Fraunhofer

IWS Dresden

FRAUNHOFER INSTITUTE FOR MATERIAL AND BEAM TECHNOLOGY IWS

HIGHLIGHTS

CONTENT

RESEARCH FOR PRACTICAL APPLICATION

Research for practical application is the central task of the Fraunhofer-Gesellschaft. With its clear focus on applied research and its focus on future-oriented “key-development technologies“ the Fraunhofer-Gesellschaft plays a central role in the innovation process of Germany and of Europe as a whole. The research and development work of the individual Fraunhofer institutes contribute to the global competitiveness of the German and European economic zones. The institutes promote innovation, strengthen technological capabilities, improve the acceptance of modern technology and ensure the much needed training of the next generation of scientists and technicians.

The researchers of the Fraunhofer Institute for Material and Beam Technology IWS Dresden gladly take on this task. Through direct contact with the client, our employees develop products, processes and individualized solutions up until the level of practical application. It is our goal to solve problems in a customer friendly manner. A problem is not solved when the customer receives a research paper or a development report. It is not solved when we develop a new part or demonstrate a new process. We believe that a problem is only solved when the customer makes money with our solution. This is our mission.

The Fraunhofer IWS is characterized by two overlapping fields of development. These are laser technology and surfacing technology. The development of technologies and systems with tailored laser light and the manufacture of functional surfaces are exciting fields of research with excellent prospects for the future.

"WE BELIEVE THAT A PROBLEM IS ONLY SOLVED WHEN THE CUSTOMER MAKES MONEY WITH OUR SOLUTION. THIS IS OUR MISSION." (PROFESSOR E. BEYER, INSTITUTE DIRECTOR)

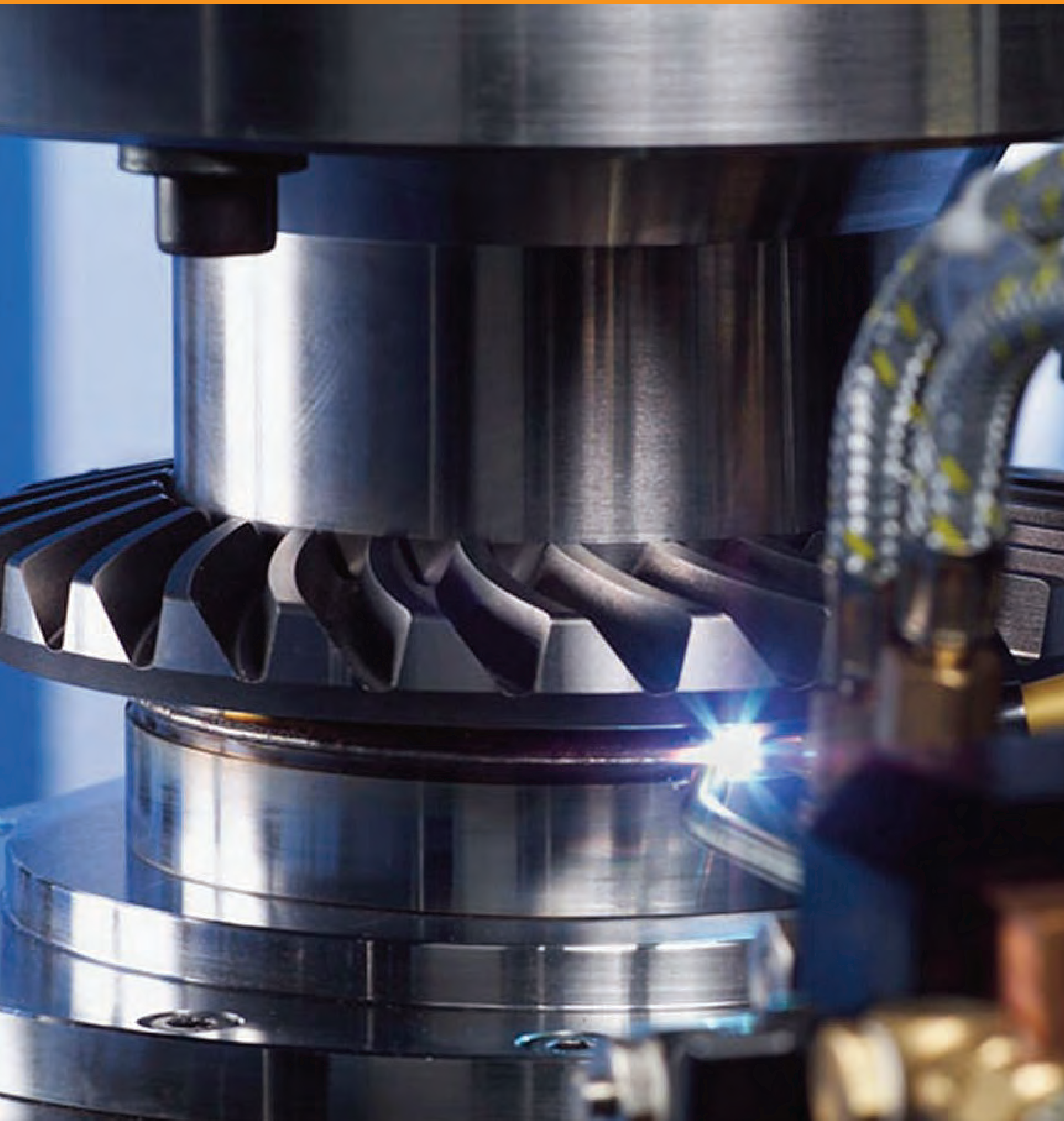
Through close collaboration with equipment and system manufacturers, we can offer our customers one stop solutions. These usually create new concepts which are based on the overall view of the machining system, the process and the material and component behavior. The material is a key element of the production technology. Nanotechnology is gaining in importance as the materials and manufacturing technology of the future.

In both areas, the Fraunhofer IWS Dresden has expanded its core competencies and expertise. The continuous expansion of the facilities of the IWS guarantees the effective, high standard, and state-of-the-art processing of tasks. In recent years, the Fraunhofer IWS has greatly expanded its core activities; mainly in the field of energy efficiency and energy technology. Numerous projects on the subject of energy were addressed and successfully completed, for example in the area of battery research, friction reduction and improving electrical sheet.

Since its establishment, the Fraunhofer IWS has implemented a variety of developments throughout various fields into industrial series production. We would like to introduce the most important innovations in this brochure.

Prof. Dr. Eckhard Beyer
Institute director Fraunhofer IWS Dresden

MODERN PRODUCTION TECHNOLOGIES
FROM THE FRAUNHOFER IWS




1

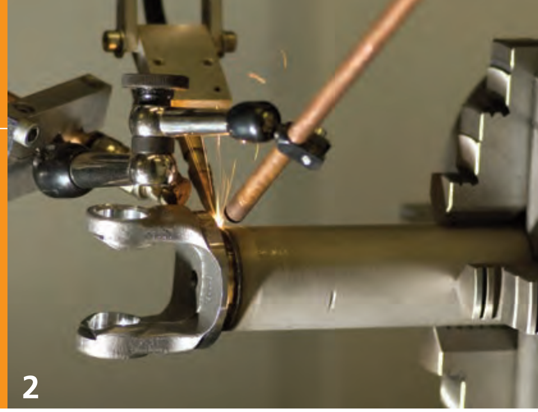
LASER WELDING - PROCESS DEVELOPMENT FOR INDUSTRIAL PRODUCTION

Modern laser welding, developed and promoted by the Fraunhofer IWS Dresden and its industrial partners, has established itself in recent years as one of the most economical and energy-efficient joining processes in the automotive industry. For the global manufacture of cars, this technology has become indispensable. New beam sources continue to blaze the trail even further. The intensive cooperation of the Fraunhofer IWS with system manufacturers such as ARNOLD, EFD, EMAG, IPG, Rofin Sinar and TRUMPF guarantees results which are practical, feasible, cost-effective and sustainable.

A look back: until the early 1990s laser welding was hardly used in the automotive industry. The reason for this was the unsatisfactory performance of welding laser processes in industrial applications, as well as the fact that some material pairings were inherently bad for welding. In practice, this meant additional parts such as rivets, screws, clips, springs, wedges, pins or other fasteners had to be used for the relatively simple task of joining two components into one. This led not only to further machining and material costs, but designers were also forced to make compromises in function and design.

0 Process of laser welding with filler material

1 Typical application of laser welding in the powertrain



The introduction of lasers with higher beam quality and power density has created new options for the laser welding of very hard or non-melting steels. The engine of this process was the Fraunhofer IWS Dresden. Today, as a result Q&T steel can be welded without cracks. Even the damage-free joining of cast-iron is now possible. This is all thanks to three fundamental technologies of the IWS: (1) laser welding with high frequency beam oscillation, (2) laser induction welding with localized inductive heat input integrated into the welding process, and (3) laser welding with material adapted welding filler.

Laser welding in gear manufacturing - a success story

Gear manufacturing: until a few years ago most gears in passenger cars were mechanically installed with screws and rivets. This process was connected with a high expenditure of materials and energy. The reasons why automotive manufacturers and suppliers all over the world are eager to replace conventional screwed variants with modern ones, such as laser welding, are obvious.

The IWS laser welding technologies promise:
- significantly shorter production times and thus cost savings,
- a greater degree of structural freedom for components, the possibility of light-weight constructions with minimal space requirements,
- possible weight and material savings of one to two kilograms per differential gear
- savings in fuel consumption and greater energy efficiency.

3

4

Sustainability during implementation in modern manufacturing

Today, industrial customers with different requirements for welding seam quality, component design or unit quantity rely on a powerful network of competent system suppliers. The scientists of the Fraunhofer IWS developed different powertrain technologies that can be used alone or in combination to meet the customer's wishes and requirements. These technologies include: laser induction welding, laser cleaning, inductive short time annealing of laser-welded components and plasma spectroscopic process monitoring.

By 2012, 26 industrial applications managed by the Fraunhofer IWS in 22 plants testify to its successful cooperation with automakers such as BMW, Daimler, Ford, Volkswagen and gear manufacturers and suppliers such as AAM, GETRAG, GKN, Visteon, Winkelmann and ZF throughout Europe, the United States and Asia.

1 *Shortening of process chains through laser welding with filler material and replacement of expensive and weight-intensive screw connections on differential gears; left: laser welded differential gear, right: conventional screw joining*

2 *Laser welding of gear component*

3 *Torsen differential gears, manufactured by laser welding with filler material; component: cast iron / cast iron*

4 *System for laser welding of differential gears*

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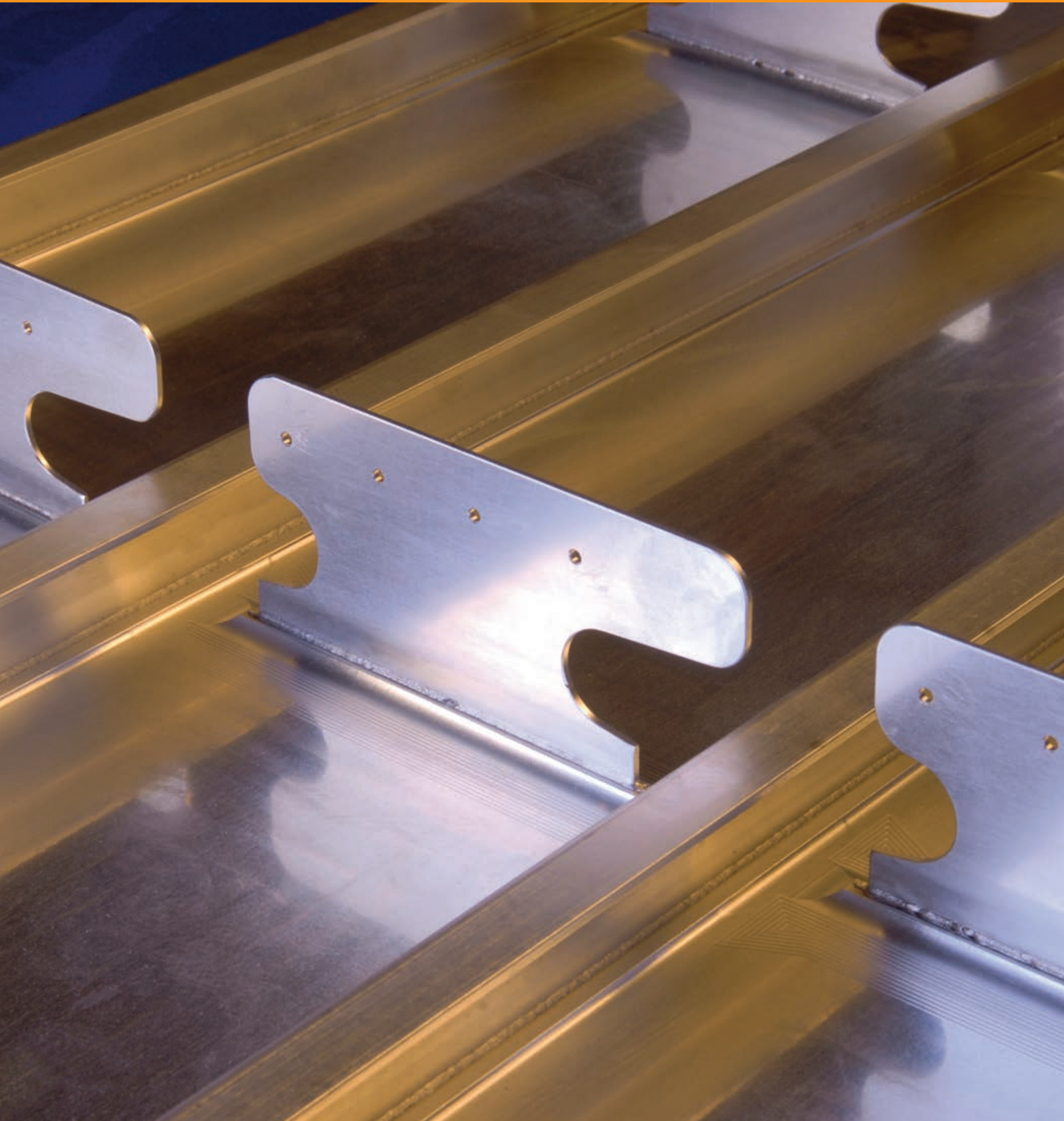


