
Colloquium for Laser Technology AKL'02
This year the 4th annual Aachen Colloquium for Laser Technology positioned itself again as the primary forum for applied laser technology. Over 400 participants, including representatives from numerous laser manufacturers and users of laser technology, gathered in Aachen to discuss success stories, potential applications and recent developments in the field of laser technology. Using examples from practical industrial applications and innovative R&D projects, a total of 36 technical lectures provided participants a visual perspective on laser technology across a variety of applications in industries such as automobile manufacturing, shipbuilding, metal processing, tool and die making, electronic and optical engineering, plastics and glass. Non-financial sponsors of the conference included the organizations VDI, VDA, VDMA and SPECTARIS.

In addition to lectures provided by laser experts from industry and science, more than 60 presentations organized by the Fraunhofer ILT and companies from the Laser Application Center provided participants with information regarding the newest in laser systems and processes by demonstrating examples of future-oriented applications. An exposition area with 30 exhibitors offered an ideal venue for the exchange of professional information.

The proceedings from AKL'02 have been published in a 545-page volume and can be ordered directly from the publisher at the following address:

Verlagsgesellschaft Grütter
Grütter GmbH & CO. KG
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Phone: +49/(0)511/4609 -322
Fax: +49/(0)511/4609 -320

The next AKL will be held at the Eurogress in Aachen, April 28-30, 2004.

18.9.2002, Aachen
Laser Business Conference 2002
By attracting more than 100 participants, the inaugural Fraunhofer ILT Laser Business Conference proved to be a natural extension of this year's AKL. In three series of lectures, 11 papers were read, some providing an overview of the market for laser technology in the areas of material processing, communications and medical technology, and others supplying up-to-date information on financial services, intellectual property law and technology marketing. In addition, both startup and emerging growth companies could take advantage of the opportunity to consult directly with expert personnel on site. The 241-page conference proceeding contains the complete series of lectures and can be obtained by contacting:

Wirtschaftswoche Leserservice
Postfach 3752
D-90018 Nürnberg
Phone: +49/(0)911/2748 -100
Fax: +49/(0)911/2748 -222
www.leserservice@vhb.de

The next Laser Business Conference will be held in Aachen on April 28, 2004.

19.09.2002

Innovation Prize for Laser Technology 2002

In association with the Colloquium for Laser Technology AKL'02 held on September 18-20, 2002, two outstanding researchers were awarded the Innovation Prize for Laser Technology. The prizes, conferred during a celebration event on September 19, 2002 in Aachen, were awarded to Dr. Guido Hennig, head of the Laser Department at MDC Max Daetwyler AG (Switzerland) and Dr. Gisbert Staupendahl, head of the Laser Technology workgroup at the Technology Institute of the University of Jena. The awards were presented to the two researchers by Prof. Dr. Reinhart Poprawe M.A. and Dr. Dirk Basting, Chairman of the Board of Lambda Physik AG and member of the BDI Committee on Research and Technology Policy.

The Innovation Prize for Laser Technology is awarded by the Arbeitskreis Lasertechnik e.V. and recognizes two individuals whose achievements have successfully led to advances in laser technology innovation. The award gives special consideration to the interface between applied research and operational practice. The two innovation prizes, worth EUR 2,500 for each recipient, are advertised for the fields of »Practice-relevant Research« and »Operational Practice«. As part of an open competition, worthy candidates are nominated by the executive board of the Arbeitskreis Lasertechnik e.V. Prize-winners are then selected by the membership of the Arbeitskreis Lasertechnik e.V.

20.09.02 Aachen

8th seminar of »Aix Laser People«
The Alumni Club of the Fraunhofer ILT and the Chair for Laser Technology in association with the 4th Aachen Colloquium for Laser Technology AKL'02

17.10.2002

Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology Dr. M. Schellhorn, German-French Research Institute, Saint Louis, France, »2-µm laser sources: numerical simulation of 3-level laser systems«

21.11.2002

Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology Prof. Dr. R. Birngruber, Medical Laser Center, Lübeck, »Cellular selectivity in the laser treatment of retinal disease: From laser microsurgery to laser nanotechnology«

26.11.2002 Aachen

Seminar, Marketing-Club Aachen e.V.
Axel Bauer, lecture at the Fraunhofer ILT on the topic of »From vision to product - managing innovation at the Fraunhofer Institute for Laser Technology ILT«

28.11.2002

Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology Prof. Dr. O. Hess, German Aerospace Center DLR, Stuttgart, »Computational Nano-Photonics«

12.12.2002

Chair for Laser Technology at RWTH Aachen
Lecture in association with the Colloquium for Laser Technology Prof. Dr. A. Tünnermann, Friedrich-Schiller University, Jena, »Photonics in micro and nano structures«

13.12.2002, Aachen

Seminar at the Fraunhofer ILT for young, trainee engineers
»Laser technology - Technology for the everyday workplace«

19.12.2002, Aachen

9th seminar of "Aix Laser People"
The Alumni Club of the Fraunhofer ILT and the Chair for Laser Technology including lectures by Dr. Reinhard Noll: »New developments in laser metrology for process control and quality assurance in manufacturing« and Dr. Ulf Westheide, Accenture GmbH, Düsseldorf: »Life as a consultant at a technical consulting firm«.

