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Laser Community

THE LASER MAGAZINE FROM TRUMPF

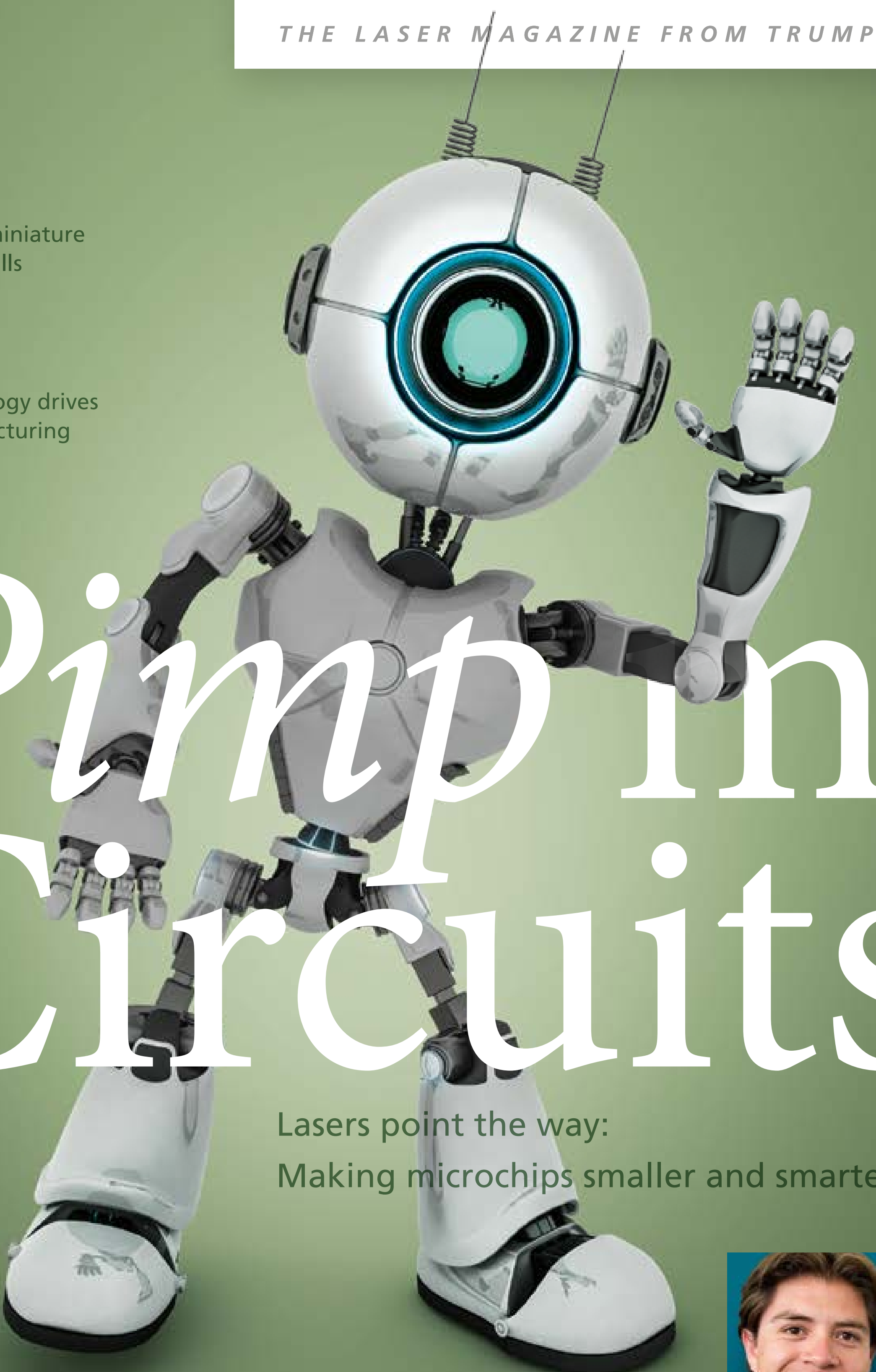
WWW.TRUMPF.COM

Light

Dow Corning's miniature plant for solar cells

Life

Medical technology drives additive manufacturing



Pimp my Circuits!

Lasers point the way: Making microchips smaller and smarter

HOT STUFF

GERARDO OAXACA CASHES IN ON THE HOT FORMING BOOM.

→ Page 20

PUBLISHER TRUMPF GmbH + Co. KG, Johann-Maus-Strasse 2, 71254 Ditzingen, Germany; www.trumpf.com
RESPONSIBLE FOR THE CONTENT Dr.-Ing. E.h. Peter Leibinger *EDITOR-IN-CHIEF* Verena Buttler, Phone +49 7156 303–31559, verena.buttler@de.trumpf.com *DISTRIBUTION* Phone +49 7156 303–31559, laser-community@trumpf-laser.com, www.trumpf-laser.com/laser-community *CONSULTING* Helmut Ortner
EDITED BY pr+co GmbH, Stuttgart, Germany; Norbert Hiller, Martin Reinhardt *CONTRIBUTORS* Florian Burkhardt, Olaf Meier, Christian Nölke, Martin Reinhardt, Julian Stutz, Julia Graf, Prof. Thomas Südmeyer
PHOTOGRAPHY KD Busch, Simon Koy, Adam Wiseman *DESIGN AND PRODUCTION* pr+co GmbH Stuttgart, Germany; Gernot Walter, Markus Weissenhorn, Martin Reinhardt *TRANSLATION* Burton van Iersel & Whitney GmbH, Munich, Germany
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IMPRINT

Cover: kirstypargeter / Fotolia

Almost half a century has passed since Gordon Moore announced that he expected chip speed to double approximately every eighteen months. From the vantage point of 1965, he would never have imagined that one day laser pulses would ionize falling droplets of tin at a rate of 50,000 times a second — or that the plasma pulses generated in this process would ultimately lead to nanometer-scale transistors on a silicon wafer.

In fact, he didn't need to foresee these things. All he needed was a rough idea of how Intel would approach the next five iterations over the following 10 years. Other than that, he simply trusted in progress and people's creativity. And the last 50 years have shown that his trust was well placed.

When analyzing progress, we find that miracles are the exception rather than the rule. Progress is essentially the product of lots of hard work — thousands of people working their way through thousands of painstaking problems. You could almost say that progress is a kind of crowdsourcing.

For example, we have known since the 1970s that we need to find ways of reducing automotive fuel consumption. Since then, researchers have been steadily finding new ways of achieving that goal. High-strength steels are just one result of this ongoing quest. Car designers, steel manufacturers, production engineers and mechanical engineers successfully pooled their ideas to transform virtually unworkable steel into a promising new material for lighter weight vehicles.

Let's put our trust in progress!

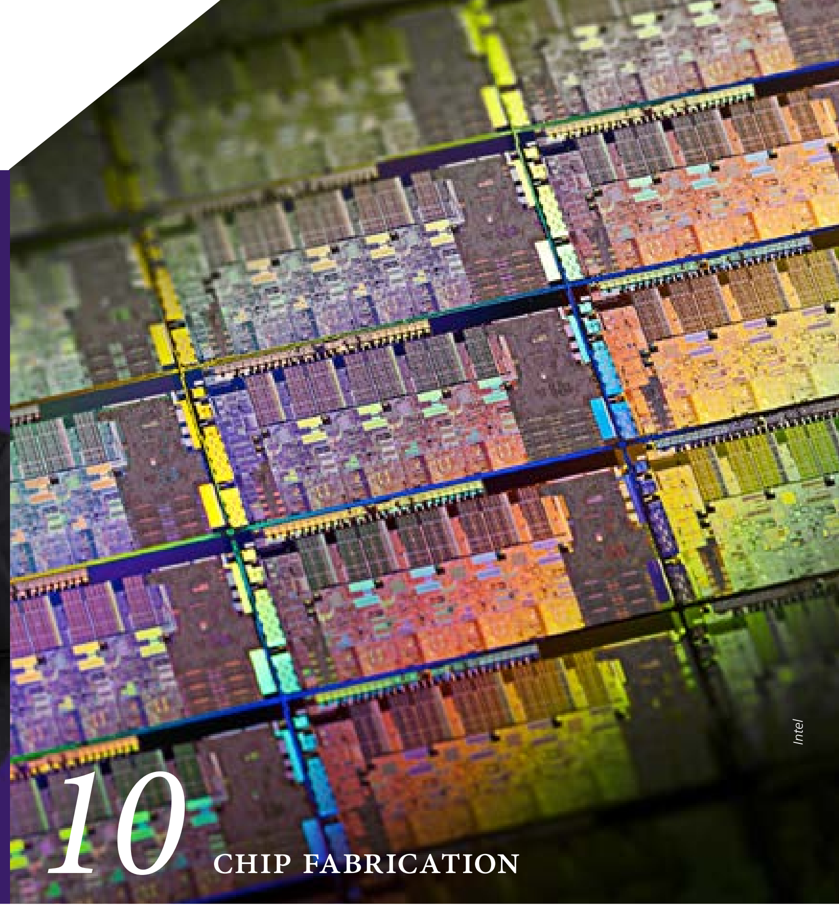
Similar progress has been made in the field of additive manufacturing. Medical technology provides one example. Doctors from the 1960s would be astounded at the ability to produce implants which gradually dissolve, parallel to the healing process, especially because these implants — fabricated from metal powders and light — are perfectly matched to the individual patient's specific needs.

There's no doubt that humanity is facing significant challenges, and we currently have no idea exactly what solutions might be developed in the future. But in hindsight we can see that when we believed we had reached the boundaries of what was possible — somebody, somewhere came up with an idea that pushed back those boundaries — or broke right through them.

Peter Leif.

PETER LEIBINGER, D.ENG. H.C.

Vice-Chairman of the Managing Board
Head of the Laser Technology / Electronics Division
peter.leibinger@de.trumpf.com



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COMMUNITY

TOPIC

PERSPECTIVES

Lasers and people at a glance PAGE 06

TOPIC

Destination nanochip

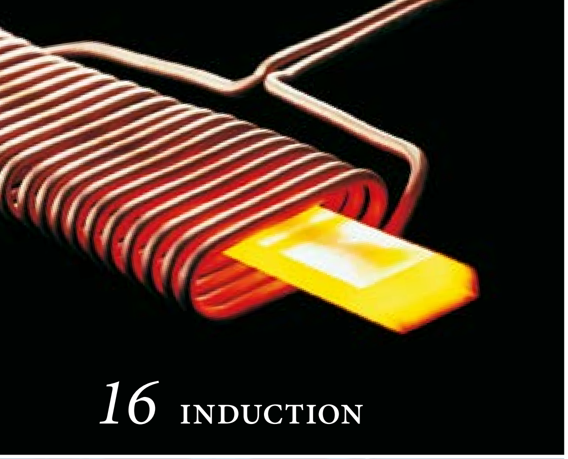
Mechanical methods are reaching their limits. Lasers offer a promising new approach to chip manufacture. **PAGE 10**