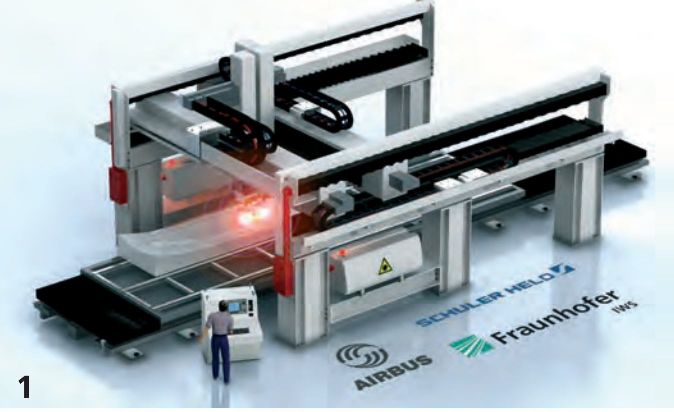
LASER WELDING OF INTEGRAL FUSELAGE STRUCTURES OF WIDEBODY AIRCRAFTS

The introduction of laser welding to aircraft construction had two causes: compared with the use of rivets, production costs are significantly reduced; also a marked reduction in the weight of the structure can be achieved. For several years, laser welded skin stringer joints have been successfully employed in the fuselage of Airbus models A318, A340-600 and A380. For large aircraft such as the Airbus A380 (according to the specifications of the AEROTEC GmbH) a weld seam of about 1,400 meters is required. As a result around 100 kilograms of material is saved in an A340-600 through the use of laser welding in the lower fuselage section. The estimated weight reduction though the use of laser welding is estimated to be between nine and eleven percent (source: www.industrie-forum.net/de).)

Implementing these necessary technologies, in whose development the Fraunhofer IWS played a decisive role, on an industrial scale, involved the extensive research and development of entirely new system concepts. This novel process required the double-sided simultaneous laser welding of large, spherically curved, 3D components to join skin-stringer and clip-skin joints in any desired direction while simultaneously fixturing the panels.

0 Laser-welded Al aircraft fuselage structure with connectors, length (stringer) and scope stiffeners (clips)

1 Photo collage



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New system technology for CO_2 and solid-state lasers

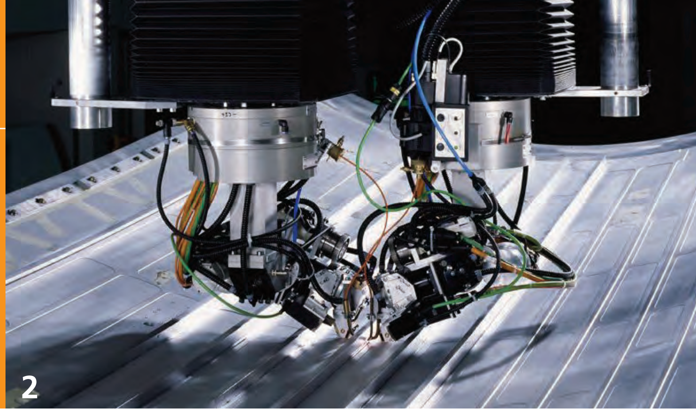
In 2001, the Fraunhofer IWS together with industrial partners designed a new principle for laser welding systems. Unlike previous concepts, this system should be developed with fixed beam sources, in order to achieve sufficiently high machine dynamics. In addition to greater flexibility, this solution offers several benefits: significantly improved acceleration values for relative motion between components, a reduced footprint and a lower variance of the beam path length when welding with CO_2 lasers.

Innovative technological solutions

Currently, the Fraunhofer IWS focuses its fundamental research on the properties of laser welded compounds employed by Airbus such as the alloys of 6xxx series, as well as future AlLi-and AlMgSc alloys. To this end IWS scientists evaluate the weld undermatchings and develop concepts with which to compensate for the difference in strength between weld and the base material. Together with Airbus, a novel Y-stringer was developed which, in the future, will allow the use of laser welding for the high-load shear-compression skin of the fuselage.

Improvement of damage tolerance

The design of complex structures must consider static loads as well as fatigue and damage tolerance criteria including the fatigue strength, the speed of crack propagation and the residual mechanical strength. The question is how to achieve skin-to-skin laser-welded connections that are as stable as the non-welded base material. There are two options: the stress in the weld area can be reduced or the welding seams in the outer direction of loading can be adjusted. To this end the Fraunhofer IWS developed and tested the first non-linear welding configurations. With this technology they achieved crack propagation and residual strength comparable to non-welded skin materials. The potential uses of this process for aircraft typical sheet metal thicknesses go without saying.



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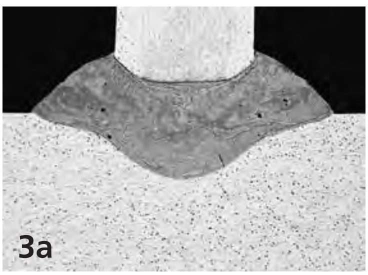
Materials and process development are closely connected

In the search for innovative welded fuselage structures, materials and process development go hand in hand – and always with regard to potential savings in production costs and weight. New weld-integrated structures are particularly interesting for the development and testing of materials, such as AlMgSc alloys. Currently, they surpass the materials used for laser-welded structures of the 6xxx series and have better processing characteristics.



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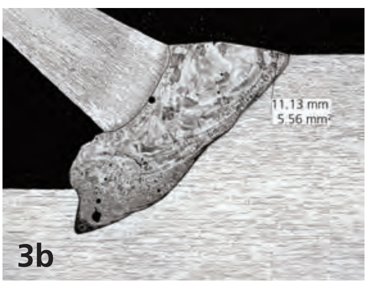

3b

"Civil aircraft manufacturers are subject to increasing pressure for continuous development of products to meet the growing demands of the airlines for performance improvements and cost reduction. The aircraft structure is substantial to the process of reduction of the weight, manufacturing and maintenance costs.

The introduction of laser welding in primary structures created a technological leap, which strengthened the metal position opposite composites. This brings new goals for the structural development of major aircraft components, such as the wings and fuselage." (Source: Airbus Deutschland GmbH, Bremen).

1 Double gantry unit for the double-sided simultaneous welding of large aircraft structures (2001)

2 3D-welding head for double-sided simultaneous laser welding of aircraft fuselage structures with integrated sliding jig, seam tracking and welding wire feed

3 Cross section of a stringer-skin joint simultaneously welded on both sides (a) and a new configuration of the stringers (b)

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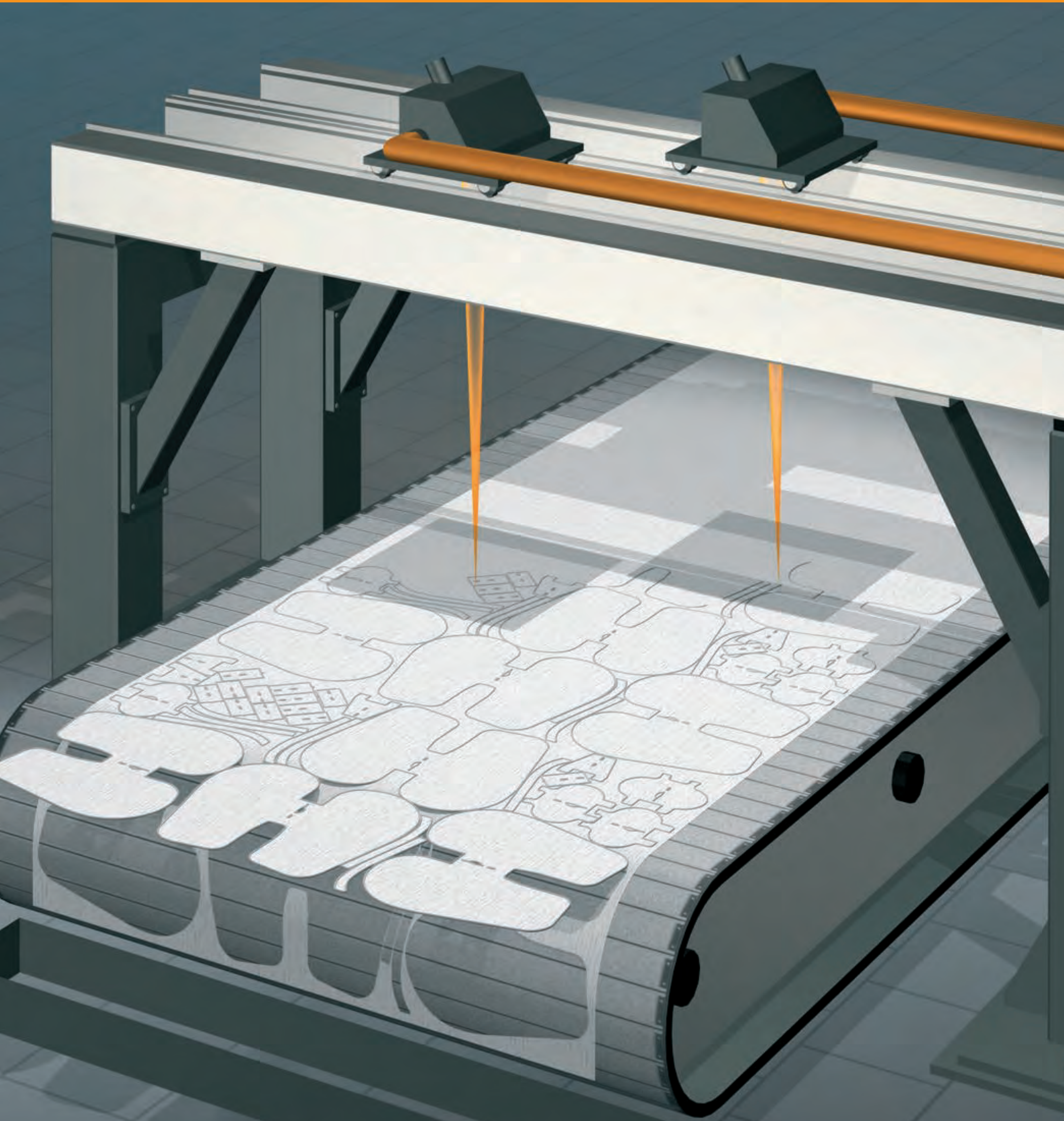

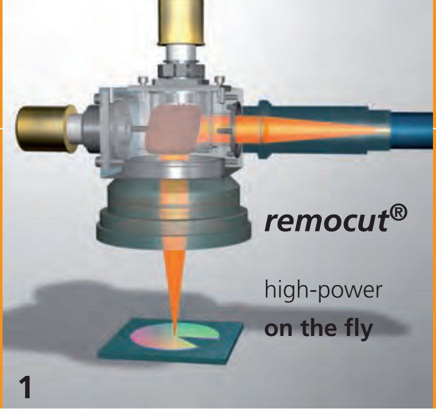

REMOTE LASER CUTTING OF AIRBAG WEBS

During remote-processing, tilting mirrors bend the laser ray with highest dynamics across the material. Thus, positioning times between individual processing steps are minimized and the processing speed of complex geometries keeps almost constant. The speed of the laser spot can reach several meters per second so that complex material processing, for example cutting airbag components, is completed in a few seconds.

The Fraunhofer IWS Dresden develops customer-specific processing optics and software solutions for process control and production preparation for the industrial application of remote technology for welding, cutting, cleaning and engraving. The combination of the remote technique of fast beam movement with a continuous material feed (several meters wide) leads to a very powerful and space-saving technical system.

System concepts with industry-proven remote processing optics

Until 2007, the form cutting of airbags from up to three meter wide polyamide fabric webs was done almost exclusively with gas-assisted laser cutting. Although productivity could be increased through the use of multilayer systems, on which up to 30 layers of material can be cut at the same time, the separation of the layers remained very expensive. Also, the cut quality of the individual layers proved inconsistent. Therefore, for high quality standards, the number of layers had to be drastically reduced.

0 System principle of remote laser cutting "on the fly" with two moving scanning heads

1 Principle of the high-speed beam deflection

Based on many years of experience in remote processes, the Fraunhofer IWS together with HELD Systems has developed a workable industry concept. The contiLAS system realizes a processing “on the fly“ in two dimensions. The remote technology allows the implementation of a laser cutting process on any cutting contours and material widths. One or several scanners can work on the fabric webs. Thus, material handling speeds of up to 25 meters per minute are achieved.