Publikations

"Your partner for innovation" (German/English)

This brochure provides a concise overview of the Fraunhofer ILT. In addition to presenting a summary of European R&D projects conducted by the ILT, the brochure also contains a short profile of the institute as well as a list of reference customers.

»Services and Contacts 2002/3« (German/English)

This brochure gives an overview of current services offered and contacts within the Institute. It also introduces focal points of each division of the Fraunhofer ILT.

Annual Report 2002 (German/English)

The annual report presents a comprehensive look at the R&D activities of the Fraunhofer ILT for the respective business year. Lists of scientific publications and lectures as well as patents, dissertations, conferences and trade fairs are also included. The English version can only be found on our website at: www.ilt.fraunhofer.de.

Mirror of the Press 2002

In the mirror of the press, the institute's activities are presented from the press' point of view.

Proceedings of the Aachen Colloquium for Laser Technology AKL'02
The technical proceedings of the Aachen Colloquium for Laser Technology AKL'02 (September 18-20, 2002) contains reports from 36 laser manufacturers and users outlining the latest developments and technology trends in industries such as optics, automobile, metal production, tool and die making, electrical and electronic engineering, plastics and glass. Practical case studies highlight various laser processes such as laser metrology, laser microengineering, laser-beam welding/cutting and laser surface technology. Copies of the 545-page proceedings can be obtained for a fee by contacting the publishers at the following address:

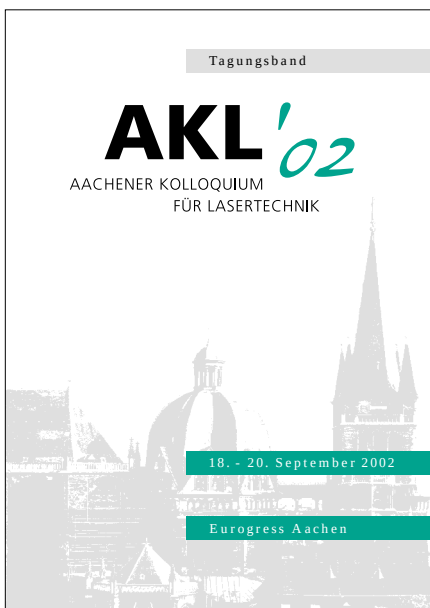
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Frau Julia Ibenthal
Lägenfeldstrasse 8
30952 Ronnenberg
Phone: +49 (0)511/4609 -322
Fax: +49 (0)511/4609 -320

Programme of the Aachen Colloquium for Laser Technology AKL'04

28. - 30. April 2004. A request for the programme of the AKL'04 can be made by phone 0241/8906 -109 or Fax: 0241/8906 -121 or internet at: www.ilt.fraunhofer.de.

Technical brochure »High-Power Diode Lasers« (German only)

This technical brochure outlines the various development activities of the Fraunhofer ILT in the area of high-power diode lasers. Included are developments such as the design of special components for laser cooling, diode laser bar packaging, diode laser burn-in characterization and the optical design and development of complete diode laser modules.



Technical Brochure »LASIM® - Laser Simulator for Training« (German/English)

This technical brochure gives an overview of the advantages of using multimedia software to train laser users and students. It introduces the application fields, program contents and the system demands of the LASIM® software. This was developed at the Fraunhofer ILT for the training of laser welding and cutting. The LASIM® CD ROM with corresponding program instructions is available at the Fraunhofer ILT.

Technical brochure »Laser Technology for Surface Modification and Forming« (German only)

This technical brochure provides an overview of how lasers are employed in the area of surface modification and forming. Included are processes such as deburring, melting and forming, polishing, roughening, structuring and activation, re-crystallization, annealing and fine pearlitizing.

Technical brochure »Laser Technology for Wear and Corrosion Protection« (German only)

Wear and corrosion protection can be created by various laser processes. This technical brochure provides insights into processes such as martensitic surface hardening, remelting, deposition welding, alloying and dispersion.