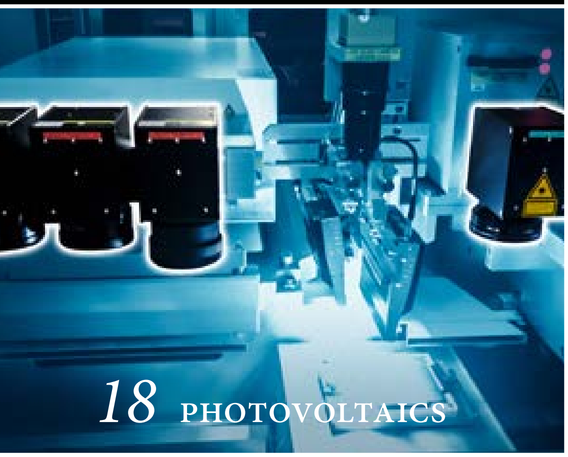
Four times smaller

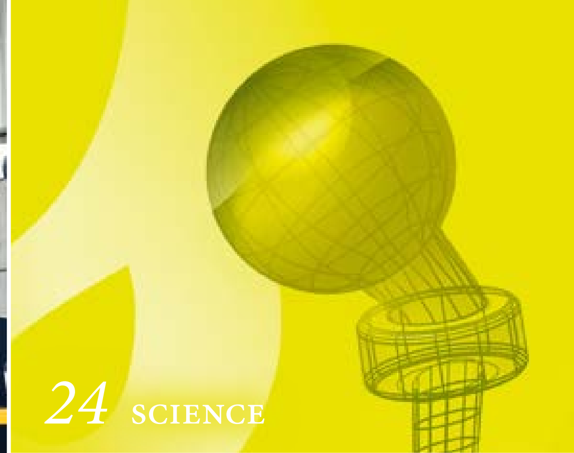
Micro-machining for large-scale applications. **PAGE 12**

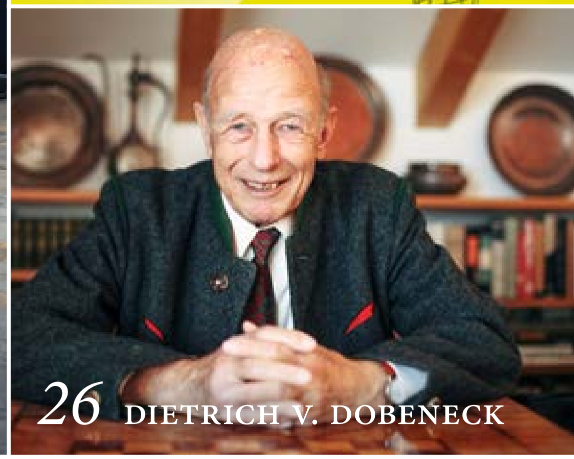
Here come the femtos!

Professor Südmeyer discusses how the new generation of femtosecond lasers is making its mark in research and industry. **PAGE 15**









2013

REPORT

A heated affair

Lasers and inductive heat, in perfect harmony.

Mini-factory

How IPTE squeezed a laser manufacturing system for solar cells into a single box.

First!

Gerardo Oaxaca saw the hot forming wave coming and dived right in.

SCIENCE

CHRISTIAN NÖLKE

A cure in 3D

Additive manufacturing takes the medical arena by storm.

PEOPLE

“Everyone had a laser”

How Dr. Dietrich Freiherr von Dobeneck turned electron beam welding into a success story.

TIG VS. LASER What’s the most cost-effective way of producing the laminated cores required to build electric motors for millions of electric vehicles? **www.laser-community.com/3372**

Bosca78/iStockphoto

S P O T

--- CRYSTAL BALL
Analysts from MarketsandMarkets predict that the market for additive manufacturing will grow by 13.5 percent a year through 2017, to reach a volume of nearly 3.5 billion dollars. *www.marketsandmarkets.com*

--- A LIGHT PUSH
A team of scientists at Aoyama Gakuin University in Japan have used a laser to move a magnetically levitating graphite disk and make it rotate. The laser light changes the temperature of the graphite, thereby controlling its magnetic susceptibility. *www.aoyama.ac.jp*

--- 3D TWEEZERS
Scientists from the University of Freiburg have devised an optical trap which can grab tiny unicellular organisms and then scan them to create three-dimensional images. *www.uni-freiburg.de*

--- MIRACLE MATERIAL
Iranian researchers have developed a way to produce large quantities of graphene by laser ablation in liquid nitrogen. Graphene is considered to be a promising candidate for tomorrow's nanoelectronics. *www.aut.ac.ir*

--- ULTRA-STABLE LASER
California's National Ignition Facility has fired a laser shot with a peak power of 500 terawatts as part of its research into nuclear fusion. The hope is that a laser of this type will one day ignite a fusion reaction. *lasers.llnl.gov*

--- LASER CHIP
A team of American and German researchers has built a silicon resonator that keeps the frequency of a laser more stable than ever before—a key step in making better atomic clocks. *www.ptb.de*

--- VIRUS LASER
Researchers from Northwestern University in the U.S. have developed a laser the size of a virus particle. The new device operates at room temperature and could be used to transmit data. *www.northwestern.edu*

"By 2017 additive manufacturing will be an established industrial process."

Professor David Jarvis coordinates the European research project AMAZE.

A new standard

EU and ESA take steps to promote additive manufacturing

The European Union and the European Space Agency (ESA) recently embarked on AMAZE, a four-year, 18 million euro project aimed at promoting additive manufacturing. This major initiative has brought together 31 partners from industry and research, including TRUMPF. Their goal is to develop methods for producing large additively-manufactured metallic components up to 2 meters in size, to be used in sectors such as the aeronautics and automotive industries. Ideally, they will leave almost no waste. A further aim is to cut production costs by half when compared with traditional processing methods. The partners are setting up four pilot-scale factories to carry out the development work. To help additive manufacturing become an established mainstream industrial process, the project sponsors are placing a major focus on standardization and certification. *www.esa.int*

Bits, photons, atoms

Digital Photonic Production project launched

The research campus in Aachen is bringing together industry, academics and researchers to create a national center for digital photonic production. The aim is to develop new, cost-effective methods that use lasers to manufacture components in small batches, based on digital data. One way of achieving this is by establishing stronger ties between laser-assisted manufacturing methods and the design planning process. "Some people are already talking about a new industrial revolution," says Professor Reinhart Poprawe, the project coordinator. The German Federal Ministry of Education and Research will be providing 30 million euros of funding for the project over a 15 year period. *www.bmbf.de*

Optimized for load bearing and resource use: additively manufactured wheel bearing

“The goal is laser chemistry.”

Katharina Doblhoff-Dier

How do you selectively break molecules? Katharina Doblhoff-Dier and a team of researchers from the Vienna University of Technology recently answered that question by using ultra-short laser pulses to break molecular structures comprising up to ten atoms. The specially shaped laser pulses drive the fast electrons into a different state. These in turn move the much larger and more sluggish atomic nuclei. “Our experiments and simulations have revealed ways of selectively intervening in chemical processes. That means we can initiate or suppress chemical reactions in a controlled fashion,” says Doblhoff-Dier. *www.tuwien.ac.at*

“We just press a button to reshape the beam.”

Sandile Ngcobo

Sandile Ngcobo and a team of scientists at the University of KwaZulu-Natal in South Africa have developed a laser with a beam that can be shaped electronically. Their solution is simple: Instead of placing a spatial light modulator in front of the laser, they have built one into the device, where it acts as the mirror at one end of the cavity. This lends the beam the desired shape as it is being amplified and before it emerges from the casing. “We call it a digital laser because the beam can be shaped electronically, with a computer, without having to calibrate the optics,” says Ngcobo. *www.ukzn.ac.za*

“A non-electrical laser is possible.”

Dr. Kathrin Sandner

Could a laser be driven by a constant temperature gradient? Kathrin Sandner from the University of Innsbruck has come up with a theoretical foundation for achieving that goal. She suggests that a quantum cascade laser could be powered without electric current by modifying the thickness of the semiconductor layers and separating the hot and cold areas in the laser while maintaining a constant temperature gradient. The laser could cool itself by converting the surplus heat into light. This concept could open up ways to make use of temperature differentials in microchips. *www.uibk.ac.at*

MACH TOOL 2013
June 4–7, 2013, Poznań, Poland; machines and tools exhibition
www.machtool.mtp.pl/en

EPHJ UND EPMT 2013
June 11–14, 2013, Geneva, Switzerland; trade fair for suppliers to the clock and watch industry and microtechnology companies
www.ephj.ch

BEIJING ESSEN WELDING & CUTTING FAIR 2013
June 18–21, 2013, Shanghai, China; welding technology fair
www.beijing-essen-welding.com

LASER KOREA 2013
July 10–12, 2013, Seoul, Korea; the only exhibition in Korea dedicated to laser technology
www.laserkorea.or.kr

MF TOKYO 2013
July 24–27, 2013, Tokyo, Japan; metal forming and fabrication fair
www.mf-tokyo.jp

MARINE MAINTENANCE WORLD EXPO 2013
September 10–12, 2013, Brussels, Belgium; international exhibition of marine maintenance technologies
www.marinemaintenanceworldexpo.com

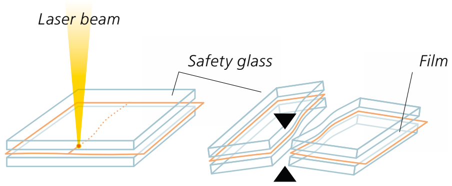
SCHWEISSEN UND SCHNEIDEN 2013
September 16–21, 2013, Essen, Germany; international exhibition of joining, cutting and coating
www.schweissen-schneiden.com

K 2013
October 16–23, 2013, Düsseldorf, Germany; international trade fair for plastics and rubber
www.k-online.de

BLECHEXPO 2013
November 5–8, 2013, Stuttgart, Germany; international trade fair for sheet metal working *www.blechexpo-messe.de*

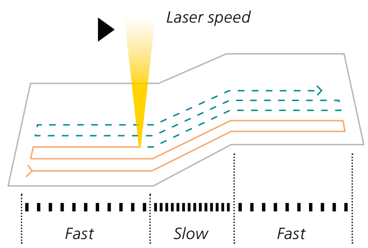
PRODUCTRONICA 2013
November 12–15, 2013, Munich, Germany; international trade fair for innovative electronics production
www.productronica.com

David Jarvis / private source;; Fraunhofer Institut für Lasertechnik ILT; Katharina Doblhoff-Dier / private source; Sandile Ngcobo / private source; Dr. Kathrin Sander / private source



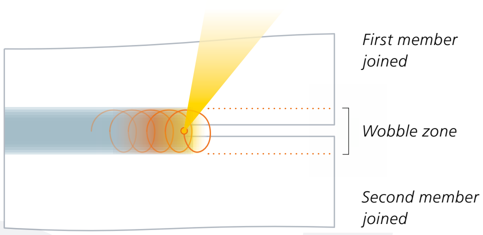
-- CUTTING LAMINATED SAFETY GLASS

The tough film between panes of laminated safety glass does increase safety. But it is an obstacle for cutting. The laser first cuts the film in the glass. Then the panes can easily be scored and broken. *www.iwm.fraunhofer.de*



-- WELD SEAMS

A new 3D programming system for laser deposition welding can calculate the optimum path for welding seams. The CAM system modifies the laser output and processing speed at equidistant or parallel paths to suit the geometry of the workpiece. *www.ilt.fraunhofer.de*



-- WOBBLE WELDING

Wobbling makes it possible to weld designs engineered for MIG/MAG welding from a distance and without welding wire. The beam circles and thus fuses additional material. This makes it possible to use wobbling to weld joints of up to 0.5 millimeter in the Golf VII. Analysis in the Internet: *http://bit.ly/LC_wobble*

New disk

Record-breaking disk lasers

New laser crystals have the potential to massively push back the boundaries of disk laser performance. Nobody knows that better than the researchers at the Institute for Laser Tools (IFSW) in Stuttgart. In recent months they have broken numerous records for disk laser performance using a range of different crystal materials. Their newly grown scandium silicon oxide crystal is seen as offering particular hope for ultra-short pulsed disk lasers, thanks to its thermo-mechanical properties. "The disk laser concept is the perfect choice for ultra-short pulsed systems in the medium output range," says Birgit Weichelt, who heads up the research group. *www.ifsw.uni-stuttgart.de*

Spacey

NASA develops hand-held laser welding system

NASA has developed a hand-held laser with dynamically variable spot size for welding and brazing metal components. The system is housed in a case approximately the size of a desktop PC while the laser torch itself looks like a thick pen. Multiple lenses contained in the housing can be adjusted using a movable camera system. This enables users to change the beam angle and vary the spot size in real time. The NASA only recently approved internal use of laser welding after deciding that the technology has now reached a stage where it fulfills its extremely strict safety requirements. *www.nas.gov*

Safer than a ballpoint pen: a drawing of the hand-held laser, based on the patent specification

Combination: —LASER—

Which is better? A conventional process or a laser? Sometimes the answer is both. Friedemann Lell from DMG / MORI SEIKI explains why he thinks a combination is often the best choice.