The advantages over gas assisted laser cutting are obvious:

- reduced part cycle time when cutting material from the coil
- improved quality of the cut parts
- processing of wide webs with the laser
- improved material usage/utilization
- elimination of separation materials
- no subsequent separation of the parts is required

The system is suitable for all applications where a space-constrained high speed beam deflection on large areas is to occur such as:

- flexible foil cutting
- welding of heat exchanger plates
- cutting of upholstery and filter materials
- processing of high performance fiber reinforced composites

With seven systems based on the technology of laser remote cutting “on the fly” successfully transferred to industry by the end of 2012, productivity has been shown to have increased 50 – 90% when compared to previous multi-layer cutting technology.

1 Laser assisted airbag production system Contilas 2500 2Sc of Held Systems Deutschland GmbH

2 Passenger automobile side airbag

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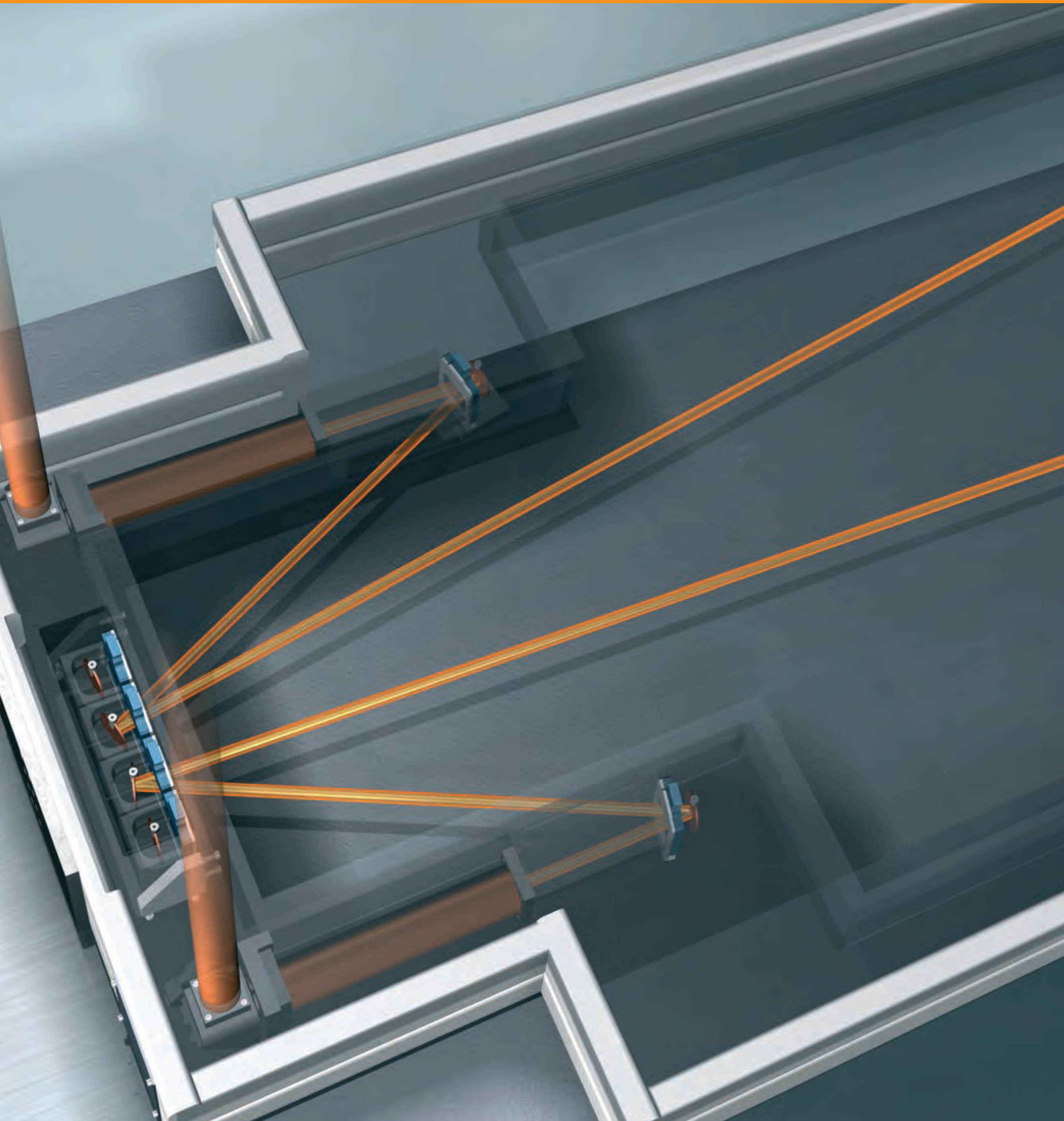

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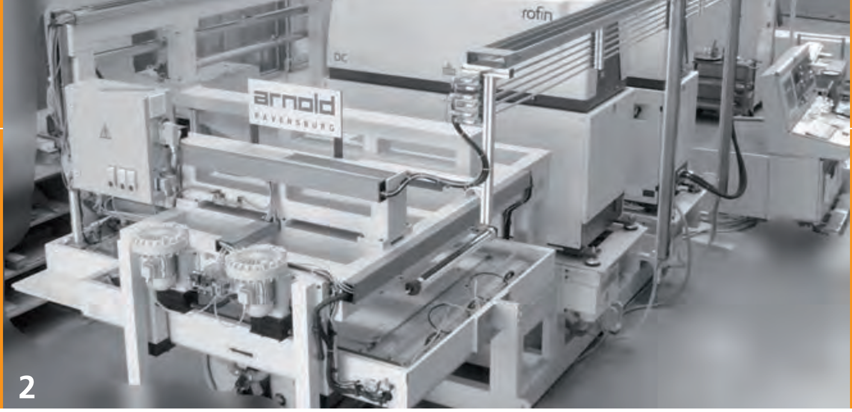
LASER TREATMENT OF ELECTRICAL STEEL SHEETS TO REDUCE MAGNETIZATION LOSSES

The need to save energy is a constant impetus for new developments. Consider the performance losses in devices such as electric motors, transformers and transmitters. This must be reduced in order to save energy, reduce heat and limit the frequency dependency of the magnetic properties.

Promising results have been shown in grain-oriented electrical sheets through the refinement of the magnetic structure by generating mechanical ot thermal stress. This is achieved by mechanical scratching, electrical discharge machining, plasma flame treatment, chemical etching and last but not least by laser scribing. This procedure is already used industrially. Laser scribing is a laser-induced increase in temperature on the sheet surface causing residual stress that refines the domains. In cooperation with appropriate process parameters, this reduces the power losses due to domain refinement.



The scanner-based systems technology lasertronic®SAO 10.6/6D

When grain-oriented electrical sheets can be produced at a speed of 80 meters per minute with a width of about one meter, there will be great industrial interest. In order to achieve the required laser spot speed of 200 meters per second conventional methods must be adapted.

The solution lies in the use of scanning technology, in which the laser can be moved very quickly by tilting lightweight deflection mirrors. On behalf of Rofin Sinar Laser GmbH, the Fraunhofer IWS in cooperation with the Maschinenfabrik Arnold in Ravensburg has developed and patented a process, which meets or exceeds all materials physics, process and systems technology demands.

The installed systems are able to reduce the core losses of grain-oriented electrical steel sheets by up to ten percent and even more. The combination of scanning technology and easily controllable lasers with excellent beam quality enables a new optical setup of the system with a minimum number of elements for the treatment of electrical sheet. At up to 3 kW these systems allow for previously unachieved dynamic properties.

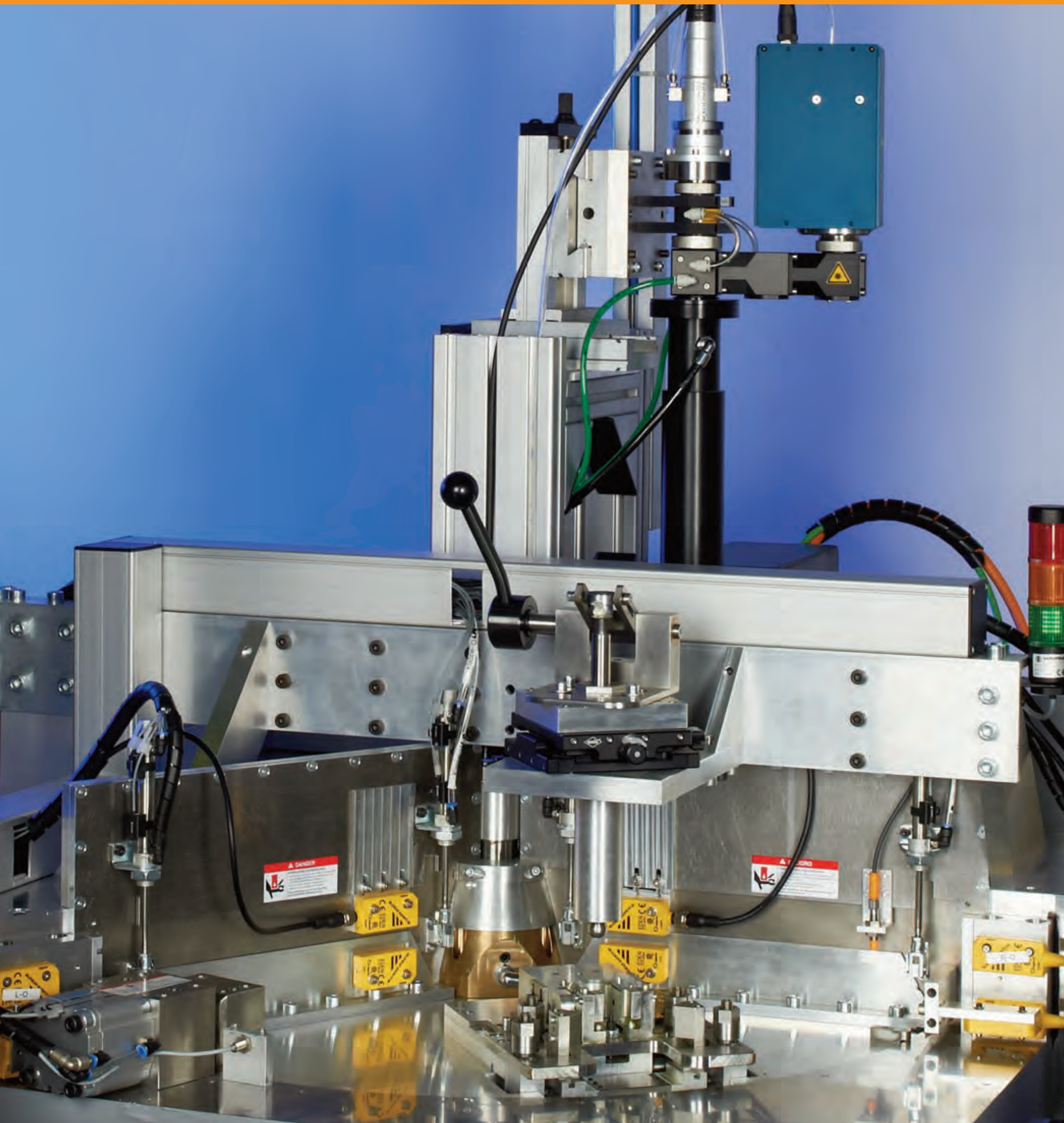
Since 2003, seven systems have been installed at customers all over the world.

0 Schematic of beam path in the scanner box

1 Test system for the laser domain refinement

2 Processing equipment during the construction phase at the Maschinenfabrik Arnold in Ravensburg

MODERN PRODUCTION TECHNOLOGIES FROM THE FRAUNHOFER IWS



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LASER INTEGRATION IN PRODUCTION ENGINEERING

Flexibility is high on the wish list for the industrial application of modern laser technology. Laser technology is often the method of choice to optimize existing machine design and automated processes; it also leads to completely new applications. It is suitable for shorter, small batch manufacturing processes, where maximum adaptability is the goal, as well as for mass production, where costs optimization is a primary concern.

Laser hardening - integration in manufacturing allows for lean processes

An example of customized solutions is the hardening of machine or vehicle components made of steel or cast iron, a standard procedure, which increases the wear resistance and the strength of parts. In the conventional process, the components are hardened in an oven or with vacuum plasma equipment. If the entirety of the component is not to be hardened however, local hardening can be achieved with flame, induction, and (since very recently) lasers. That in the past ten years the laser hardening of locally stressed components has established itself, is attributable to the significant contribution of the IWS Dresden.
The mold and tool manufacturing industry as well as the automotive industry have begun to increasingly rely on this technology.