Technical Brochure: »Laserstrahl-auftragschweißen« (Laser Beam Deposition Welding) (only German)

This technical brochure provides an introduction to the processes and systems used in laser beam deposition welding. It also elucidates the differences between conventional powder feed nozzles and those used in laser beam deposition welding.

Technical Brochure: »Rapid Prototyping und Rapid Manufacturing für Metallbauteile« (Rapid Prototyping and Rapid Manufacturing of Metal Parts) (only German)

This brochure describes the selective laser melting process developed at the Fraunhofer ILT which enables complex metal parts to be manufactured directly from 3D CAD data. It also provides examples of applications of the laser beam generation technique.

Technical Brochure: »Laser Cleaning« (German/English)

This technical brochure explains the possible applications of laser beam cleaning.

Technical Brochure: »Lasers in Microstructuring« (German/English)

This technical brochure describes processes such as laser ablation, precision cutting, drilling and laser-assisted microforming.

Technical Brochure

»Lasers in Packaging and Assembly« (German/English)

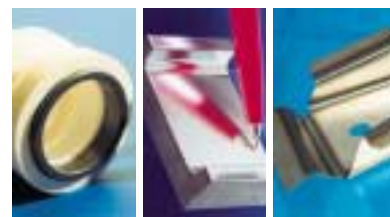
This technical brochure gives an overview of the use of lasers in packaging and assembly and demonstrates for example micro joining processes such as laser beam bonding and laser beam soldering.

Technical Brochure: »Lasers in Plastics and Paper Processing« (German/English)

This technical brochure describes the use of lasers in the processing of plastics, composite materials, paper and glass.

Technical Brochure: »Lasers in Life Science« (German/English)

This technical brochure deals with applications of laser technology in medical engineering. It also describes the use of lasers as tools in microreaction processes and biotechnology.



Lasertechnik für die Oberflächenmodifikation und das Umformen

Fraunhofer
Institut
Lasertechnik



Lasers in Polymer and Paper Technology

Fraunhofer
Institut
Lasertechnik



Hochleistungs-Diodenlaser

Fraunhofer
Institut
Lasertechnik

Technical Brochure: »Material Analysis and Identification with Laser Radiation« (German/English)

This technical brochure describes the processes and systems for analyzing the composition of materials with laser radiation, which were developed at the Fraunhofer ILT. The initial testing of different materials, testing for mixed products, sorting of materials as well as online analysis of melting problems can be solved quickly and reliably with the laser.

Technical brochure »Oberflächen- und Schichtanalyse« (Surfaces and Layer Analysis) (only German)

The technical brochure offers an overview of the present measuring methods for surface analysis at the Fraunhofer ILT and the LLT at the RWTH Aachen. This includes different spectroscopy processes, the ellipsometer and metallographic measuring methods.

Information Brochure »Laser Region Aachen« (German/English)

This brochure was published by the Aachen Society for Innovation and Technology AGIT mbH with close cooperation from the Fraunhofer ILT. It gives an overview of the laser activities in the Aachen region as well as the central participants in industry, science and the service sector.

Information Brochure »Networks of Competence« (German/English)

»Networks of Competence« was set up on the initiative of the BMBF and serves as an international marketing instrument and presentation showcase for the most highly skilled networks of competence in Germany. Its Internet portal, at: www.kompetenznetze.de, with its efficient search engine and many useful links, provides an ideal information source and communication platform for individuals and organizations in Germany and elsewhere looking for information and potential working partners.

Information Brochure »Virtual European Laser Institute VELI« (only English)

This brochure provides information on the European network of recognized centers of R&D in laser technology coordinated by the Fraunhofer ILT. The members of this network have set themselves the goal of making existing laser know-how in Europe accessible to all interested parties in industry and science. The project is sponsored by the European Commission. Further information can also be found at: www.veli.net.

Fraunhofer Magazine 3.2001

»Light for the Next Chip Generations« (German/English)

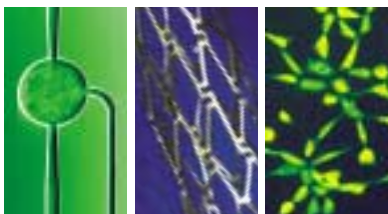
The Fraunhofer magazine 3/2001 reports on the activities of the ILT in the field of lithography for future chip generations. The EUV radiation source developed at the Fraunhofer ILT is generally regarded as a promising candidate to take over as the successor to optical lithographic techniques.

Special Edition »User profile CLT« from the Magazine »Industrial Laser Solutions« (10/2000) (only English)

This article gives an overview of activities at the Fraunhofer Center for Laser Technology CLT in Plymouth, Michigan, USA.

Product and Project Data

Descriptions of projects from the Fraunhofer ILT annual reports and specific product information can be downloaded from our website at: www.ilt.fraunhofer.de.