Friedemann Lell heads up the sales department at Sauer GmbH, a subsidiary of DMG / MORI SEIKI. A qualified engineer, he was engaged in a project to develop a machine that combines 5-axis milling with laser texturing for surfaces.

What prompted you to develop a combination milling and laser machine?

The tremendous flexibility of the new, fiber-guided lasers has made it possible to integrate them into a wide variety of different systems. That's helping to open up whole new application fields. What prompted us to develop the new machine was the realization that the era of simple leather grains in vehicle interiors and one-size-fits-all surfaces for consumer goods is over. Nowadays, customers want more exciting surface structures. Laser is the perfect tool for engraving the negative images of these patterns into the surface of a casting or forming die because light is fast and is free of any mechanical limitations. So we decided to develop a system that could mill the dies and then apply the surface texture with a laser, all in a single clamping operation.

More than just functional: Since the engine is hidden from view, there's all the more reason for the sound-absorbing engine cover to look its best.

What are the challenges of creating that kind of system?

To create a laser-assisted solution which offers superb across-the-board performance, it is imperative to have expert knowledge of both processes. On top of that, you need to make the laser a genuinely user-friendly experience for the machine operator. We focused on a number of issues in developing our solution, including making the switch between milling and laser operation as smooth and rapid as an everyday tool change.

How much does an operator need to know about lasers?

A good software package can generally take most of the strain off the operator. In our machines, the processing parameters are stored in a table of material properties. Operators learn everything they need to know about working with lasers in our one-day training session.

The laser milling machine developed by DMG / MORI SEIKI: Laser combination machines offer significant potential for milling.

How has the market responded to this combination of laser and machining technologies?

Well, since this is a completely new technology, we're basically developing the market based on the design potentials. And we're not just dealing with one market here. The potential applications range from vehicle dashboards to toothbrushes. For example, who would have thought a few years ago that a tire manufacturer could gain a competitive advantage by adding an attractive patterned texture to the sidewall?

Contact: DMG / MORI SEIKI, Alexander Sauter, Phone +49 8363 89-2040, alexander.sauter@gildemeister.com

Gernot Walter; Institut für Strahlforschung IFSW; NASA; Blickfang Fotografie; DMG / MORI SEIKI

Resonator assembly: High-power CO_2 lasers ignite the light sources to expose the chips of the future.

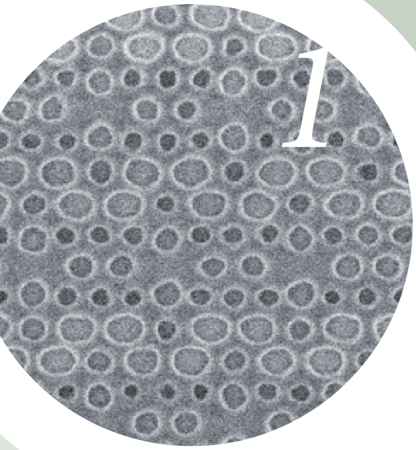
KD Busch

Ever smaller and ever faster: Miniaturization and higher clock rates have been the key trends in semiconductor manufacturing for decades, but mechanical methods are gradually reaching their limits. It's time for the laser to step up to the plate.

Destination nanochip

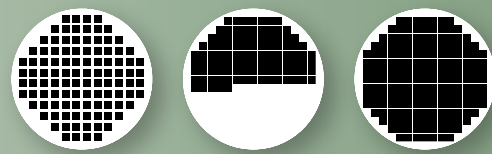
The world is clamoring for more microchips — and it expects them to be smaller, faster and cheaper. In 1965, Intel cofounder Gordon Moore revealed to the semiconductor industry his prediction that the number of transistors incorporated in a chip could be expected to double approximately every 18 months. Since then, the industry has been fighting for every square nanometer in a titanic, billion-dollar struggle. A transistor in a modern smartphone CPU is roughly the same size as a flu virus. Soon the transistors will be so small that they will only come up to a virus's knee, and not long after that the virus will be stepping on transistors and thinking "Where did these crumbs come from?" But how much smaller can transistors really get? A whole lot smaller, says the extraordinarily innovative semiconductor industry — but we need more light!

Thirteen point five A chip's life starts with the light in a lithography system. The lithographic lens projects an image of a circuit onto a silicon wafer coated with photoresist. This projected pattern is reduced in size thousands of times. →



1

Lithography: *Extreme ultraviolet light is already producing chips with features below 16 nanometers, such as the nodes in this SRAM chip.*



2

Better use of space: Laser-etched trenches squeeze chips closer together so you can fit 210 chips on a wafer that previously held just 120.

Dicing: *Ultra-short pulsed lasers produce edges like these and have the potential to achieve trench widths of 40 rather than 200 microns.*

3

Marking: *Laser markers still offer plenty of scope to increase the amount of information that can be inscribed on ever smaller spaces, at ever faster speeds.*

TRUMPF, ASML

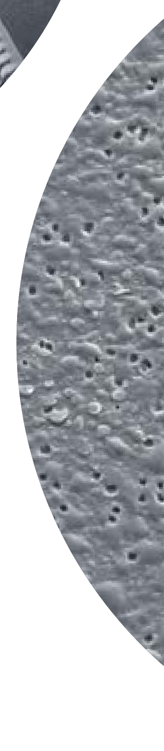
According to the Abbe resolution limit, a light source cannot image structures that are smaller than its wavelength. In the meantime, however, scientists have discovered that this rule can be stretched. Current lithography systems operate with light at a wavelength of 193 nanometers, though they use a number of ingenious techniques to achieve feature sizes as small as 22 nanometers. Nevertheless, it is becoming increasingly clear that the light sources we currently use are reaching their limits. To help create the tiniest of features at the lowermost level of the chip, key players in the semiconductor industry instituted the EUV lithography project, which has now been up and running for more than 15 years. Their objective was to develop a source of extreme ultraviolet light, at a wavelength of 13.5 nanometers.

The basic idea was seductively simple. A laser pulse strikes and ionizes tiny droplets of tin falling in a vacuum chamber. This generates a plasma that emits EUV light at the desired wavelength. To do this, however, the laser has to achieve a rate of 50,000 hits a second. The CO_2 laser pulse for this high-tech skeet shoot is supplied by the TRUMPF Laser Amplifier. Since the spring of 2012, the company has shipped several second-generation laser systems to manufacturers of lithography systems, embodying every bit of knowledge TRUMPF has acquired in 30 years of experience in high-performance CO_2 lasers.

EUV lithography is now entering the production stage. Developers are already using it to make 13.8-nanometer features — equivalent to just half the size of a virus — and the single-digit nanometer range, which is equivalent to the diameter of a DNA strand, is now within reach. Previously, industry customers had admired the TRUMPF CO_2 laser more as a robust workhorse. But now it is paving the way to the future of semiconductor manufacturing.

Smaller means laser EUV lithography has raised hopes that Moore's Law will continue to apply for the next few decades. Shrink the transistors and you also shrink the superstructure, thereby reducing the size of the chips. The conductor layers are already so close together that manufacturers have to fill the space between them with an insulating layer of low-k dielectric material. Yet when it comes to dicing, i.e. sawing the wafer into individual chips, this low-k bless-

There are certainly lower limits. But no one has bumped up against them yet.



How chips are made (video): http://bit.ly/LC_cpu_e

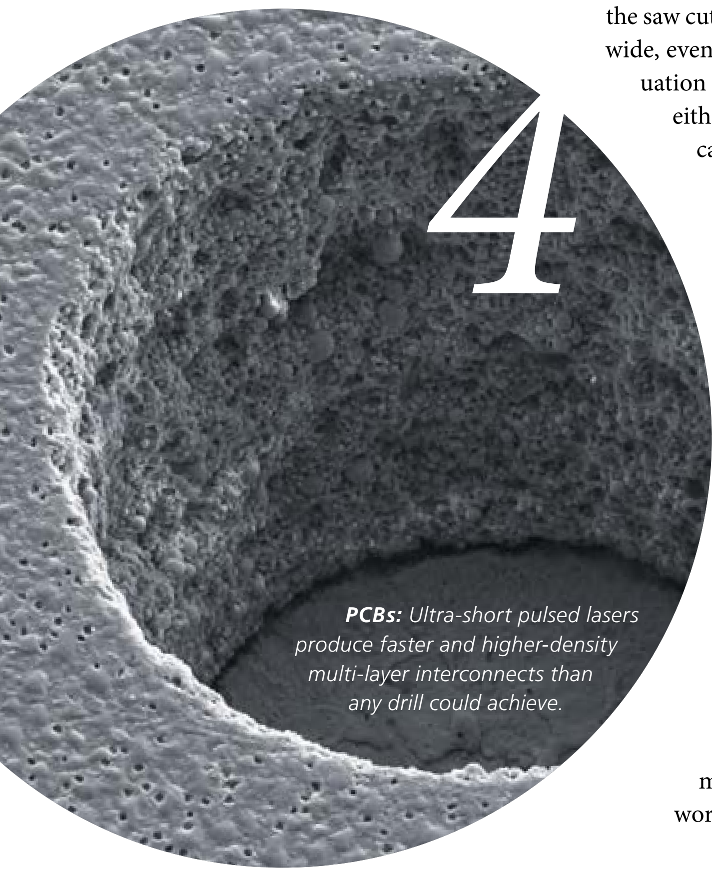
4 x smaller

How lasers can help to miniaturize semiconductor technology

Moore's Law says that the number of transistors on an integrated circuit will double every eighteen months. That's why you can fit some 2,100 mainframe computers from 1960 in your trouser pocket!

TRUMPF, IBM

ing becomes something of a curse. Low-k materials are prone to all sorts of sawing problems, sometimes crumbling due to their brittleness, and other times gumming up the saw blade. In low-k grooving, a laser is used to remove the low-k layer, which is just a few microns thick, before sawing commences.



***PCBs:** Ultra-short pulsed lasers produce faster and higher-density multi-layer interconnects than any drill could achieve.*

But even then the space for the saw is tighter than ever. In the past, small wafers were sawn into a handful of relatively large chips. Nowadays the saw has to cut ever-larger wafers into increasing numbers of ever-shrinking chips. A few square millimeters here and there never mattered much in the past — but now they do. A modern LED chip is barely 10 times wider than the saw cuts, which are still around 200 microns wide, even with the thinnest saw blade. The situation is further complicated by a zone on either side of the trench where mechanical strain leads to microfissures. In contrast, a TruMicro picosecond laser can easily achieve a trench width of just 40 microns with virtually no damage zone. That immediately makes it possible to fit 50 percent more chips on a wafer — and that means 50 percent more profit.