0 Laser hardening system with rotating mirror optics

1 A selection of laser-hardened components

Technology developments for the effective surface hardening of rotationally symmetrical parts

The more complex a component is, the more difficult it becomes to use conventional hardening methods. Components with rotationally symmetrical or other complicated shapes require procedures and beam forming units, which can harden them in a consistent and tempering-free manner. In addition to technical advantages, automotive and other industries expect a noticeable reduction in costs. A number of industrial applications demonstrate how the developments of the Fraunhofer IWS meet the diverse needs of manufacturers:

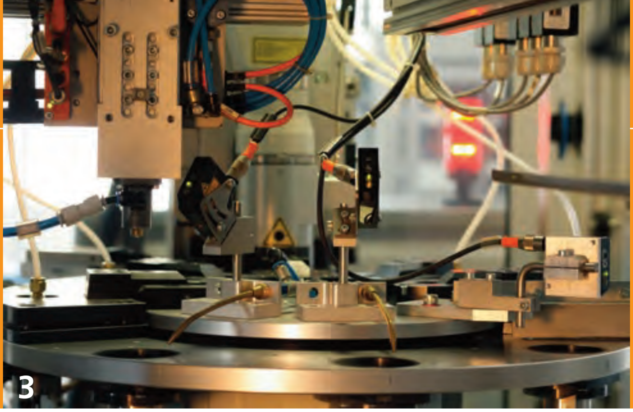
Example 1: Systems for the surface hardening of the turbocharger shaft for commercial vehicles

The temperature-controlled lasertronic®LompocPro ("LompocPro"), developed by the Fraunhofer IWS is employed at three plants of BorgWarner Turbo Systems GmbH in Kirchheimbolanden, Germany. There, the laser was integrated into a manufacturing cell where the turbocharger shafts are partially hardened at their bearing points. The systems are used in three phases with a cycle time of around 60 seconds.

Example 2: Hardening process integrated in lathes

In 2008, the Fraunhofer IWS, in cooperation with the lathe manufacturer Benzinger, delivered several lathes with integrated high-performance diode lasers to Bosch Rexroth AG in Lohr/Main for the production of hydraulic components. The cycle times of only three or four seconds speak for themselves, especially when compared to 75 seconds in the previously used mechanical process. In Lohr, a fiber-coupled high power diode laser operates three systems sequentially. Because the machine is a two-lathe system, work on the main lathe occurs almost constantly during the entire laser process.

The flow of material from raw rod material to completed valve was reduced from 20 hours to 20 minutes.



Example 3: Local Hardening of spherical caps for commercial vehicles

The IWS scientists developed a special flexible optics using a rotating mirror system with integrated temperature control for strongly curved, rotationally symmetrical convex or even concave component surfaces. An example of the industrial use of the IWS rotating mirror optics is the local hardening of the spherical cap components of chassis technology. The optimal laser process time is in the range of seconds, thus the process is suitable for mass production. "LompocPro" is used for process control. Temperature measurement is carried out with the "E-MAqS" camera system, developed by the IWS. The system generates significant savings in time, logistics, and costs.

Example 4: Process development for hardening systems for use in diesel-injectors

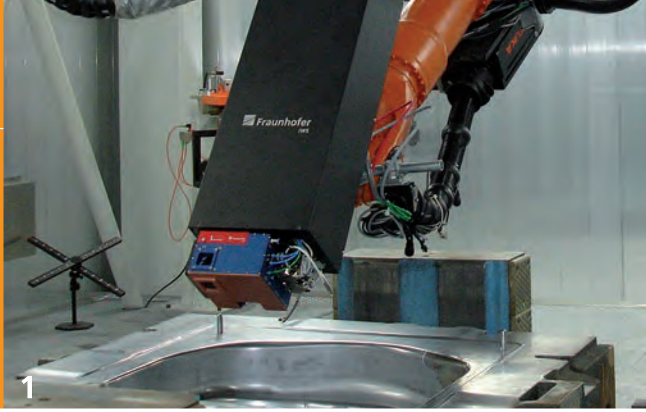
Collaboration between the SITEC Company and the Fraunhofer IWS found a solution for the hardening of diesel injectors. This involves the hardening of a highly precise rotationally symmetrical component (the wall of difficult-to- access hollow). The component must meet specific requirements after hardening because post processing is not possible. Due to this fact, lasers are used. Due to the precise spatial and temporal controls of the heat input, it is possible to process installation-ready parts. A 1kW diode laser from Rofin Sinar is used. Thanks to its compact size, this laser is fully integrated into the equipment. With the temperature-controlled power control LompocPro, quality control over the entire system is achieved. The use of a diode laser makes sense for both technical and economic reasons: Low initial costs, moderate operating costs, and a wavelength that is particularly suitable for surface finishing.

Through the use of this technology, five laser hardening systems have hardened 50 million components since the beginning of production in 2004.

1 *Laser hardened turbocharger shaft*

2 *Lathe with integrated laser optics at Benzinger factory*

3 *Hardening system for the hardening of diesel injectors, manufactured by SITEC, with 1 kW diode lasers by Rofin Sinar and "LompocPro" of the Fraunhofer IWS*



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Process and system development for hardening and cladding in tool manufacturing

The most popular application of high-power diode laser for surface hardening is in large tool manufacturing. The laser allows the partial hardening of finished tools without the delay of reworking. It is therefore ready to use immediately after hardening. Numerous contractors, as well as the tool construction departments of car manufacturers, use this procedure. In connection with the project "Integrierte Härterei", funded by the BMBF, a portal system was installed for demonstration purposes at BMW Fahrzeugtechnik GmbH in Eisenach. Later the production plant was optimized and has been in use ever since. Here, for the first time, a camera-based temperature monitoring system and a dynamic beam shaping for high-power diode lasers with a scanning mirror were used.

On behalf of ALOtec Dresden GmbH, the Fraunhofer IWS from 2004 to 2009 implemented robot-based systems for hardening and surfacing to Härterei Gerster AG in Egerkingen (Switzerland), C. F. Monsano (Italy), EMO in Celjie (Slovenia), STAV in Barberino (Italy) and an Indian Research Institute. The machines were equipped with system components for quality assurance of the temperature-controlled hardening, laser welding processes. The contractors, as well as the ALOtec Company itself use the facilities for the hardening of tools or manufacture tools as their core business.

Example: Tool making at Audi AG

In 2010 a robotic laser system for cutting and forming tools began production at Audi AG in Ingolstadt . This system was created in collaboration with the Fraunhofer IWS Dresden and KUKA Roboter GmbH. This system for the laser hardening and buildup welding is aimed at the repair and new manufacture of auto body tools. The Fraunhofer IWS supplied special system components for beam shaping, process control, and powder feed, as well as modules for the installation on the robot arm. In addition, the IWS delivered process parameters for different applications and coordinated the start-up of the process control systems. Following the success a plant with similar functionality was completed at the Volkswagen AG Wolfsburg site in 2012.

3

Surface protection, coating, repair - flexible repair of jet engine components

In September 2012, an automated laser system for precise laser cladding was placed into commission at MTU Aero Engines in Munich. This system is used for the repair of complex-shaped and high-stress flight engine components and is equipped with a brilliant disk laser to achieve the highest accuracy and quality coatings. Due to the extensive research of the IWS engineers in close cooperation with their counterparts at MTU, processes have been developed for the defect-free, two- and three-dimensional material coatings. For the reactive, high-performance material titanium, they specially created a process-adapted, closed protective gas chamber. The process know-how and specially developed weld-head, and the measurement and control components “E-MAqS“ and “LompocPro“ were integrated into the system. The design, installation, and commissioning of the machine was facilitated and supervised by the IWS specialists all the way up to series production.

The adaptation is new in repair: the actual shape of each individual blade is captured, compared with the nominal contour and then tailor welded. The appropriate, geometry generated set point is then passed directly to the process control system.

According to MTU, this system reduced process times for a typical turbine blade repair by 30 percent.

1 Robotic system for cutting and forming auto body tools at Audi AG

2 Process of laser cladding on a cast iron tool mold

3 System for laser cladding in engine repair at MTU Aero Engines, Munich

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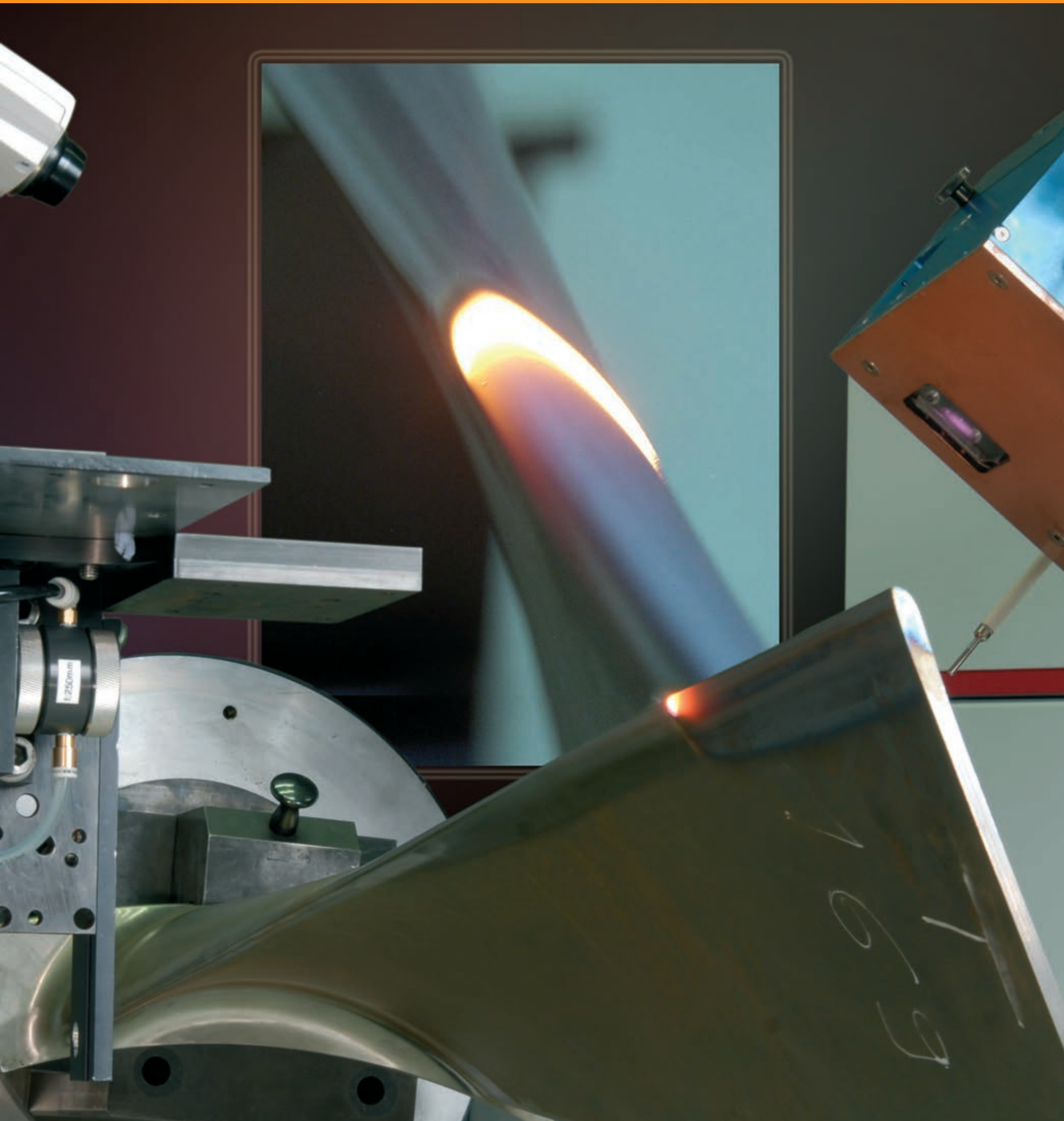


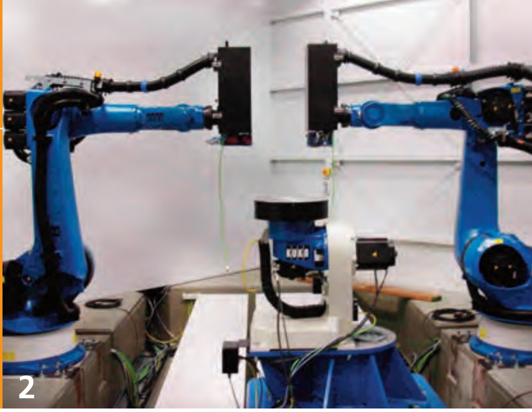
LASER - THE PERFECT TOOL FOR INCREASING THE SERVICE LIFE OF TURBINE BLADES

For more than a quarter of a century, the IWS has been working with laser assisted surface finishing processes to reduce the damage to turbines caused by condensed water droplets at low pressure. The water droplets destroy the leading edge of the turbine blades, which are designed for decades-long use. The result is considerable economic damage. With laser hardening with flexible beam shaping, scientists have found a solution for Martensitic hardened steel turbine blades which also deals with the constantly changing blade geometry. The result is a significantly increased wear resistance and, thanks to a hardness zone expansion, which will reduce stress, a significantly longer service life.

The question of how to increase the energy efficiency of steam turbines remains a topical issue for the IWS. The mechanical properties of Martensitic steels, however, are not sufficient to achieve the desired goal of free-standing, very long final stage blades with reduced gap loss without steam elements or the use of cover blades. Precipitation hardenable CR-NI steels were a suitable material for this purpose, however its use required the development of a new localized heat treatment technology for the leading edge.