Laser in Life Science

Fraunhofer
Institut
Lasertechnik

Video Films and Multimedia Software

Video »Laser - the Extraordinary Light for Material Processing« (German/English)

This training video was made at the Bergische Universität - Gesamthochschule Wuppertal in cooperation with the VDI-Technologiezentrum in Düsseldorf, the Fraunhofer ILT and other laser centers and companies. It delivers an overview of all important laser machining processes and was specially made for use at colleges, universities, technical colleges, vocational schools and internal company training. This especially applies to manufacturing engineering courses of study. The VHS video is 30 minutes long and is available in both English and German from the Bergische Universität - Gesamthochschule Wuppertal.

The program runs using Acrobat Reader 3.01 on computers with Windows 3.1 and higher, UNIX or MacOS.

The printing and use of unaltered graphics and pictures is only allowed for educational purposes.

Further information and order forms for the CD-ROM »Laser Technology« are available through the laser technology association AKL e.V., Steinbachstraße 15, 52074 Aachen.

Contact:
Diana Heinrichs
Telephone: 49 (0) 241 / 8906 -122
Fax: 49 (0) 241 / 8906 -112
E-mail: heinrichs@ilt.fraunhofer.de

CD-ROM »Laser Technology« (only German)

This CD-ROM is a collection of graphics and pictures from the lectures Laser Technology I and II by Prof. Dr. rer. nat. Reinhart Poprawe M.A.

It was produced by the Department for Laser Technology LLT in the machine faculty at the Technical University Aachen RWTH in close cooperation with the Fraunhofer Institute for Laser Technology ILT.

It contains the basics of laser technology as well as physical and technical processes for modern manufacturing processes. Furthermore, the current state of economic use of laser and industrial applications is demonstrated in numerous examples.



Multimedia Software LASIM® (German/Englisch)

LASIM® is a multimedia training program for laser cutting and welding. The combination of text, pictures, sound and animation within the multimedia software has opened new horizons in laser training. In the theoretical part of the curriculum, complicated processes and models are vividly presented. This contributes to a better understanding of the material. In the practical part of the training, numerous experiments can be made through simulations. The user can personally set the process parameters without causing problems in the real laser system.

By installing several computer workstations, personnel costs can be reduced. Furthermore, the multimedia program is suited for private study. The laser user is able to work on experiments on the virtual system at any time.

Multimedia technology ideally supplements practical training on real laser systems. In the initial phase, the exercises are conducted at a beginner level. In the following phases, the user is able to use the knowledge acquired to solve concrete problems on real laser systems.



The advantages of using multimedia software for training of specialists and students are obvious:

- Visualization of complex correlations and process development
- Simulation of a real laser workstation
- Ability to carry out experiments on virtual systems with evaluation of results
- Unlimited availability and no risk from operator error
- Low support costs and suitability for private study
- Interactive theoretical and practical exercises to strengthen knowledge

The software LASIM® is obtainable from the Fraunhofer Institute for Laser Technology in both German and English. Current information and order forms are available through the internet site www.ilt.fhg.de.

Contact for further information on LASIM®:

Dr. Dirk Pertring

Telephone: 49 (0) 241 / 8906 -210

Fax: 49 (0) 241 / 8906 -121

If you would like more information about the research and development at the Fraunhofer Institute for Laser Technology please go to our website at www.ilt.fhg.de. Information can also be ordered using this form.

Broschure: »Your Partner for Innovation«

- ☐ German
- ☐ English

☐ Brochure: »Services and Contacts 2002/3«
(German/English)

☐ Annual Report 2002
German
(English version only available online at www.ilt.fraunhofer.de)

☐ Annual Report 2001
German
(English version only available online at www.ilt.fraunhofer.de)

☐ Annual Report 2000
German
(English version only available online at www.ilt.fraunhofer.de)

☐ Mirror of the Press 2002

☐ Mirror of the Press 2001

☐ Mirror of the Press 2000

☐ Order form for the proceedings of the Aachen Colloquium for Laser Technology AKL 2000 (German)

☐ Order form for the proceedings of the Laser-Business-Day (German)

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- ☐ German
- ☐ English

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- ☐ German
- ☐ English

Technical Brochure:
»Lasers in Packaging and Assembly«

- ☐ German
- ☐ English

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- ☐ Technical Brochure: »Lasers in Plastics and Paper Processing«
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- ☐ Information Brochure: »Virtual European Laser Institute VELI« (English)
- ☐ Order form for Multimedia Software LASIM®
German (also available online at: www.ilt.fraunhofer.de)
English (also available online at: www.ilt.fraunhofer.de)
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