Sawing also creates dust. At microchip scale, these dust particles are like boulders crashing down on the wafer, so a protective coating is applied to the wafer to make sure that delicate features are not damaged. The saw blade — turning at 10,000 revolutions per minute — then moves through the semimetal, while a jet of water cools the workpiece. After sawing, the protective coating has to be removed. The process also requires diamond-coated ceramic saw blades which rapidly wear out and require replacement, increasing the cost of the process even further. A UV laser requires no protective coating, no water cooling and no tools that are subject to wear. And, unlike sawing, the ongoing reduction in wafer thicknesses actually benefits lasers, because light cuts much faster than a saw at thicknesses below 100 micrometers.

Sorting the good from the bad When the first manufacturer began to mark finished chips with their power/performance class, it heralded something of a commercial revolution. The marking shows the camera-controlled sorting system which chips have been identified as perfect, close to perfect, adequate or entirely unserviceable. All at once it became possible to actually use significantly more chips per wafer. This die sorting process has since become a standard part of chip fabrication — as has the laser marking system it depends on.

Laser markers really are the only feasible option. That's because it's not only batch sizes and production rates that are increasing, but also the amount of information that must be applied, to meet traceability requirements. Yet the size of the available surface is shrinking, so the size of the markings is getting smaller and smaller. Currently, solid-state lasers can apply markings at a rate of some 1,000 characters a second with a track width of 30 microns. These applications generally use diode-pumped vanadate green lasers which produce a change of color in the dark plastic used to encase the chips. This method leaves the surface unchanged and keeps the marking from being rubbed off or manipulated.

Thirty µ? No problem The steady shrinking of components also applies to the production of electronics. In the past, PCB manufacturers drilled thousands of holes in millimeter-wide conductor tracks, but nowadays they drill millions of holes in half a square meter, with each hole having a diameter of just 100 microns and a depth that must be precise down to the micron. Printed circuit boards are no longer boards at all. Flex circuits that have been folded 12 times over are now a standard feature in smartphones, and servers are already being folded into as many as 40 layers. Hundreds of thousands of holes, filled galvanically, bring each new layer in contact with the layer below. Materials are changing, too: The manufacturers of high-frequency chips are turning to ceramics, while cell phone manufacturers favor flexible foil circuits.

Generally speaking, the industry still uses mechanical drilling methods, but the benefits of lasers are gradually coming to the fore. A drill bit is only good for a few thousand holes, which means that the machines need a new drill bit every 3 minutes or so. Each drill bit costs approximately one euro, so the consumables required for the process are one of the key cost factors — just like with pod coffee makers.

Mechanical drilling has also reached the end of the line in terms of its technological limitations. Hole diameters can't be any smaller than 100 microns, and drilling more than 20 holes a second is simply not feasible. But the market wants smaller and faster results — and that's precisely what lasers can provide. A CO_2 laser can achieve a rate of 100 holes a second with a diameter of just 75 microns. An infrared picosecond laser has no trouble drilling holes just 30 microns in diameter, and — depending on the material — it can drill anywhere up to 1,000 holes a second.

But perhaps the greatest strength of the laser is its precision. To ensure that each track matches up perfectly with the ones above and below, the drilled hole cannot deviate from its target position by more than 10 microns. And the penetration depth is just as critical, because even one defective contact in the circuit is enough to land the circuit board in the trash. TRUMPF has therefore developed precise and reliable control technology for the TruMicro laser. Its patented double feedback loop control system monitors each individual picosecond pulse and maintains output and pulse energy at exactly the right levels, regardless of any outside influences. It does this by using an external modulator which decouples the pulse build-up from power regulation, thereby ensuring that the system always delivers precisely the required levels of power and pulse energy, while simultaneously maintaining constant beam quality and pulse duration.

Mastery of miniaturization The semiconductor industry is venturing into ever smaller realms and the trend towards miniaturization is expected to continue for many years to come. In fact, researchers are already working on concepts for making integrated circuits out of single atoms. One thing is for certain. Both now and in the future, we will only achieve complete command of the micro and nanoworlds if we put our faith in the most elegant tool available to us — focused light. ■

Contact:
TRUMPF Laser- und Systemtechnik GmbH, Michael Lang,
Phone +49 7156 303–30108, michael.lang@de.trumpf.com
Dr. Ute Gauger, Phone +49 7156 303-32033,
ute.gauger@de.trumpf.com

In the TRUMPF Laser Amplifier, four multi-kilowatt lasers amplify the pulses emitted by a fifth laser. Providing peak pulse output of multiple megawatts, they generate EUV light from plasma. 50,000 times a second.

EUV litography (video): http://bit.ly/LC_euv_e

TRUMPF

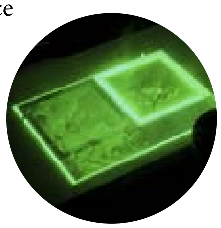
Here come the *femtos*!

Laser physicist Thomas Südmeyer is confident that the next generation of ultra-short pulsed (USP) lasers will enjoy broad acceptance as a standard tool for research and industry.

The unique characteristics of ultra-short laser pulses — extremely short pulse durations, high spatial coherence, and a broad optical spectrum — have already led to a number of scientific breakthroughs and Nobel Prizes. Their short pulse duration can trigger and even control processes with extremely fast dynamics, while their superb spatial coherence makes for outstanding pulse focusing properties. Femtosecond lasers also enable intensive spatial and temporal focusing of the light energy. That paves the way for extreme light-matter interactions — which has laid the basis for numerous experiments in attophysics and nonlinear optics.

In recent years, ultra-short pulsed lasers have made inroads into the fields of biology, chemistry, material sciences and medicine. They are used to measure mental processes in neural networks, investigate the dynamic processes and response mechanisms of catalysts, make detectors more compact, and help us to understand nanomaterials. Research with, and into, ultra-short pulsed lasers will continue to be a fascinating topic. Simpler, more compact and more economical ultra-short pulsed lasers will increase the acceptance of this technology and open up new areas of interest. Diode-pumped solid-state lasers will replace more complex, ultra-short pulsed lasers such as titanium sapphire lasers. And an increase of several orders of magnitude in average output power and repetition rate will make it possible to develop innovative systems in many fields.

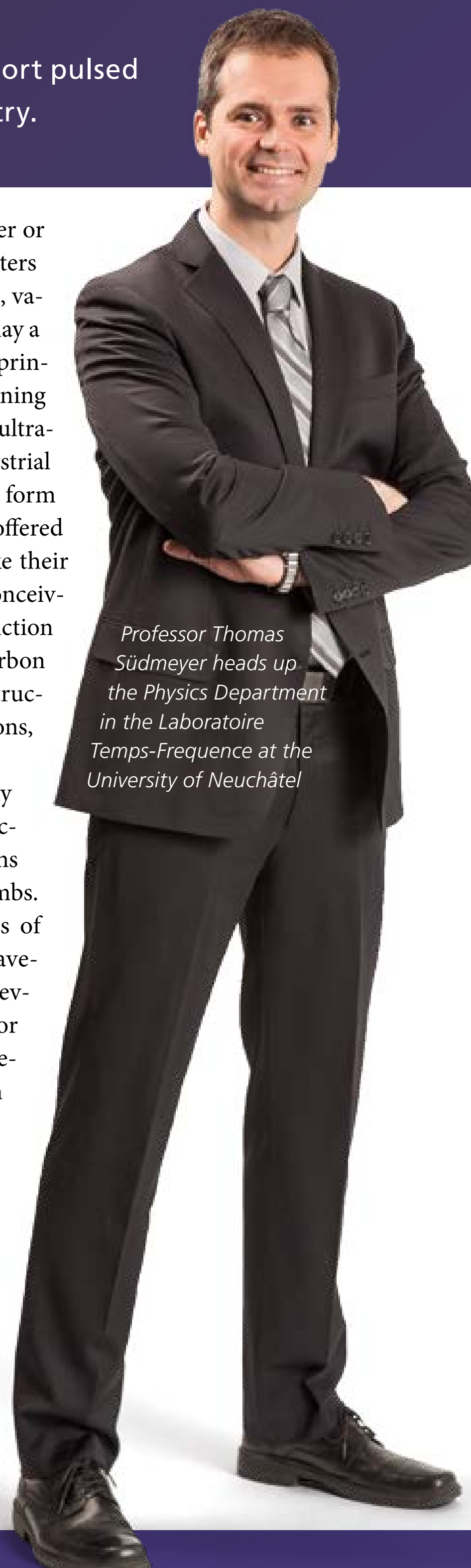
These developments are of great interest to industry, too, since new materials such as fiber-reinforced matrix composites, high-strength steels, temperature-sensitive biomaterials and tempered thin glass are difficult to machine with conventional tools. Ultra-short laser pulses can interact with materials via multiphoton absorption, thus performing what is known as “cold machining”, a process in which the energy pulses are absorbed in a tiny layer, leading to a direct sublimation from solid to gas. This prevents damage to the surrounding material and enables precise structuring in the nanometer or micron range. Traditional material parameters such as homogeneity, absorption properties, vaporization temperature and hardness only play a subordinate role in this process which, in principle, can be used for high-precision machining of any material. Yet it was only recently that ultra-short pulsed lasers started to be used in industrial production. The breakthrough came in the form of diode-pumped solid-state lasers which offered enough output power and stability to make their use cost-effective. The potential is huge. Conceivable applications include structuring low-friction surfaces for efficient engines, machining carbon fiber reinforced plastics, generating microstructures in small batches for medical applications, and many, many more.



Picosecond laser pulses cut display glass for devices such as cell phones

Femtosecond lasers will expand into many other markets in the years ahead. One particularly promising area involves sensor systems that make use of optical frequency combs. A single laser can generate tens of thousands of ultra-stable wavelengths simultaneously — a revolutionary step forward for spectroscopy and measurement techniques. Although femtosecond lasers are currently too expensive and complex for high-volume applications, new technologies such as ultra-short pulsed semiconductor lasers offer enormous potential for mass-volume applications in biotechnology, medicine and environmental technology. ■

E-mail to the author: thomas.sudmeyer@unine.ch



Professor Thomas Südmeyer heads up the Physics Department in the Laboratoire Temps-Frequence at the University of Neuchâtel

Inductive hardening of a gear component. Just like lasers, induction has an extremely localized effect. This makes it a good companion in efficient process chains that must remain flexible.

A heated affair

Induction is proving to be an ideal partner for laser welding: for pre-heating, cleaning and hardening

An differential's tripod joint at the pre-heating station. In a demonstration, the flange is made to glow.

Behind the protective doors of the laser welding station, the inductor surrounds the drive shaft without touching it. While power is flowing, nothing is visible to the naked eye. But if Zoran Bubic, responsible for process planning at GKN Driveline, were to touch the spot where tripod and tube will soon be joined by a laser beam, he would burn himself. The metal here — and only here — has reached a temperature of about 500 degrees Celsius. Mr. Bubic turns away from the manufacturing cell and explains: "The inductor provides a large amount of heat extremely quickly, to a very small volume of steel. The laser then works a welding point that has been perfectly pre-heated, resulting in a highly reliable process."

Many successful welding processes today make use of induction, particularly in applications that call for pre-heating. The laser's minimal heat input has a downside when it comes to deep penetration welding of high-carbon steels. The cold workpiece chills the welding seam, and this can lead to hardening and quality defects such as cracks in the zone affected by the heat. Conventionally, pre-warming has meant heating an entire component in a furnace. With the inductor, however, the heat is generated in a matter of seconds, on a very limited space. Moreover, "pre-heating takes place in the welding cell," says Zoran Bubic. "This lets us eliminate the preheating station and avoid handling hot components. What's more, we can save quite a bit of heating energy, not to mention a lot of time."

Induction can be regulated to almost one Kelvin.