0 Simultaneous, double sided laser solution heat treatment of a steam turbine blade's leading edge (collage)

1



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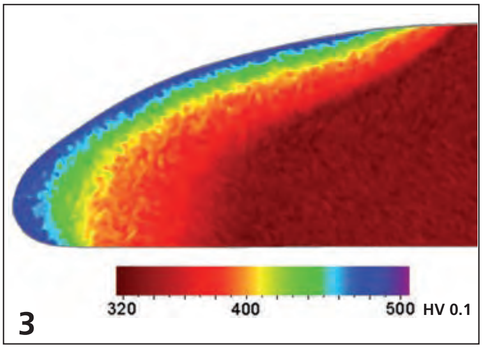
"Hard surface - resistant core"

To solve this general problem, researchers of the Fraunhofer IWS have developed a new laser-assisted procedure for localized surface layer hardening. This process won them the 2006 Joseph-von-Fraunhofer Award. Through laser heat treatment of the surface layer with two semi-simultaneous working lasers and a subsequent hardening, they succeeded in producing a consistent wear and fatigue-resistant surface layer. The result is a hardness zone, geometrically optimally adapted to the localized wear and stress of turbine blades. A cavitation wear test shows that the damage to the turbines is reduced by two thirds. At the beginning of 2013, the Fraunhofer IWS installed a complex robotic system for the laser treatment of turbine blades at Siemens AG in Mühlheim/Ruhr thus handing this technology over to production.



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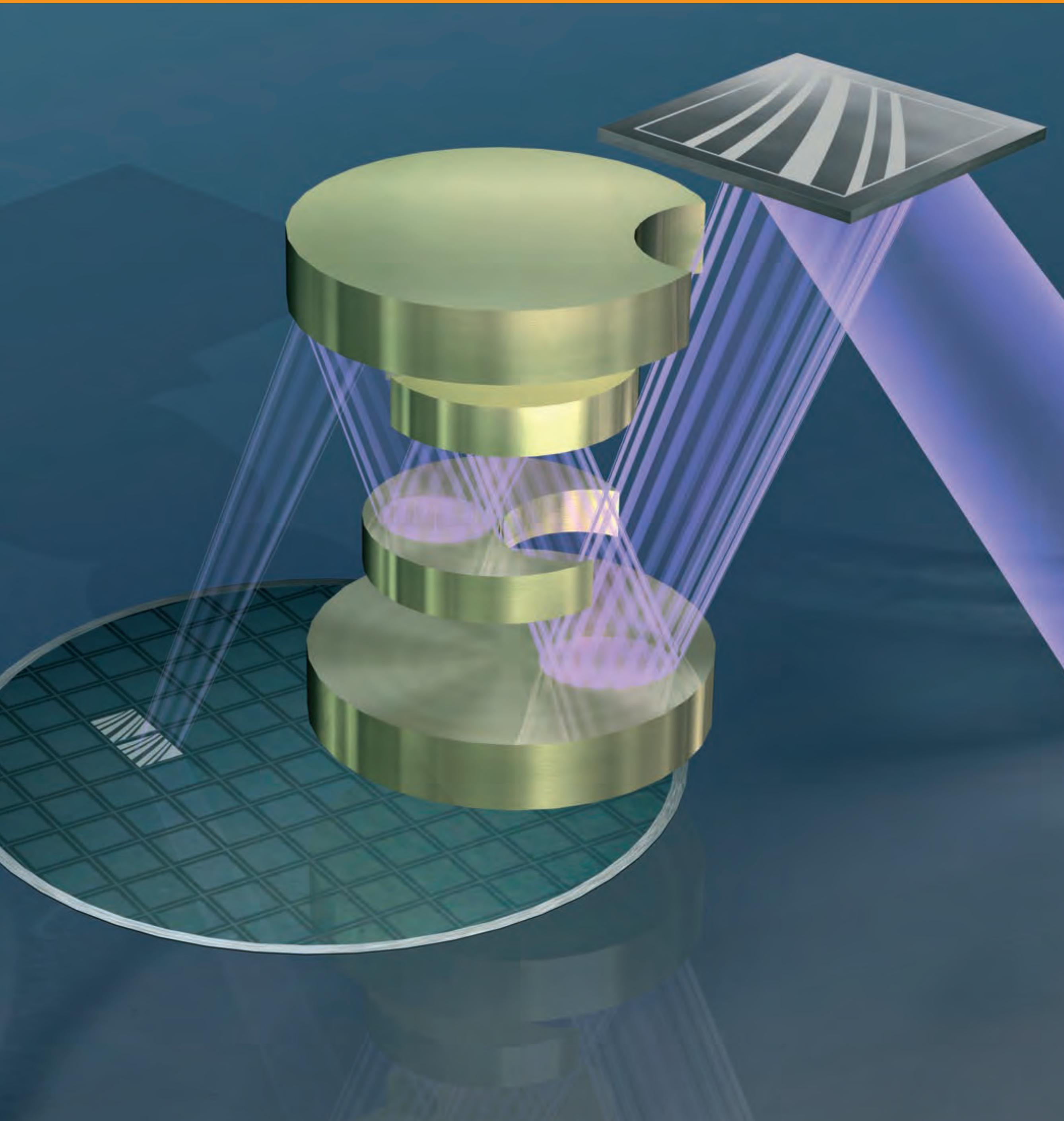
After gathering conclusive data, around 34,000 laser hardened turbine blades are now stored or in use in more than 180 power plants worldwide (fig. 1). The so-equipped turbine rotors have a longer lifespan, and provide a higher electrical efficiency.

1 *Turbine rotor on a low pressure level with laser hardened turbine blades.*

2 *Robot system for laser treatment of turbine blades at Siemens AG in Mühlheim/Ruhr*

3 *Color coded two-dimensional micro hardness distribution HV 0.1 of a laser hardened turbine blade*

MODERN PRODUCTION TECHNOLOGIES
FROM THE FRAUNHOFER IWS



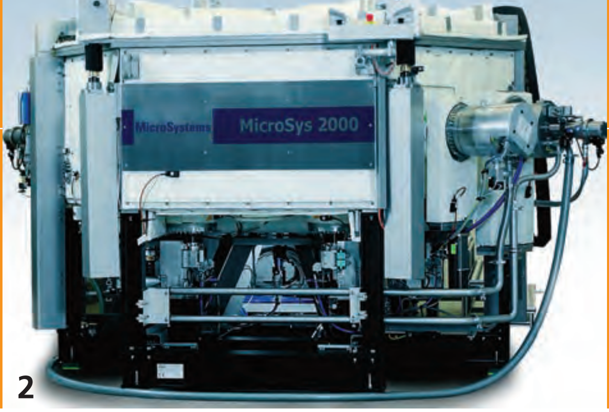
1

REFLECTIVE COATINGS FOR EUV LITHOGRAPHY

Notebooks, smartphones and tablets are judged by how thin, powerful, and sturdy they are. The successful application of “Moore's Law“ since the 1960’s made the current boom possible. “Moore’s Law“ states that the density of semiconductor structures on a chip must double every 18 to 24 months. The result is that semiconductors become more functional, take up less space and consume less energy. So that this roadmap can also be followed in the future; new technologies that allow for the “printing“ of smaller structures must be developed and applied to industrial production. The “printing“ of structures is achieved by means of lithographic processes, where the scaled down image of a template, the mask, is depicted upon silicon wafers and then developed.

Due to the reduction of wavelength in EUV Lithography (EUV = extreme ultraviolet) to 13.5 nm no lens materials existed that were sufficiently transparent. This represents the crucial difference between the previously used lithographic techniques and EUV. Even air has too much absorption. Therefore the exposure process must take place in a vacuum and with the use of mirrors.

In order for the mirror to achieve the best possible reflection, high precision nanometer multilayers must be applied to highly polished glass elements. For this process high vacuum technologies must be employed. At the IWS, magnetron sputter deposition (MSD) technology has been used for such coatings successfully for several years. Excellent results were achieved on comparably small areas (substrate diameter 150 mm to 200 mm). These results were recently transferred to large-scale coating plants.



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Industrial coating system for large-area substrates

An IWS pilot unit provided evidence as to the value of this technology on substrates with diameters up to 150 mm. The use of the technology to coat actual EUV mirrors requires scalability to substantially larger substrate surfaces. Together with MicroSystems GmbH, IWS scientists developed the MS2000 system and requisite processes for high precision coatings of mirrored substrates with diameters of up to 670 mm. The system is equipped with six coating sources, allowing for an effective deposition of the layers. The scalability of MSD allows for picometer precision.

At a diameter of 450 mm, homogeneity of the thickness of the coating layers has been shown to be above 99.9 percent. This means that the thickness variances in a single layer of a multi-layer with an expected thickness of 7 nm amount to less than 7 pm. This process impressively demonstrates the reproducibility of high quality coatings, one of the most important criteria for production.

Several systems have already been built, where these optical elements are used in the measuring analytics as well as in the microelectronic lithography systems.

0 Schematic representation of the exposure of semiconductor structures in the EUV Lithography

1 Coated mirror pair (Schwarzschild lens)

2 MS2000 MSD coating system, which is marketed by MicroSystems GmbH and based on an IWS developed coating process

MODERN PRODUCTION TECHNOLOGIES
FROM THE FRAUNHOFER IWS

LASER-ARC MODULE AND DIAMOR® WEAR-PROTECTIVE COATINGS

Recent trends towards energy efficiency and $C0_2$ emission have given a boost to Diamond-like carbon (DLC) films. Fuel savings of up to ten percent are possible with the appropriate coating of engine and transmission components.

When used as a protective coating for tools, components and parts, DLCs offer a unique combination of high hardness, low friction and low tendency to stick. DLC coatings protect against wear and are ideally suited as friction-reducing coating in poorly lubricated or even dry conditions.

Among the diversity of DLC films, a new generation of a ta-C film (tetrahedral amorphous carbon) is becoming more important. The ta-C layers are made of 100% carbon and are two to three times harder than the classic hydrogenous DLC films. It opens possibilities for lifetime resistant-coating for surfaces under extreme load conditions. IWS scientists developed Diamor® coating (diamond + amorphous), a ta-C-based coating system designed in a wide range of coating thicknesses and applicable on almost any tools and components.

0 With Diamor® coated gear components

1 Laser-Arc module of the Fraunhofer IWS for the deposition of ta-C films

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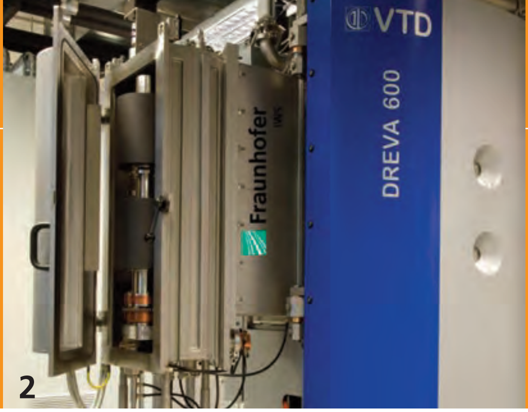

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Laser-Arc module for the industrial fabrication of ta-C films

The efficient production of ta-C layers with a high proportion of diamond binding is only possible with graphite vacuum arc evaporation (ARC). The Fraunhofer IWS succeeded in introducing a laser-guided vacuum arc, which achieved a stable and high speed deposition of ta-C films.

For wider industrial applications, the IWS has implemented a modular concept for the Laser-Arco^{Tm} technology. The Laser-Arc module (LAM), due to a standardized rectangular flange, can be installed or retrofitted on any commercially available vacuum coating system. After testing this system in the equipment of the Fraunhofer IWS and several industrial plants, such as the DREVA 600 coating system of VTD Vakuumtechnik Dresden GmbH, it was possible to deliver several complete LAM systems to customers in the automotive and other industries.

The latest generation of LAM for a deposition height of 500 mm contains a plasma filter for the separation of macro particles from deposition plasma, allowing the deposition of very smooth ta-C layers. This system has been successfully installed in several DREVA 600 coating systems at VTD Vakuumtechnik Dresden GmbH. The package, LAM 500 + DREVA 600 with plasma filter, is offered as complete system and is currently being transferred to industrial applications.

3

4

Diamor® layers to improve performance of components and tools

The industry-tested uses of Diamor® coatings range from ultra-thin precision films to several micrometers thick protective coatings for high-load sliding components and tools. An example of this is the application of Diamor® coated gears in the transmissions of the company HarmonicDrive for special machine tools in lubricant-critical environments. With Diamor® it was possible to refrain from lubricating the gearbox at all. The system was successfully tested in continuous industrial operation.

Example: ta-C coated knife by Nesmuk company

A vivid example is the introduction of Nesmuk's ta-C coated knife. Due to the ta-C coating, the commercially Nesmuk Diamor® knife has a lifetime sharpness guarantee. Diamor has also proven itself useful as a coating for tools used in cutting wood, fiber-reinforced plastics, and even in the cutting and shaping of aluminum.

1 Laser-Arc module LAM 500 on a PVD coating system of VTD Vakuumtechnik Dresden GmbH

2 Latest generation LAM 500 with plasma filter

3 Gears HarmonicDrive with Diamor coating

4 Successful transfer in small lots at KVT Kurlbaum GmbH: thermally sprayed hard metal coating of the ball of a ball valve, additionally coated with a friction-reducing Diamor® protective coating

MODERN PRODUCTION TECHNOLOGIES
FROM THE FRAUNHOFER IWS

CULTURAL HERITAGE MADE CLEAN AND VISIBLE AGAIN

Let us take brief trip away from industry and down the path of the fine arts. Fine arts can be excellently cleaned and restored through the laser ablation of differently thick layers of material in the millimeter range. This makes lasers the perfect partner of art restoration. Work is done with very short, high energy impulses. Depending on the settings, different objectives can be achieved: a shaping process, anti-slip features of polished stone surfaces or the laser cleaning of different surfaces. A particular advantage of this method is that the laser is self-regulating and interrupts itself when the base material is reached, in the case in which it is transparent or reflects back to the surface layer.