Precise, fast, and contact-free

Even the most enthusiastic lecture on induction is likely to put a room-full of mechanical engineering students to sleep. Induction sounds a lot like high school physics and it's everywhere — even in an IKEA cooktop. But induction's low-tech nimbus soon dissipates when real know-how is involved. Every induction application is dedicated to a specific workpiece as a balanced system that combines an inductor and a high-frequency generator. Locally, its effect can be precisely controlled, to within one Kelvin. This controllability and the speed at which heat is generated make induction a wonder weapon of sorts. And induction really is easy to handle: induction systems can easily be integrated into manufacturing processes, interlinked automation systems, and production plant concepts.

Applications range from work at room temperatures to work at several thousand degrees Celsius. As of 200 degrees Celsius, things start to get interesting for metal processing and laser technology. Above this temperature, many non-metallic protective and functional coats evaporate. This means that the same inductor that pre-heats the weld spot can now also clean or decoat this spot — and this spot only. At temperatures exceeding 900 degrees Celsius, workpieces can be hardened or softened locally. When it comes to induction, the possibilities are just about endless.

Pearls on a string

"At first glance, using induction in laser processing isn't always an obvious choice," says Georg Schneider, induction sales representative, at the TRUMPF subsidiary HÜTTINGER Elektronik. "But while user-programmable lasers remove the limitations of mechanical processes, the pyrometer-controlled induction systems replace conventional heating systems such as furnaces and put thermal processes exactly where they belong. In power trains, for instance, they are located directly at the welding joint." At the same time, the inductors can be designed to handle a large number of component variants. As a result, it no longer matters which transmission model is being welded, as Georg Schneider explains.

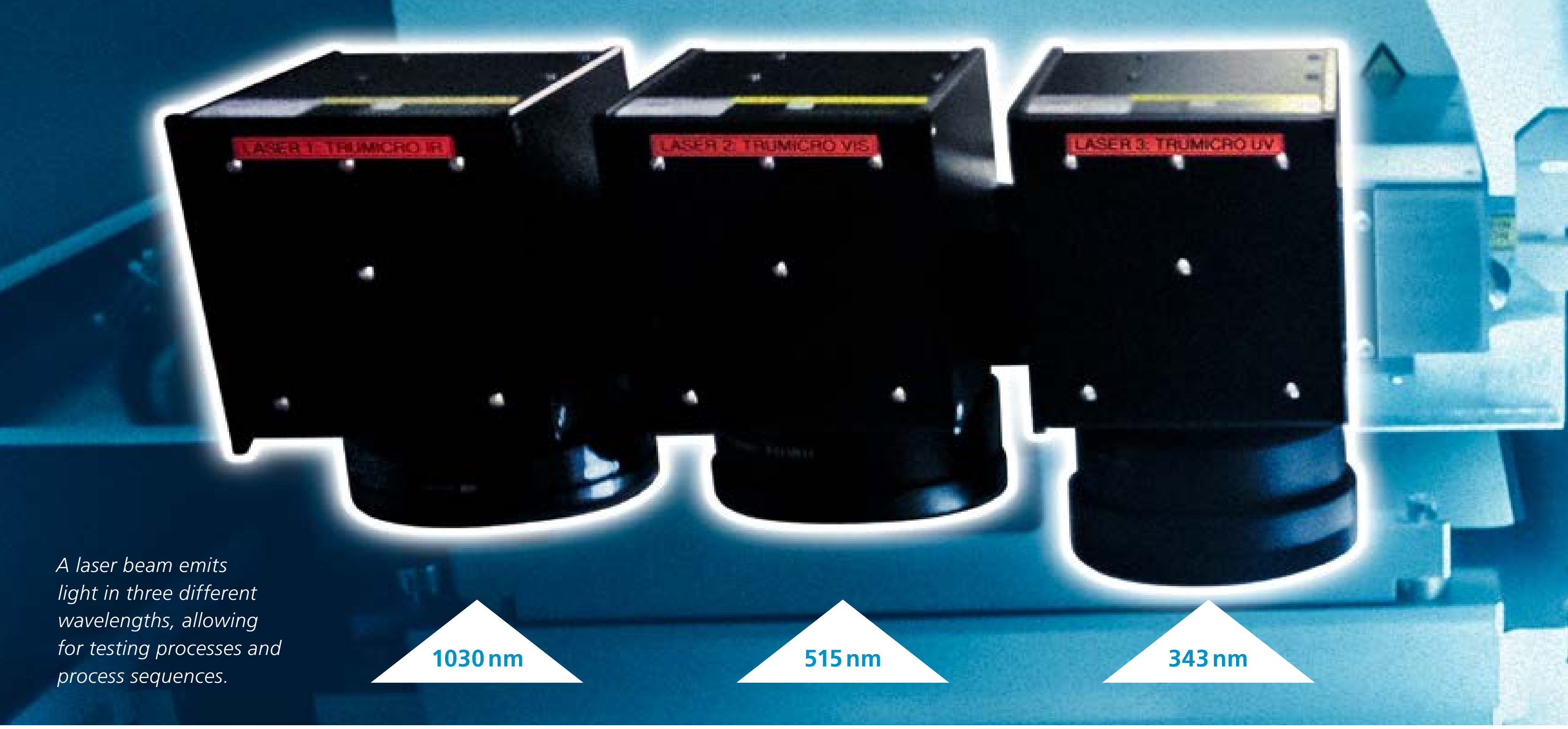
In the hot-forming process sequence, too, induction offers more than one possibility for heating sheets prior to pressing. Locally induced heat can soften specific sections of hardened components. The automotive industry is now discovering this can be useful, both to make welding joints possible and to actively influence how high-strength body parts deform in the event of a crash. While these parts need to be rigid, the steel must not break if a crash occurs. Energy is dissipated only if the part deforms. For this reason, manufacturers are beginning to soften up the areas that are at risk of breaking in a crash, with the aim of increasing their ductility in defined areas. Once again, this takes place directly in the laser processing cell, where the laser perforates and trims the pressed and hardened component. Once this is done, inductors soften the areas that are to bend in the event of a crash.

Room for two

No contact, no mechanical forces, and limited energy consumption. Its effect can be restricted to a limited area, it can act on a large surface if desired, and its user-programmable heating parameters provide complete process control. Indeed, the laser has had a sibling for several years now. At first glance, it does not appear as exciting as the sci-fi tool of light. But having a closer look is worthwhile. Induction technology not only shares many of the qualities that make lasers so interesting; it also contributes a wealth of benefits. ■

Contact: HÜTTINGER Elektronik, Georg Schneider, Phone +49 761 8971-2125, georg.schneider@de.huettinger.com

From making electric motors to melting samples: a gallery of induction applications: http://bit.ly/LC_induce



A laser beam emits light in three different wavelengths, allowing for testing processes and process sequences.

MINI-FACTORY

Dow Corning uses a fully automated laser system to produce silicon solar cells for photovoltaic applications. Housed in a remarkably small space, the pilot-scale research plant carries out processes that would normally require a multi-stage laser station.

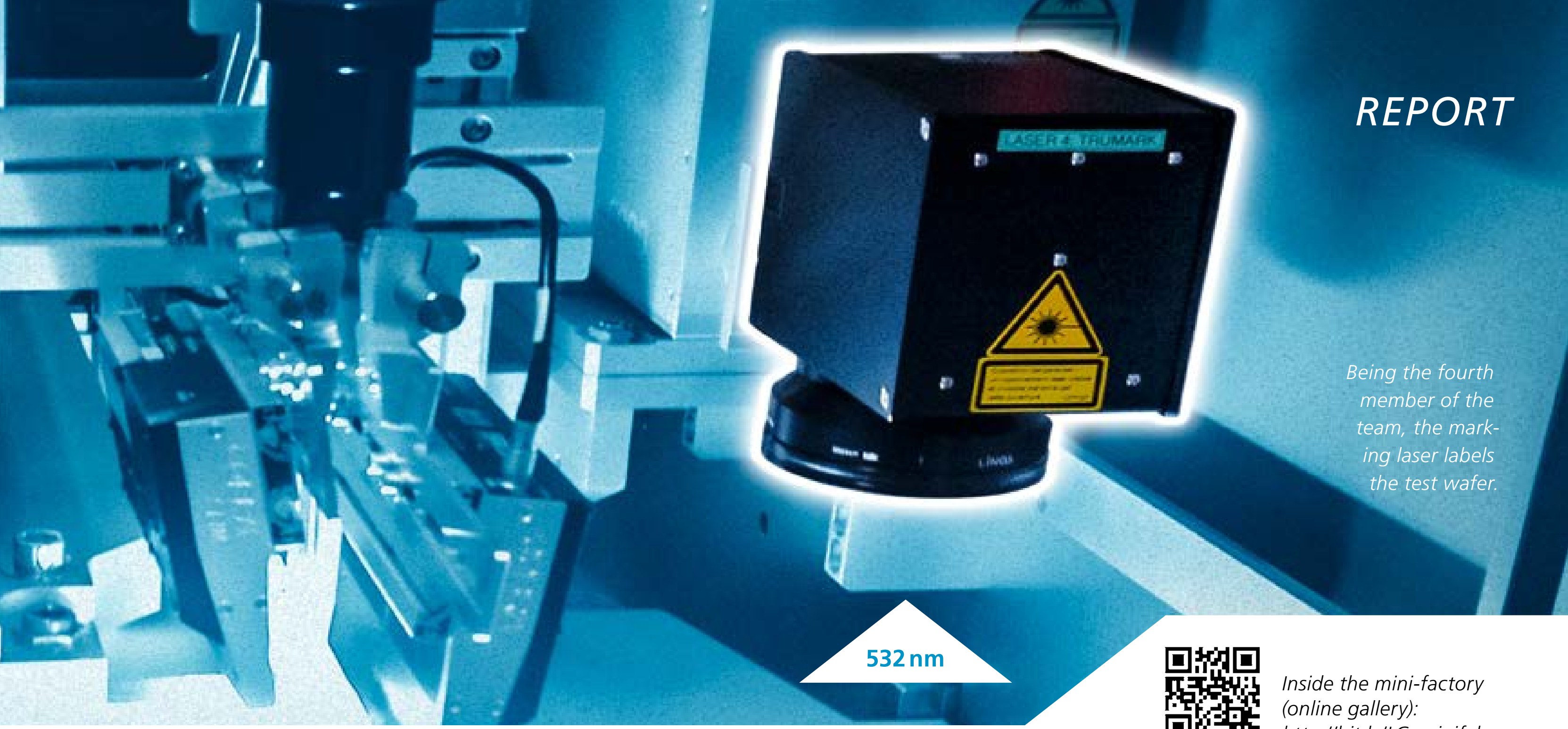
Anyone interested in seeing how tomorrow' solar cells might be produced should head to the Belgian town of Seneffe, where the multinational chemicals company Dow Corning is busy conducting research into crystalline silicon solar cell manufacturing processes for the photovoltaic industry. A key tool for its research is a laser workstation that combines all the relevant production steps within a single, highly compact system. It removes functional layers from the wafer selectively and precisely, drills thousands of holes through the silicon, machines the edges, and then marks the wafer with a Data Matrix code in a final step.

The various process steps would normally require multiple manufacturing stages with different lasers — but Dow Corning had other ideas, as Guy Beaucarne, head of the Solar Cell Department, explains: "Modern solar cell manufacturing lines make extensive use of laser processes. For our R & D activities, we wanted a compact laser workstation that not only could execute laser processes that have become common in the industry, but also could provide broad research flexibility, enabling us to apply the more advanced laser processes needed for emerging solar cell technologies." With this concept in mind, the project manager decided to call up TRUMPF.

Project Engineer Jörg Smolenski recalls what happened next: "We were fascinated and fairly sure we could come up with a solution for the laser components. But we needed a systems partner capable of designing the complex automation package the lasers would require."

Three jobs in one Smolenski placed a call to IPTE in Belgium. TRUMPF and the systems integrator have a long history of working together on automation projects. His call was answered by Kris Smeers, Business Development Manager Automation at IPTE: "We're very familiar with the production stages because we do a lot of work in the PV industry. And we were quickly fascinated by the challenge of squeezing an entire plant into the smallest possible space and controlling it with micron precision."

To ensure the system would be able to handle all the processes involved in laser manufacture for solar cells as well as have additional built-in flexibility for upcoming R & D projects, Dow Corning asked that three wavelengths be emitted by no more than two beam sources: 1,030 nanometers (infrared), 515 nanometers (green) and 343 nanometers (ultraviolet). In addition, it was essential for Guy Beaucarne to have the option of carrying out additional modulation of the light and working with pulse lengths in the nano and picosecond range. That's the only way for the beams to ablate the various substrates while still supplying enough energy to cut the material. A key goal of Dow Corning's design concept was to maintain flexibility with regard to the sequence of the process steps.



Being the fourth member of the team, the marking laser labels the test wafer.

Inside the mini-factory (online gallery): http://bit.ly/LC_minifab_e

The TRUMPF application engineers proposed using two beam sources, one of which would be a marking laser: "The TruMark lasers are reliable, compact systems, so it wouldn't have made sense to choose anything else," says Smolenski. With its green 532 nanometer light and a pulse repetition frequency of between 25 and 100 kilohertz, the TruMark 6230 proved to be the perfect tool for marking silicon.

But the main workhorse in this miniature plant is a TruMicro Series 5000 ultra-short pulsed laser. Depending on the application, it delivers pulses as short as 10 picoseconds, pulse energies up to 250 microjoules and an average laser output of up to 100 watts. These parameters would also allow for converting its light into the green and ultraviolet ranges. TRUMPF used it as a basis for creating a triple-frequency solution. A special "box" developed by Xiton Photonics, based in Kaiserslautern in Germany, in collaboration with TRUMPF acts as the frequency conversion module. It either lets the infrared light through or converts the laser pulses into either green or ultraviolet laser light as required, each of which is sent through its own individual scanner optics.

High-precision system engineering To control the box, scanner and overall system, IPTE developed a special automation solution. "The biggest challenge for us was the level of precision required in positioning the wafers under the lasers," says Kris Smeers. In some cases, the all-in-one system has to position the wafers with an accuracy surpassing 10 microns while still being able to handle a broad range of different formats.

Kris Smeers and his team decided to implement a high-precision image capture system: "As long as the machine can *see* what workpiece is coming and how it is positioned, then the exact shape doesn't matter," says Smeers, explaining how they reached their decision. The camera used for image acquisition offers a resolution of 12 x 12 megapixels and the positioning drives utilize fully adjustable motors and high-precision encoders. To ensure that no external factors interfere with this precision work, IPTE limits human interaction to the programming of the process steps through the user-friendly interface — plus, of course, constantly feeding fresh wafers to the machines. This is one area where the miniature plant differs clearly from its larger counterparts: In bigger machines, IPTE also automates the process of loading the silicon wafers.

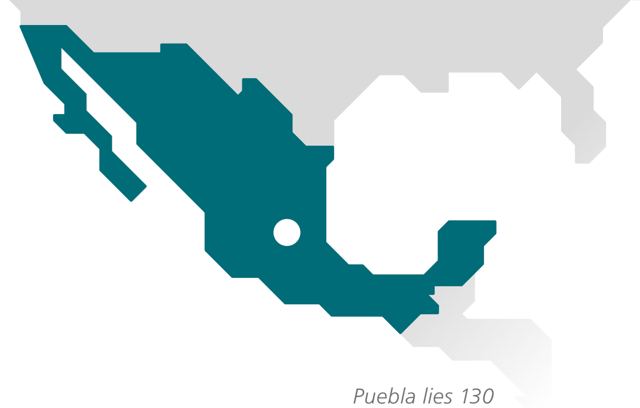
The system has been operating in the research center since the fall of 2012. Answering the question as to why it specifically had to be a laser system, Guy Beaucarne explains that he sees the laser as one essential tool of the future for the solar industry. "Lasers are very flexible, fast and reliable. They are easy to control and they ensure a reproducible process. At the same time, they can offer a smaller footprint and lower total cost of ownership when compared with alternate patterning and machining methods," he says. "Many in the solar industry see the laser as a necessary tool for advanced solar cells." This applies not only to the miniature plant that Dow Corning is using for its research; it is also true for industrial scale. "IPTE and TRUMPF have managed to create an extremely flexible tool that we can use for many different process steps," says Guy Beaucarne, emphasizing Dow Corning's satisfaction with the miniaturized production facility.

Contact: IPTE Factory Automation, Kris Smeers, Phone +32 89 623 038, kris.smeers@ipte.com

IPTE FACTORY AUTOMATION is a supplier of automated production equipment for the electronics industry and one of the market leaders in this segment. It operates twelve engineering and production sites around the world.

DOW CORNING CORPORATION is one of the world's leading suppliers of technologies and innovations based on silicon. In Belgium, the company runs the Solar Energy Exploration and Development Center.

IPTE FACTORY AUTOMATION



Puebla lies 130 kilometers to the southeast of Mexico City and is Mexico's automotive heartland.

First!

The boom in high-strength steels triggered a second boom — in job shops able to cut them. In Mexico, Gerardo Oaxaca was one of the people who forged his own success.

Hot forming is a hot deal. That's not just because the mold hardening process for high and super-strength steels takes place at about 900 degrees Celsius. Designs using these steels are one of the hot trends wherever it's a question of reducing weight. Five years ago, the automotive industry used only two to three hot-formed parts per vehicle; in the meantime, that number has grown to between six and eight. And the future will probably see toward more than ten such parts per passenger compartment. Something that has picked up speed in recent years in Europe's automotive industry has long since reached vehicle builders in the Americas. On both sides of the Atlantic, this phenomenon has an inseparable companion: 3D laser cutting. What other process technology might you use to cut hot-off-the-press, high-strength blanks, and to do it economically, as well?

This new age has also dawned in Puebla, Mexico. Here old Mexico and the new world meet, about 100 kilometers southeast of Mexico City. Puebla, with its historic town center, has been named a World Cultural Heritage site. But the city is also a center of industry and a home to automotive engineering. Entrepreneur Gerardo Oaxaca, chief executive at the Superlaser & Fixtures company, puts it this way: "Here, just about everybody works for the automotive industry, in one way or another." Oaxaca was the first to jump on the hot-forming bandwagon. That was a leap that turned him into a specialist for laser cutting, virtually without competition. This made him the best example of what the market for hot forming can offer to a small company with high-quality laser cutting equipment. In February 2008, "Superlaser & Fixtures" was still known as "Margger Ingenieros" and was in fact a small job shop. Mario Oaxaca had launched that business together with his son Gerardo and a colleague. They started out doing repair work, using CNC lathes and milling machines, presses and engine lathes. It was in the summer of 2010 that a visit to an automotive industry contractor for safety-critical components turned that young company upside down. Hot forming had reached full bloom in the customer's factory. The customer asked whether Margger could handle 3D laser cutting, since his own shop was working almost to capacity. "Our client was looking to outsource some work and was seeking greater flexibility in manufacturing. He also talked about finding a solution more economical than expanding his own capacities," says Gerardo Oaxaca.

And so an avalanche of 3D laser cutting rolled right onto the Oaxaca lot. "We had identified a market that was entirely our own. There were simply no other contractors in and around Puebla that could do high-speed laser cutting in three dimensions," according to Gerardo Oaxaca. "To make our competitive lead as large as possible, we decided to purchase the best quality available." The choice was a TruLaser Cell 8030. Oaxaca carefully planned its market debut, with intense marketing efforts in Mexico and training at TRUMPF in Ditzingen for the operators and for himself. →

The cutting process, right up close (video): http://bit.ly/LC_hf-cut_e

Gerardo Oaxaca (left) was the first contractor in Mexico to jump on the hot forming bandwagon.

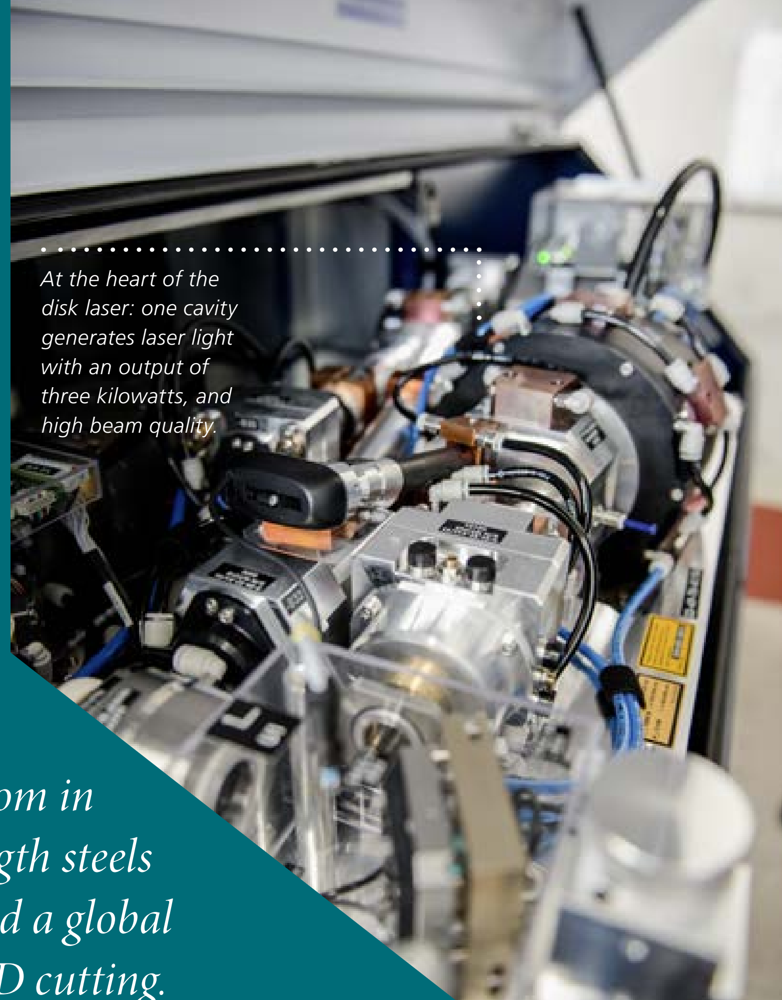
900°

Laser cutting a B pillar. Once the steel has been formed and hardened, there's only one tool that can tackle it economically—the laser.

The boom is in full swing: 60 colleagues work six days a week in three shifts.