The non-contact operation, the self-limiting and the sensitively adjustable intensity of the laser beam in combination with the generally low penetration are the main features and benefits of laser cleaning. The Fraunhofer IWS has more than 15 years of experience in the restoration and maintenance of cultural heritage both in industrial environments and in the field.

0 Preliminary tests in the restoration of a mural; bright surfaces are cleaned

1 Saxon coat of arms generated by laser ablation

2 Restored bronze bust: the cleaning of the closed patina surface in the entire chest and shoulders area has been achieved with the laser.

1

Laser beam cleaning in historic preservation

The first successes in the treatment of limestone and sandstone statues were seen in the 1990s. The mostly black contaminations, caused by different pollutants were quickly evaporated with short laser pulses. The dark surface absorbs the light while the layers beneath scatter or reflect it. The non-contact operation of the laser makes laser cleaning especially attractive in heavily damaged, complex surfaces. Even the difficult task of cleaning metal sculptures were mastered by the researchers of the Fraunhofer IWS as the 1997 cleaning of the bronze busts of Johannes Buegenhagen in Wittenberg and Victor Aimes Hubers show. Wood materials provide the best results. This could be seen in the restoration of the wooden parlor of the Tetzelhaus in Pirna from 1994 to 1998.

Example: Cleaning an Egyptian burial chamber

In 2006 the laser was used by the restorers of Neferhotep e.V. to clean an Egyptian Tomb. This provided a new challenge: the cleaning of murals, which consisted of different types of paints. By adjusting the removal parameters such as pulse energy, repetition rate, and beam speed, the mobile system of the company Clean Lasersysteme succeeded in removing the dirt while preserving the paints.

Example: Mural "Einzug von Jerusalem", Church of St. Martin in Meerane

A further example of the use of laser technology in the preservation and restoration of monuments was the restoration of the triumphal arch mural "Der Einzug Jesu in Jerusalem" (Jesus enters Jerusalem) in the Church of St. Martin in Meeran. This artwork was created in 1906 by the Dresden born artist Karl Schultz. The preliminary tests for the removal of dirt on a part of the mural resulted in the recommendation to laser clean the entire mural. While the variety of colors with different and partially unknown pigments proved particularly challenging; uncovering the original color version of 1906 was achieved with the help of a mobile, scaffold supported pulsed solid state laser, whose energy density could be adjusted based on the area, color and surface.


2


3

Mobile laser beam cleaning

The availability of light-weight, high-performance and stable pulsed fiber laser systems enables the implementation of an air-cooled, compact and mobile system for cleaning and restoration. The Fraunhofer IWS has developed a system which is easily suitable for tasks ranging from restoration to cleaning of components. Integrating a scanner in the light-weight and compact hand-piece allows free beam deflection in workspace of 100 x 100 mm. A laser pointer ensures the range of the working field. The pulse sequence is dependent upon the job and adjustable from a single shot up to 550 kHz.

Body scanners for art work

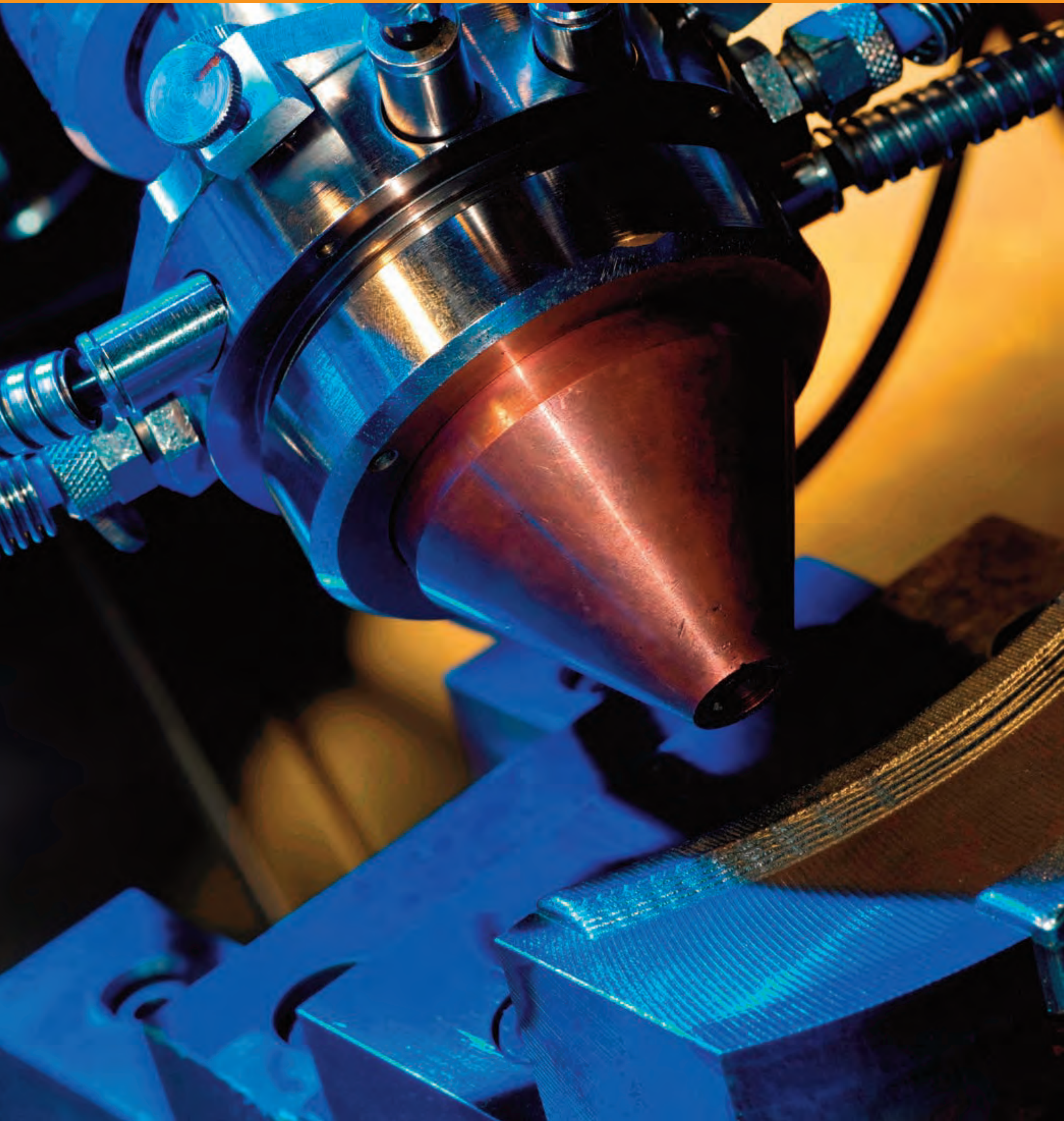
Painted murals, especially in churches, were long considered irretrievably lost. With terahertz radiation, researchers want to non-invasively “unveil“ the original artwork. A femtosecond laser generates short electromagnetic pulses, each with a duration of one to two picoseconds. Each layer and each pigment reflects these pulses differently, so that information on both contrast and depth can be obtained. The results indicate, for example, information about the thickness of the layers, which pigment is present and how the colors are arranged. A specially developed software converts this information into a picture of the “lost“ painting.

1 *Laser cleaning of the mural “Einzug von Jerusalem” in the Church of St. Martin in Meerane*

2 *Mobile laser cleaning equipment MCL-1064 (Fraunhofer IWS Dresden) in use*

3 *THz-TDS-scan of a hidden painting in the church Beesdau*

SYSTEM COMPONENTS FOR FLEXIBLE
AND STABLE MANUFACTURING PROCESSES



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COMPONENTS FOR LASER CLADDING AND GENERATIVE MANUFACTURING

Powerful and robust technology creates the preconditions that allow for the coating, repair and design of long-lasting and complex components and tools. A key function in industrial application is the laser welding head, which orients and shapes the laser and, in particular, guarantees precise powder and wire feeds. The IWS has developed many tools with the modular powder nozzle system COAXn and the new coaxial welding head with centralized, directionally independent wire feed. These tools, together with the necessary laser technology can be easily integrated into tooling and robotic systems.

An essential part of the process preparation is the programming of coating paths according to the optimal cladding strategy. The DCAM software, co-developed by the SKM Company and the IWS is used for the offline programming of the complicated geometries of components of engines, turbines, motors, molds and tools. The program enables the generation of single tracks, contours, surfaces and any volume elements on flat as well as curved surfaces. The Fraunhofer IWS developed a model for the simulation of machining processes that can perform 1D, 2D or even 3D calculations of individual weld beads and multi-lane weld strategies.

0 Modular powder nozzle system COAXn

1 COAX8: This annular gap powder nozzle shoots a cone-shaped powder jet, which is coaxially with the laser directed at the material.

2 Coaxial beam splitter processing optic for laser wire cladding

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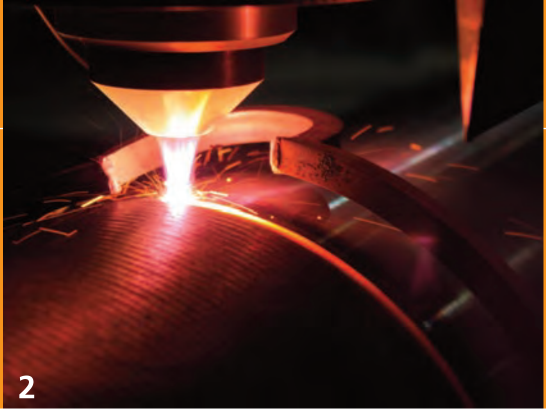

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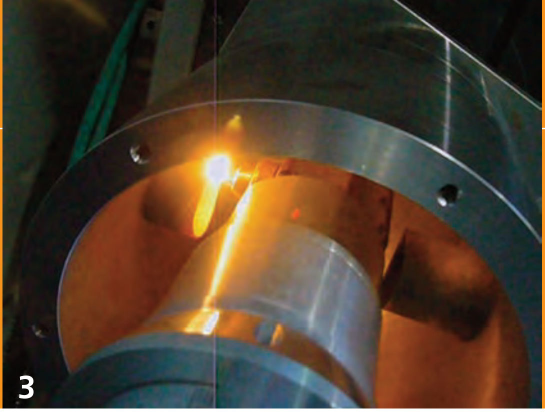
Modular COAXn

Dependent upon the laser type and machining task a suitable welding head of the COAXn system can be quickly and flexibly tailored to work piece geometry, accessibility, coating material, accuracy and build up rate. Depending on the application, the welding head can be configured for high precision or high productivity.

The coaxial welding head COAX12 is specially designed for 3D applications. Instead of an annular gap, four separate channels shape the powder stream to the working point. In this way, the powder flow is nearly independent of gravity, and can, even during the welding process, achieve nearly unlimited welding positions through nozzles that pivot and move at all possible axis.

COAXpowerline

The high-performance processing head COAXpowerline is designed for large area coatings such as large hydraulic cylinders. This laser processing head is optimized for the highest cladding rates, which can, with inductive support, process up to 18 kg / h of metal powder. This head is also modular and can be combined with different laser optics and induction modules. In addition to the high application rates this hybrid configuration allows for defect-free welding of harder, more crack- sensitive metal alloys and composite materials. The IWS temperature control system "E-MaqS" can be used to ensure the quality of the processing head.



Inner diameter welding head $COAX_{ID}$

The modular interior coating system, $COAX_{ID}$ enables the directionally independent coating of complex, deep-set inner contours. Even 3D structural layers in a horizontal welding position can be easily achieved on an interior wall with the processing optics. Stable and continuous operation of more than an hour has been recorded; even in rotationally symmetrical internal surfaces. In widths of up to 4 mm, completely water-cooled, uninterrupted processing times of hours are possible with flow rates from 0.6 to 1.2 kg per hour. Here, Nd:YAG or discs lasers are used.

Precision technology for additive manufacturing with central wire feed

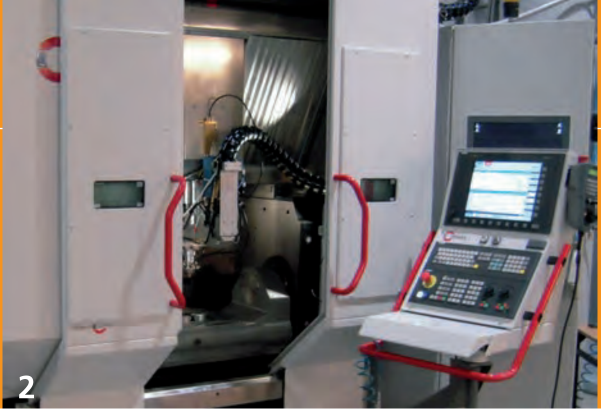
Various new applications of laser additive processes require the use of wires as an alternative to powders as a welding filler. The wire-based additive manufacturing processes are clean; the wire material is always used completely. In certain metal alloys a significant advantage to the metal structure is achieved. The previous solutions of the lateral wire feeder in the laser focal spot limits accessibility and geometry in real components. The newly developed laser machining optics with central wire feed intelligently combines the advantages of the wires with the directional independence of laser powder-weld systems. Thus, the application field of laser wire cladding expanded to complex contour coatings, as well as the generative manufacturing technology. Similarly, precise surface coatings with particularly good surface quality are produced.