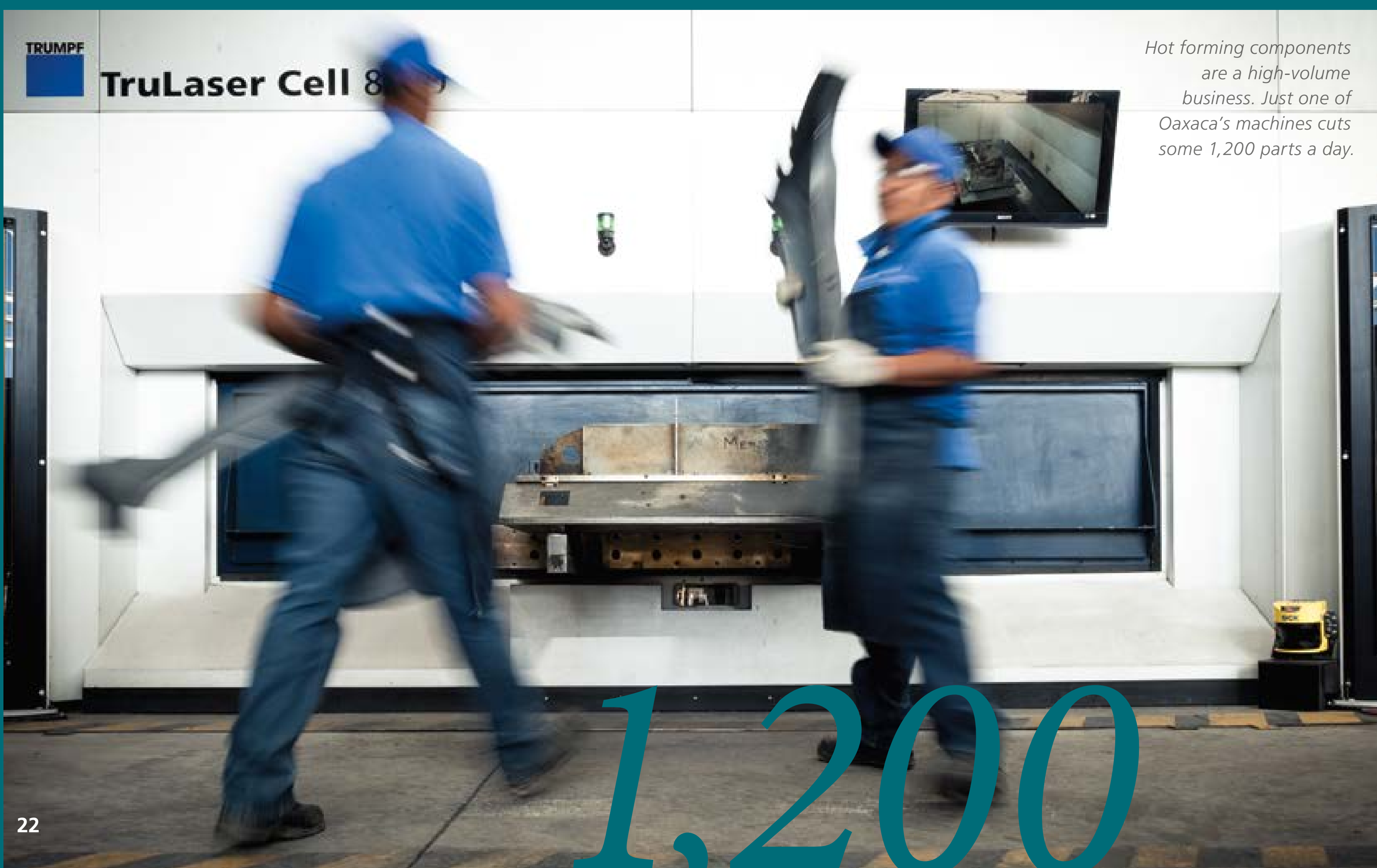
Adam Wiseman

Branching out: Stainless-steel exhaust diffusers, ready to be lasercut.



At the heart of the disk laser: one cavity generates laser light with an output of three kilowatts, and high beam quality.

The boom in high-strength steels has triggered a global boom in 3D cutting.



Hot forming components are a high-volume business. Just one of Oaxaca's machines cuts some 1,200 parts a day.

1,200

In 2005 the Passat B6 heralded a breakthrough in auto construction using high-strength steels. Depending on the manufacturer and vehicle class, the proportion of high-strength steel in car bodies is expected to rise from between 5 and 15 percent to between 35 and 40 percent.

In preparation for working this new market for laser cutting, Gerardo Oaxaca founded a new company: "Superlaser & Fixtures". With thorough preparation and training, the team was able to tackle its first order just as soon at the TRUMPF machine reached Mexico in the summer of 2011. "The hot-formed parts we cut with the laser are safety-critical components in the vehicle — like the A and B pillars," Gerardo Oaxaca explains. The laser lets the company handle very large volumes. "The B pillar is one of the largest vehicular components we cut. Finishing one part takes about a minute. That means that we can cut 1,200 parts per day — and thus pave the way for the production of 600 cars daily," Oaxaca says.

The machine quickly started attracting orders

Among them were contracts for cutting safety components for new models being assembled in Mexico by a variety of European carmakers. Convertibles and hybrid versions destined exclusively for sale in North America received from Puebla the laser-cut reinforcements needed for the interiors. As a result of this rousing success, that first laser system was soon joined by another. This time, however, it was a TruLaser Cell 7040 with two-station operation. That was because Gerardo Oaxaca didn't want to rely solely on the high volumes associated with hot forming. The 3D welding and cutting machine not only lets the company cut long production runs. It also helps the firm respond flexibly to other orders.

The laser quickly shed light into new niches in the market. All this success has not only expanded the staff from three to almost 60 employees — who now work in three shifts, six days a week. It also gave Gerardo Oaxaca and his colleagues the freedom to think about new areas where their laser machinery might be useful. As the appendix "Fixtures" in the company's name reveals, fabricating accessories and prototypes has in the meantime become the firm's second major activity. "We build, for example, fixtures for both welding and laser machines," Gerardo Oaxaca explains. "This is something like à la carte work for our customers – when a rapid change is needed in ongoing production, for instance. "Here, too, the demand is high. Our clientele has learned that it's worthwhile to outsource special assignments like this."

The hot-forming surge continues to roll. The management consultants at McKinsey estimate that the share of high-strength steels will rise from today's 15 percent to 40 percent. According to the same study, the market for lightweight components – and here high-strength steels take the lion's share — will expand from 70 billion to more than 300 billion euros. This is the crest of a wave upon which Gerardo Oaxaca could surf his way into becoming a direct supplier to carmakers. Moreover, Oaxaca's company was certified for compliance with the ISO 9001:2008 standard, awarded by the Mexican office of TÜV Rheinland in November 2012. But "becoming a tier one supplier is not the step we're striving for right now," says the CEO. "On the one hand, the company is simply too young for such a move. And secondly, it is precisely our independence that lets us do such flexible work for a wide variety of customers." And there are more and more of them in Mexico. "Not only do we have a generous amount of land, but good work ethics and high quality expectations, too. It's true enough that we import high-tech machinery. But the expertise needed to use them in an ideal fashion is something we have acquired ourselves," Gerardo Oaxaca sums up. "Cutting hot-formed parts provided the impetus. It opened up opportunities — in things we had no idea we could profit from!" ■

Contact: Superlaser & Fixtures, Gerardo Oaxaca,
Phone +52 1 222 554 7433, gerardo.oaxaca@superlaserandfixtures.com

Christian Nölke

A cure in 3D

Whether 3D printers will some day be found in every home shop remains to be seen. But one thing is certain. Additive processes are well on their way to maintaining health and saving lives.

The general public has dreams about the 3D laser printer. This multifunctional device can take some dust and light and conjure up whatever the heart desires, from a coffee cup to a compact car. And yet hardly anyone realizes that industry has taken this dream and started achieving real results. Its goals are just very different from those of the ordinary person. Industry does not want a device that can do a little bit of everything. It works instead on developing processes, materials, and systems that can perform specific tasks in a highly precise manner — tasks that can be programmed and reproduced at industrial scale.

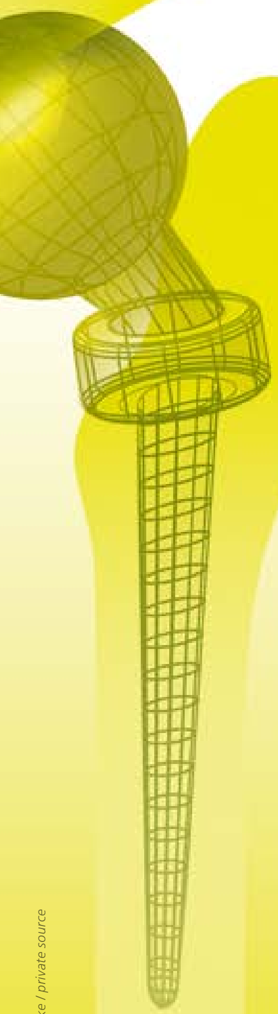
In recent years, the major progress made in the realm of laser additive manufacturing (LAM) has gone largely unnoticed. Based on rapid prototyping, additive manufacturing has become firmly established in a broad range of areas thanks to the geometric freedom it allows. It is also common now for small-scale production and in tool manufacturing. Rapid manufacturing and rapid tooling are key concepts here. Especially in the aerospace and automotive industries, experts are hard at work to develop industrial processes based on innovative process designs. Taking a look at the other end of the scale, medical technology research is attempting to push back the boundaries of the feasible.

One of the aims of medical technology is to make components compatible with the natural biological surroundings in which they are used. Today, computer tomography provides high-resolution 3D images prior to complicated surgery. These precise scans of the patient's bones, organs, and extremities make it possible to produce made-to-fit surgical implants and prostheses. Surgical aids such as templates for the operating room are already commonplace, as are tools designed to support the planning of surgical interventions and the fitting of implants. One of the first implants to be made in large numbers using LAM is the acetabular prosthesis made by Lima Corporate s.p.a. Its porous surface structure is designed to facilitate tissue integration, albeit with the additional help provided by a system that exposes the implant to electron beam radiation. Literature on LAM regularly reports on customized implants also being used in oral, jaw, and facial surgery. Dental implants are already being produced at large scale using this technology.

The research aims to develop industrial processes for made-to-fit surgical implants and other prostheses.

Despite the progress that has already been made, further work is needed on the complex software infrastructure required for the widespread use of LAM implants. Moreover, production processes still need to be certified to meet EU Directive 93/42/EEC. At the moment, industry and research are working at full speed to close gaps with regard to production technology, software, and eligibility for certification. In so doing, medical technology is not only conducting research close to the applications. The needs in this sphere are also initiating a great deal of basic research. Here, experimentation focuses on processing hard-to-weld, bioresorbable, or functional materials. For instance, the Surface Technology Group at Laserzentrum Hannover e.V. is currently researching laser additive processing for magnesium powders. These investigations are part of a project carried out jointly by the Ger-

The work on laser melting of magnesium alloys is funded by the German Research Foundation DFG under project code HA 1213/77-1. The work on laser melting of NiTi shape memory alloys is funded by the German Federal Ministry of Education and Research BMBF as part of the GentleCI project under project code 16SV3944. The work on SLµM in the REMEDIS joint research project is funded by the German Federal Ministry of Education and Research BMBF as part of the program "Leading-edge Research and Innovation in the New German Länder" (project code: 03IS2081).



man Research Society, the Department of Oral and Maxillofacial Surgery at Hannover Medical School, and the Hannover School of Veterinary Medicine. The aim of the project is to enable the production of hybrid implants with controlled bioresorption for nearly natural reconstruction of craniofacial defects.

Such an implant could initially replace the injured parts of bones and support reconstructed tissue where the bone itself is missing. Over the course of the healing process, this implant disintegrates and makes way for the regenerating bone cells. This also means that the forces encountered by the bone are gradually transferred to the new bone as healing progresses. The aim is to manufacture the resorbable magnesium body using laser additive methods. Once produced, it is coated with a polymer. Where necessary, the compound is reinforced with a titanium component. To speed up and improve tissue integration, the hybrid implant is populated with bone cells in the laboratory at the very start.

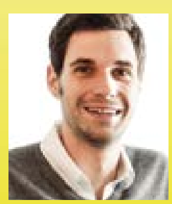
Micro-processes provide new solutions for transporting of active substances and for functional surfaces.