1 *Welding head COAXpowerline, the new generation: compact design with internal supply for highly productive surface coatings.*

2 *Process of induction- supported high performance laser-build-up process with COAXpowerline*

3 *Coating process with inner diameter welding head* $COAX_{ID}$

4 *Process of additive manufacturing with coaxial wire welding head*



Application examples

Laser based coating technologies have a key role in modern production and repair processes of aerospace, power generation, and mold and tooling construction. Other users of this technology are oil and natural gas production, mining and metallurgy/metal forming, but also laser build up manufacturers as well as universities and research institutions.

Robot system for highly productive cladding of tools in the mining industry (fig. 1), equipped with:

- welding head COAXpowerline
- E-MAqS system
- IWS technology components for laser cladding

CNC machine system for the direct generation of metallic prototypes and components in cooperation with Maschinenfabrik ARNOLD GmbH & Co.KG (fig. 2), equipped with:

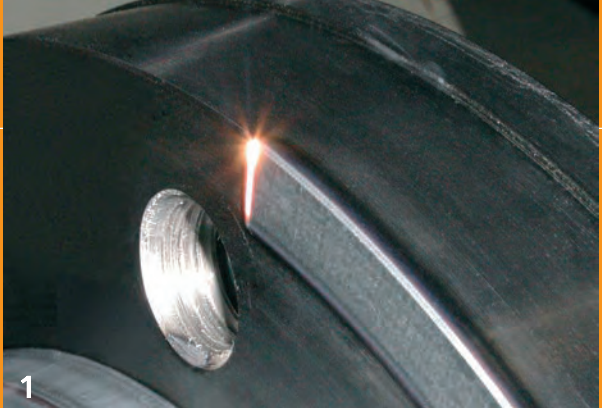
- welding head COAX9
- E-MAqS system
- IWS/SKM-DCAM software package
- IWS technology components for generative laser cladding (DMD: direct metal deposition)
- IWS technology components for generating titanium structures in an enclosed inert gas atmosphere

Since the beginning of the development of such systems about ten years ago, a total of 140 welding heads for customers in Australia, Europe, North America, China, India, Russia and of course in Germany have been installed.

1 *Robot system by REMKON Katowice, Poland with the IWS welding head COAXpowerline, working with a camera-based temperature control system*

2 *CNC machine system with integrated system components of the IWS, user CAMT, Breslau, Poland*

SYSTEM COMPONENTS FOR FLEXIBLE AND STABLE MANUFACTURING PROCESSES



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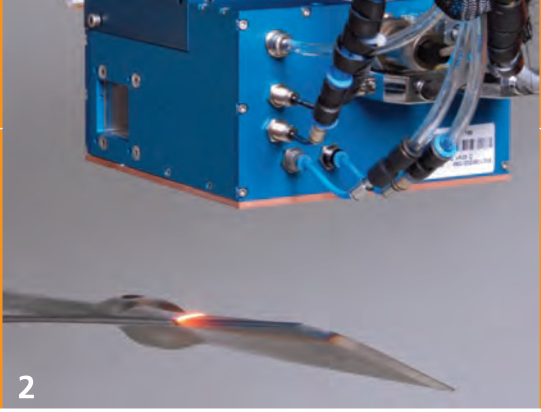
COMPLICATED LASER PROCESSES EASILY MONITORED AND CONTROLLED

It is well known that the Fraunhofer IWS is significantly involved in the development and distribution of laser hardening and buildup welding processes for industrial application; yet in addition that the IWS has developed the corresponding special systems. Thus, the most complex processes can be easily monitored, controlled or regulated and adapted to the requirements of each application. The components are constantly optimized and tailored to new customer requirements. With the IWS measuring and control systems, the users have the tools at hand to ensure the highest precision and modularity.

Dynamic beam shaping system “LASSY”

In order to harden different component geometries and still allow them to remain flexible, the Fraunhofer IWS Dresden has developed the dynamic beam shaping system “LASSY“ for industrial applications of high-performance diode lasers. This enables, for example, the creation of a uniform hardening depth despite locally different component thickness. The system is used with laser surface treatment processes such as laser hardening, melting and alloying.



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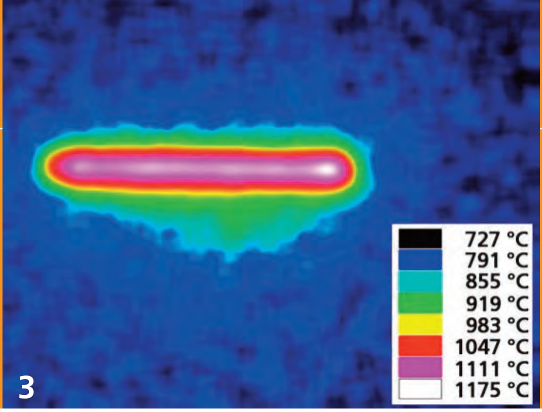

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Variable software control system lasertronic®"LompocPro"

The variable software control "LompocPro" (laser online monitoring power control program) forms the basis of the IWS measuring and control systems. Depending on the case, different temperature monitoring systems can be connected, allowing "LompocPro" to control temperature for a number of laser procedures, such as laser hardening, laser soldering, laser annealing and laser cladding. The Fraunhofer IWS control software is especially suitable for fast processes.

Easy operation and automation of complex heat treatment processes is ensured, inter alia by the following parameters:

- flexibility due to individual adjustment of control behavior
- graphical representation of all process data during the process,
- permanent backup of all parameters,
- »Profibus« communication to CNC
- user-defined interfaces to temperature measuring devices.

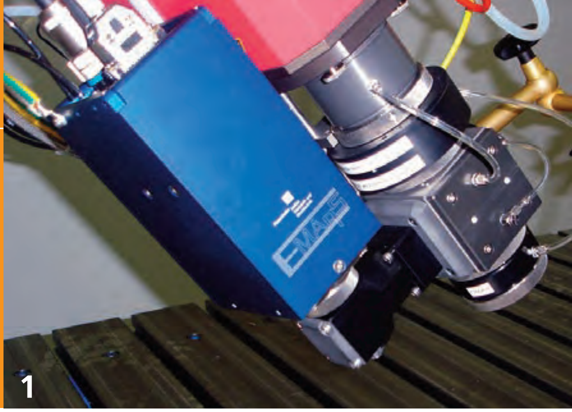
The first application was the system in ALOtec Dresden GmbH heat treatment plant in 1999. Since then "LompocPro" has been continuously developed and has been used in the process control, process monitoring, process data backup, and quality documentation of more than 80 chiefly industrial applications.

0 Operating status of a laser cladding system with integrated process control "LompocPro"

1 Laser hardening process on the head of a main drive spindle

2 Laser hardening of a steam turbine blade with dynamic beam forming unit "LASSY"

3 Heat vision picture of a hardening process



“LasMon“ - analysis of shaped laser beams

The measuring system for beam analysis for large laser spots “LasMon“ is the quality control of laser sources and laser optics. Traditional beam diagnostic devices are either not able to measure several square-millimeter-wide laser spots or incapable to do this with high power in the range of kW. With this device, it is possible to analyze scanned or otherwise shaped laser beams with a power up to 10 kW. Thus, a reliable process management and constant control of the laser is possible before or during the process. In addition to the analysis of laser sources and optics, “LasMon“ can be used as an alignment aid for scanner drives and other beam formations to optimize the power density distribution of laser beams, as well as to determine the baseline for the simulation of heat conduction or laser processes.

Temperature measuring system “E-MAqS“

“E-MAqS“ is a camera-based temperature measuring system used for demanding measurement applications. The IWS scientists developed it as a space, time, and money saving alternative to conventional thermal imaging systems. The “E-MAqS“ system is usually used in combination with the temperature control system LompocPro. Laser hardening is its chief application; however, “E-MAqS“ is also used for industrial laser welding. Since the signal and image analysis can be easily adapted to customer requirements, other applications for temperatures above 600 °C, such as heat conduction welding or soldering, are possible.

Fast temperature measurement with "E-FAqS"

The modular system of the Fraunhofer IWS offers the fast pyrometer for high speed processes "E-FAqs". This device is able to record temperatures from about 160°C with sampling times of less than 30 µs. "E-MAqS" has been primarily used in laser hardening and cladding. The much faster "E-FAqs" system is more often used in industrial plants for laser soldering processes. "E-FAqs" is also suited to laser annealing and plastics welding. The entire measuring and control system is compact and suitable for industrial use in the machine body.

Example: laser soldering of solar cells

In close cooperation with the company teamtechnik Maschinen und Anlagen GmbH in Freiberg am Neckar, the Fraunhofer IWS has shown that the "E-FAqs" is suitable for the laser soldering of solar cells. Since 2008 it has been used in industrial mass production. A special feature of the laser solder machines of teamtechnik is that both standard as well back-side contact solar cells can be soldered. Also short cycle times of three or four seconds per cell are possible. The systems are modularly designed so that different solder processes and modules for solar cell processing can be integrated.
This is important, as the dynamic developments in photovoltaics through new semiconductor materials or new layer structures require quick response capabilities from the equipment.

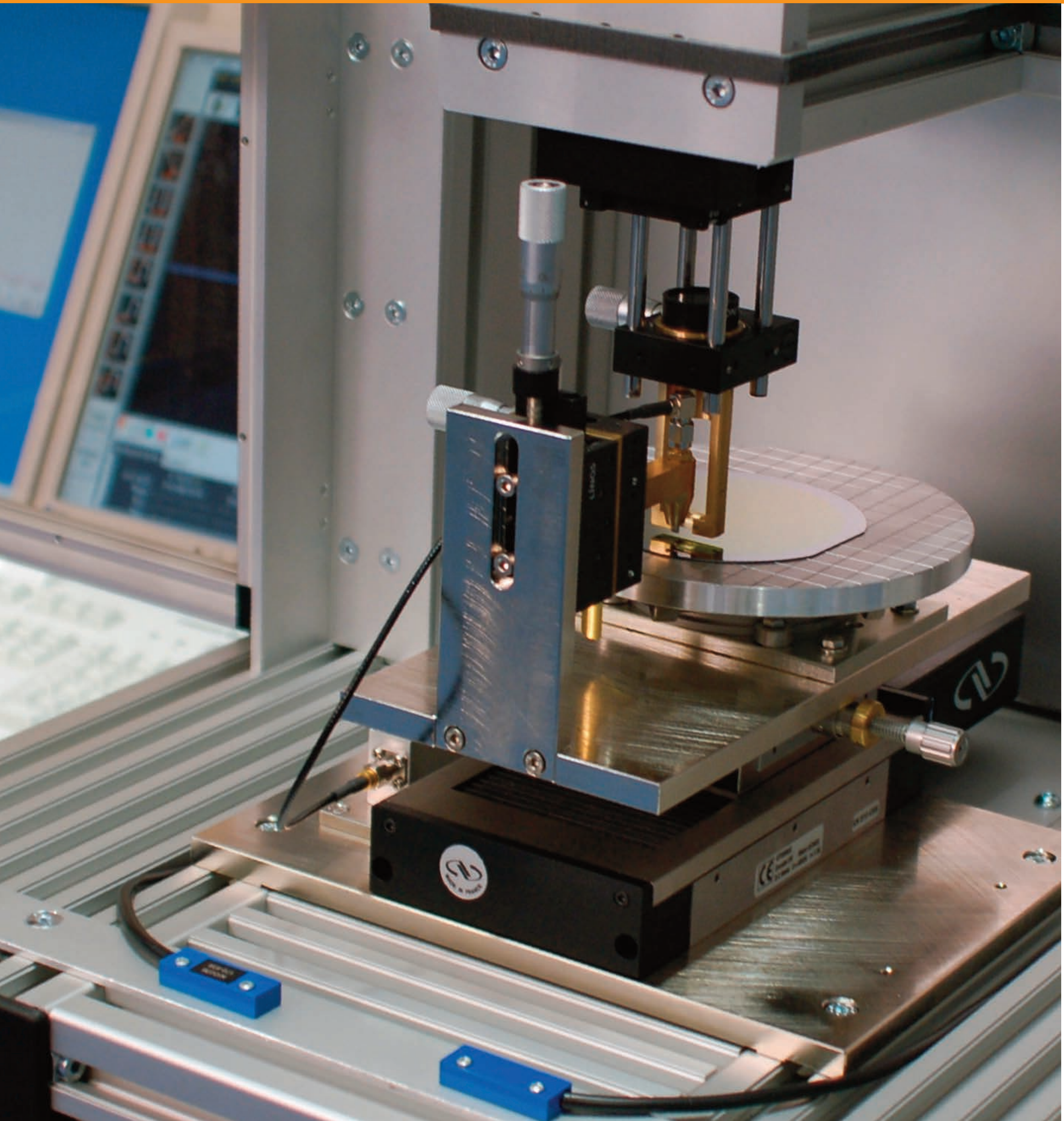
Through the process development of the Fraunhofer IWS a total of 30 "E-FAqs" systems were installed in 10 plants from 2007-2012. Worldwide more than 170 of the Fraunhofer IWS system components for process monitoring, process control, and quality control were successfully used in industrial plants.

1 Camera based temperature monitoring system "E-MAqS"

2 Fast measurement and control system "E-FAqS"

3 Laser soldering system of teamtechnik Maschinen und Anlagen GmbH in Freiberg a. N.

SYSTEM COMPONENTS FOR FLEXIBLE AND STABLE MANUFACTURING PROCESSES



LAwave

INNOVATIVE MEASURING SYSTEMS FOR QUALITY CONTROL IN INDUSTRY AND RESEARCH

When thin layers make waves – laser acoustic measuring system LAwave®

To mechanically and nondestructively determine the different properties of layers and surfaces, researchers of the Fraunhofer IWS developed the laser acoustic measuring system LAwave®. No matter whether the surfaces are hard as diamond or as yielding as polymers; made of conductive material layers only a few nanometers thick or several hundred micrometers thick, as rough as thermally sprayed coatings; they can all be measured. In laser acoustic measuring, laser pulses with durations of a few nanoseconds hit the component and cause only its surface to vibrate. The form and duration of the wave, which depend on the coating material, are detected and immediately evaluated with a signal evaluation process. Young`s modulus, density and thickness of the layer affect the signal sequence. A further application is the processing of surface layers, for example those on the surface of semiconductor wafers, when they are sawed and processed.

Twenty-six LAwave® devices have found their way to research and industrial customers in Europe, Russia, Japan, Canada and the USA. This technology won the Fraunhofer prize in 2000 and the "R&D 100 Award" in 2001.

0 LAwave® measuring station for the nondestructive analysis of surfaces and coatings

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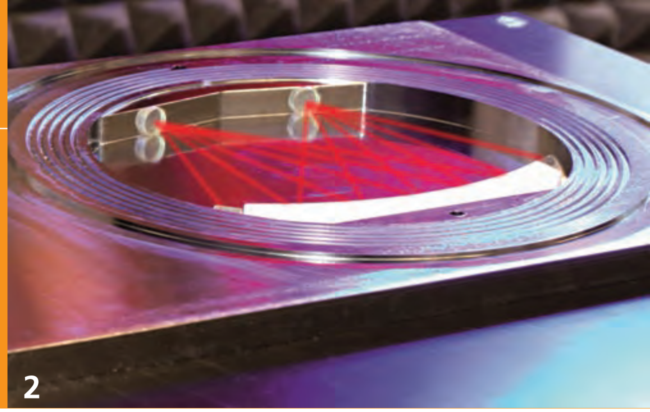


2

HiBarSens® – Determining the permeation rate of flexible ultra-barrier materials

Packaging materials for food, pharmaceuticals, and even encapsulation materials for electronic circuits and components have one thing in common: in addition to providing mechanical protection they should insulate from atmospheric gases, thus increasing quality, durability, and stability.

To suppress permeation (gas passing through a solid), flexible, in part coated materials with barrier properties are often used, that means with permeation rates (WVTR: Water Vapor Transmission Rate) of WVTR $< 10^{-2}$ g m^{-2} d^{-1}. New, technically advanced applications (such as flexible OLED displays) make extremely high demands on barrier layers. In close cooperation with Dresden SEMPA Systems GmbH, the Fraunhofer IWS has developed a sensor concept with extremely high detection sensitivity, which allows the reliable measurement of the permeation rate of ultra-barrier materials.

The key to this was the use of a laser beam, which helps to detect the smallest quantities of permeated water vapor, and thus calculate the corresponding WVTR. Within the framework of a European cooperation project, this principle was successfully applied to an industry- ready device and given the name HiBarSens®. Less than 10^{-5} g of water vapor per day and per square meter of a coating surface can consistently be detected.

In 2012, together with Sempa Systems GmbH, the series manufacturing of HiBarSens® for end users was started.

3

4

Quick tester for porous materials

New porous materials are being intensively researched all over the world. This research includes the determination of the properties of the inner surface of these materials. For this purpose, the time and cost-consuming BET measurements were previously used. However, the increase in combinatorial high throughput synthesis and the associated high volume of samples needed, called for a quick way to determine the properties of a large number of samples.

At the Fraunhofer IWS, a measurement process was developed that verifies the adsorption ability of a material on the basis of the amount of heat release during the gas adsorption. The sample is exposed to a gas stream which contains the gas to be adsorbed. When an adsorption takes place on the material, the adsorption releases heat. This is measured by a non-contact optical temperature sensor. The measuring time for the examination of a sample is only a few minutes. Thanks to this simple and modular measuring principle it is possible to measure several samples in parallel.

The measuring system infraSORP is licensed to the Rubotherm Company. This system is capable of measuring up to twelve samples in parallel. Additionally, a user-friendly software was developed. The operation of the system only requires a computer and a gas supply. This measuring process does not only saves time and costs for the synthesis of new materials, but it also can be used for process and quality control in existing manufacturing processes.

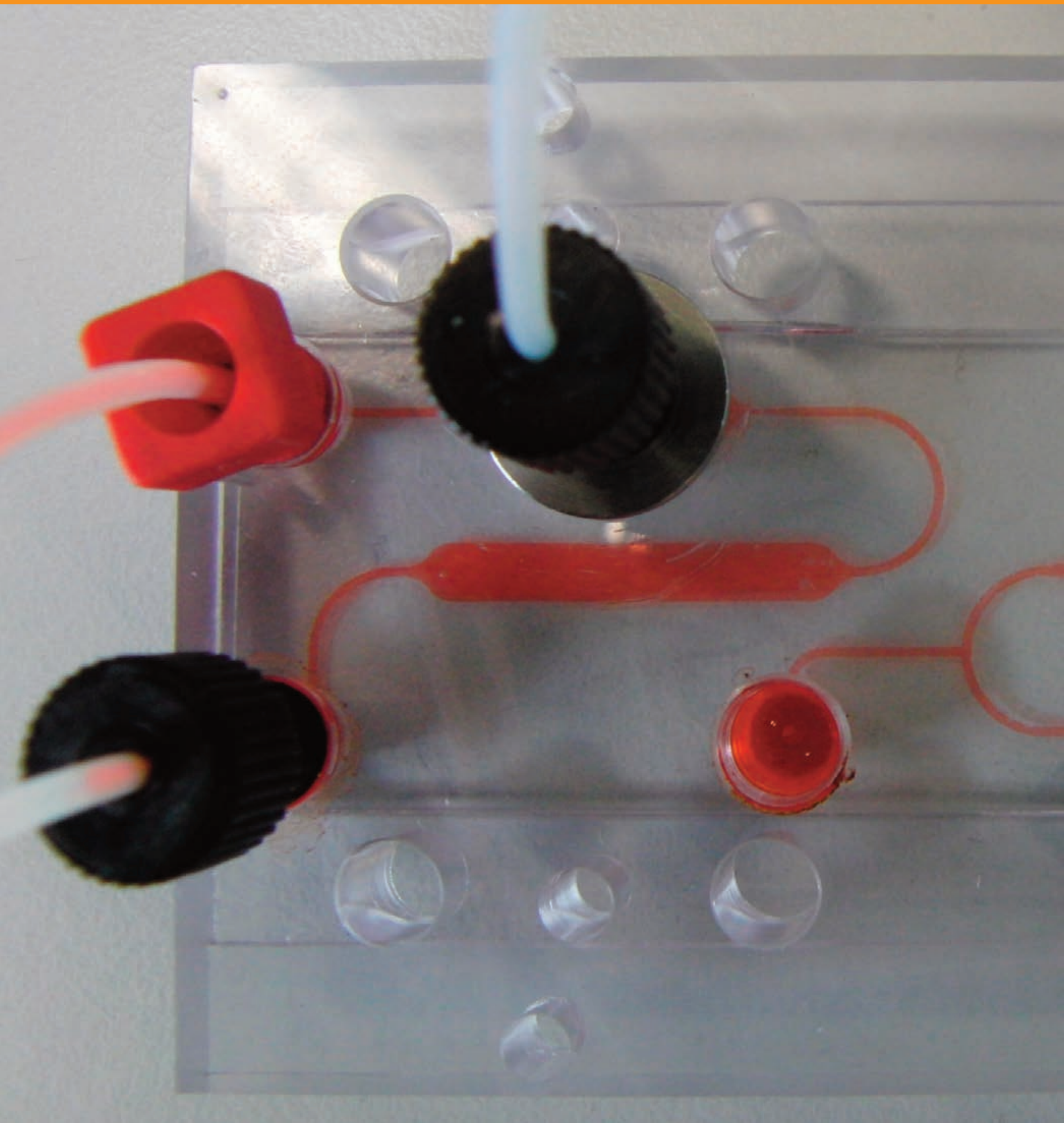
1 *HiBarSens®: measuring device for the highly sensitive determination of the water vapor transmission rate (WVTR) of ultra-barrier films*

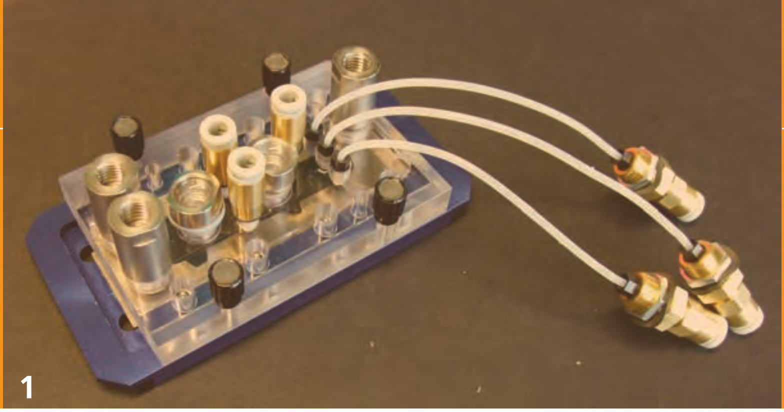
2 *Beam path in the permeation measurement cell*

3 *Samples of novel metal-organic framework (MOF) compounds*

4 *Series production of the adsorption quick tester infraSORP*

SYSTEM COMPONENTS FOR FLEXIBLE AND STABLE MANUFACTURING PROCESSES

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MICROREACTORS CUSTOMIZED WITH LASER

Microreactors are steadily gaining importance in chemical pharmaceutical synthesis, environmental analysis, molecular diagnostics, drug discovery, and even substance testing, because they allow the implementation of more complex chemical and biological actions with minimal technical and human effort. In addition to low investment and operating costs, these systems are characterized by a compact design, high function density, and easy handling. In addition, reliability can be increased by reducing the number of pipes and joints.

At the Fraunhofer IWS, a closed process chain from the design to simulation to rapid prototyping and up to series production has been developed for the effective mass production of application-specific microreactors. The microreactors are quickly made and are flexible as multi-layer systems out of the material combination of silicone, glass and metal or polymer. With the developments of the IWS, a tool is available for the easy and uncomplicated transfer of existing processes on microreactors, as well as the development of new processes.

Since 2009 the Fraunhofer IWS has successfully cooperated with capitalis technology GmbH. So far, seven application-specific microreactors for the market have been developed, for example, for the determination of the bio-compatibility of surfaces, the sample preparation of SPR biochips, as well as for living-cell-based fluorescence and chemiluminescence sensor platforms. In the future, microreactors developed for TissUSE GmbH will allow for animal-free substance testing.

0 Biochip with an open and closed micro-circulatory system

1 Microreactor for the characterization of the biocompatibility of surfaces

Since 1978, the Fraunhofer-Gesellschaft has annually awarded prizes for outstanding scientific achievements, which were transferred to industrial use. Since its foundation as a Fraunhofer institute 20 years ago, scientists of the IWS have been honored five times with this prize.

1992

The Fraunhofer IWS commenced activity as an independent research institution with the working areas “laser thin film technology” and “laser materials processing”.

1997

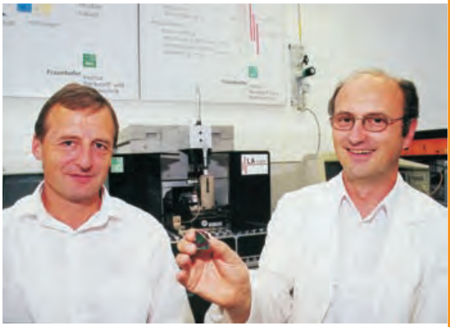
Professor Berndt Brenner received the Joseph-von-Fraunhofer Award for the successful development and industrial transfer of inductively supported laser welding.

1998

The Joseph-von-Fraunhofer Award was awarded to the scientists Dr. Hermann Mai, Reiner Dietsch and Thomas Holz for the further development of pulsed laser deposition and their applications to the manufacture of X-ray optical elements.

2000

The Joseph-von-Fraunhofer Award went to the IWS scientists Dr. Dieter Schneider and Dr. Thomas Schwarz for the laser-acoustic LAwave® process for measuring nanometer-thin layers.



2006

Prof. Berndt Brenner and Frank Tietz received the Joseph-von-Fraunhofer Award for the surface hardening of materials through the production of nano-scaled precipitates.

2012

Dr. Stefan Braun is one of the three award winners of the Joseph-von-Fraunhofer Award for the development of the essential elements of EUV Lithography: the IWS developed the necessary lighting and projection mirror.

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