The biggest challenge of laser additive manufacturing for three-dimensional components made from magnesium is the small difference between the melting and vaporization points. Under normal ambient conditions, selective laser melting (SLM) will only be able to produce a simple fusion track and exhibit a strong tendency toward "balling". The strategy employed in the project aims to carry out the process under elevated pressure, increasing the spread between the melting and vaporization points. With support provided by the SLM Solutions company, a commercial laser melting system was modified and equipped with a process chamber developing 2 bar of gauge pressure. The first three-dimensional test structures have already been produced, and this is a major step toward achieving the project's aim.

The Surface Technology Group also focuses on laser-based additive microprocessing, including selective laser micro-melting (SLμM) and laser micro-deposition welding (μLMD). Here, it is possible to build up medical micro-implants or to lend a functional structure to surfaces. Drug delivery systems made of surgical steel for the direct administration of medication to target tissue is one area of focus, as is the processing of the shape-memory alloy Nitinol — used in micro-actuators, for instance.

As a result, the application determines the process, involving either a two-stage SLμM powder-bed process or the single-stage μLMD. Both approaches create objects without pores or imperfections, incorporating structures within the range of 30 to 40 μm in size. In contrast to SLM, μLMD does not require a powder bed, as it introduces the powdered additive directly into the processing zone. μLMD is better suited to creating surface structures on complex freeform surfaces or on relatively large components. When it comes to producing a high number of components and complex undercut 3D structures, the SLμM process shows significant benefits.

Recent events and publications indicate that laser additive manufacturing is well on its way to being used for industrial applications, either as an alternative to conventional process approaches, or because it opens up new opportunities that can only be realized with this technology. While the maturity and penetration of various processes are clearly divergent, it is important to note that SLμM und μLMD are in the early stages of development. Ongoing developments have encouraged interaction between users and research, contributing to a clearer picture of the requirements of industry and of the direction that new research must take. In the years to come, significant progress can thus be expected in the realm of laser additive manufacturing. ■



***Christian Nölke** is head of the Surface Technology Group at the Laserzentrum Hannover e.V. He is active in a number of committees, among them the FA13 "Generative Processes" technical committee of the German Welding Association (DVS). He also works on this topic for the standards committee of the German Institute of Standardization (DIN), where he is co-drafting the DIN ISO/TC 261 standard. Contact: c.noelke@lhz.de*

"Everyone had a laser"

More than almost anyone else, Dr. Dietrich Freiherr von Dobeneck has been a trailblazer in electron beam welding. In this interview he explains his driving passion for technology and his determination to compete with lasers.

What was your first contact with electron beam welding?
The first time I heard about electron beam welding was in an article in *Spiegel* about the 1969 Russian Soyuz Project. The magazine described welding experiments in space with a manually controlled electron beam gun. I read a letter to the editor, in which Dr. Steigerwald recalled his inventing this technique. My response was to apply to study beam technology with Steigerwald and spent five years learning the nuts and bolts of how it all worked. As a physicist I enjoyed the complexity of the systems and processes and found it a welcome challenge.

Was it this passion for technology that prompted you to set up your "pro-beam" company?
Steigerwald's laboratory was a huge financial drain because every customer interested in buying a machine first required proof that this welding process would actually solve the problem at hand. Our experience back then was still fairly limited, so making this promise required a major effort, every single time. That's why, in 1974, I bought the laboratory's two machines and took over responsibility for that specific task. Steigerwald sent his customers to me and they paid me to provide them with an impartial assessment. Those companies that had only limited need for this kind of manufacturing stayed with us as contract customers.

Lasers were still relatively new at that time. What made you think you could compete with them?
"Innovation comes from passion, not from complacency." That's a quote from Ferdinand von Steinbeis and it fits nicely in this case. At the beginning of my career, I was frustrated by many aspects of the electron beam welding processes and the equipment because they kept us from creating a commercially successful system. What we needed were innovations that could help us compete against other technologies, especially against lasers. In response to increasing refinement of laser welding in the 1990s, our team redoubled its efforts to find improvements.

Why didn't you simply switch to lasers if they were becoming so hip and trendy?
We actually got interested in lasers quite early on, and bought our first laser back in the early 1980s. Initially we used it for cutting and also to fasten components for electron beam welding and drilling. As the years went by, we purchased more of them until we eventually had four CO_2 lasers with power levels ranging from one to 12 kilowatts and a solid-state laser with 150 watts of output. We used the two high-power lasers for welding in situations where our vacuum chambers were too small. But — when we saw that competitors offering laser processing services had mushroomed in just about every university and city — we made a decision to concentrate on electron beam technology and withdraw from the laser business altogether.

Was it that decision that ultimately shifted your focus to systems engineering?
No, that came earlier. Fairly soon after we started offering welding and drilling services, we began to modify our systems and to buy second-hand machines, tailoring them to suit functions anticipated for the future. Prices were being driven down, and to survive you had to make all the process stages faster. One of our most important goals was to reduce the evacuation time. By developing our airlock concept, we were able

Dr. Dietrich von Dobeneck founded pro-beam—a company that specializes in electron beam welding—in 1974.

Simon Koy

to shift the evacuation process into non-productive time. We couldn't get hold of the machines we wanted on the market, so we ended up building them ourselves, initially for our own needs — starting back in 1986 — and then for sale from 1999 onwards. Up until then, we had struggled with the problem of losing our contract customers as soon as their batch sizes became big enough for them to buy their own machine from a competitor.

How did pro-beam develop from there?
Our next development stage was in the field of beam generators, in other words electron optics and fast and dynamic control of the beam spot. Since the maximum welding speed attainable is often determined by the material being welded, we learned to weld using multiple beams simultaneously. That not only reduced the time needed for the welding process, it also let us influence and minimize distortion by creating symmetrical heat input. We automated the positioning of the parts by getting the beam to find its way to the welding point itself, and we integrated quality assurance as an in-line process. Those steps enabled us to achieve global technological leadership within a period of just a few years.

So how's this sector doing nowadays? What's the status of electron beam welding in industrial applications?
There is a handful of companies that operate 40 or more electron beam machines to provide mass-produced parts to the automotive industry. And there are a few specialist companies, primarily in the aerospace business, which focus on hard-to-weld materials such as titanium, cobalt and zirconium alloys. They need a vacuum to protect their reactive materials from contamination. Ultimately, of course, it's the high precision of electron beam welding that permits the development of new design variants. There are certainly plenty of good applications out there, but the hard part is tracking them down. One very sustainable approach, and one that we have invested in heavily, is to make engineers familiar with the details of the process.

> *"It all stemmed from my frustration with many aspects of the electron beam welding processes and equipment."*

How has the relationship between electron beam welding and laser welding developed, in your opinion?
There was a time when electron beam welding offered better weld quality in terms of heat input, distortion and spatter formation. Lasers offered a more economical welding process for lower penetration depths — in sheet metal, for example — while electron beam welding was more economical for large cross-sections. But the development of disk and fiber lasers has changed things. The energy efficiency of solid-state lasers has improved markedly, from two to 30 percent, and weld quality is also getting very close to what we can achieve with electron beam technology. However, the investment costs per kilowatt of laser output have increased, whereas the costs for electron beam welding have fallen. So it's still true that you can achieve lower unit costs with the electron beam as weld depth increases. We've responded to that fact by building two large-scale systems for our contract work. These are capable of joining workpieces up to 12 meters long and weighing up to 50 tons. Depending on the material, they can achieve weld depths of up to 150 millimeters.

What does the future hold for these two methods?
Lasers and electron beams will continue to follow their parallel trajectories and will both play legitimate and useful roles in the welding market of the future. Of course, new developments will always influence the markets and shift applications from one ballpark to the other. But the important thing is to keep moving forward and to ensure that Germany maintains its position as a leading technology developer and exporter of these two sophisticated welding technologies.

pro-beam has joined with TRUMPF to work on a research project run by the Technological University at Braunschweig. The project aims to combine both techniques. We've already reported on how this could provide a boost for laser technology, but what benefits does it hold for electron beam welders?
Two key advantages that have already been identified in systems that combine both techniques are the savings that can be made on shielding gases — a vacuum is cheaper than argon or helium — and the reduction of weld spatter, which is often costly to remove. A laser can use beam deflectors to deliver a beam to several different welding stations, which is something you can't do with an electron beam. There are clear advantages for the laser, but the benefit for us as a service provider is that we're not tied to just using an electron beam. We can also take advantage of this new process with the laser, just as we have done in the past. Plus, we can offer our experience with fast vacuum processes. It's definitely a win-win situation.

Even though the theoretical advantages are pretty obvious to any user, we need to carry out tests to find out if there are any limitations when it comes to practical implementation of the technology. One of the goals of our mutual development project is to determine the costs and cycle times. Only then will we know whether this combination can be profitable and to what extent it could reduce costs for specific applications.

Simon Koy

LIFE Dietrich von Dobeneck studied plasma physics at the Technical University of Munich. His first job in 1969 introduced him to the world of electron beam welding. He set up the pro-beam company, a symbol of both his passion and his profession.

LASER Lasers have always fascinated him. Faced with the decision of whether to focus his future work on photons or electrons, he chose electrons.

LIFEWORK The airlock loading technique, welding with parallel beams, in-line process monitoring. Over the last five decades of electron beam welding, virtually all the major advances in electron beam processes and systems have stemmed from Dobeneck.

In spite of the benefits you've described, electron beam welding still feels like something of an outsider among welding techniques. What can be done to change that?
Well, one way of getting technological processes more widely known in industry is to make sure students learn about them while they're still at college. We've been steadfastly pursuing that goal over recent years, with considerable success. Ten European universities now have modern electron beam facilities for research and educational purposes, and the first students to benefit from them have already moved into industry. The required impetus and co-funding came from the foundation I established in 1995, though the majority of the costs have been covered by the public sector. Electron beam technology hasn't enjoyed anything like the levels of funding plowed into laser development in the 1980s and 1990s, but I tend to think that private initiative and shouldering risk are actually preferable to the windfall effects of public subsidies.

When you set up your foundation, were you aiming specifically to raise the visibility of electron beam welding?
Making people in industry more familiar with electron beam technology is one of the key objectives of the foundation, along with the goal of promoting new manufacturing methods. But I also had other reasons for establishing a foundation. I wanted to know that the company would continue after I retired rather than simply selling it. That meant I needed to find a partner who would continue to pursue my interests, and the statutes used to set up the foundation were a good way to achieve that.

So retirement hasn't lessened your enthusiasm and involvement as an electron beam pioneer?
If you really want to get something done in life, you need a clear vision. But you also need the strength and, above all, the perseverance to achieve that vision. I have an undiminished passion for technology as a whole and I take enormous pleasure in seeing how my successors have shared my enthusiasm for electron beam technology and made major leaps forward over the last 10 years. My position as the chairman of the foundation keeps me in touch with the research work and the proceedings at conferences on a broad range of projects. Nevertheless, retirement has certainly given me more free time and has enabled me to pursue some of my other interests, such as local history and culture. For example, I'm working on setting up a monument to the world's first pipeline, the brine pipeline from Reichenhall to Traunstein, which was built in 1619. As you get older you have to accept the fact that projects take longer than they used to — so there's no time left to think about retirement in its traditional sense! ■

"That led us to build systems for our job shop operations, capable of joining workpieces up to 12 meters long and weighing up to 50 tons"

Contact:
pro-beam AG & Co. KGaA,
Phone +49 89 899233-0, info@pro-beam.com

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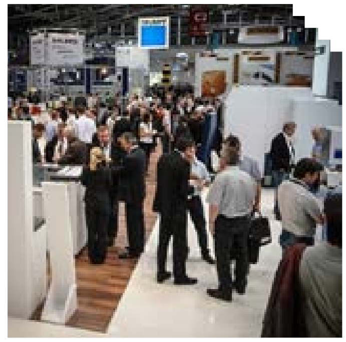
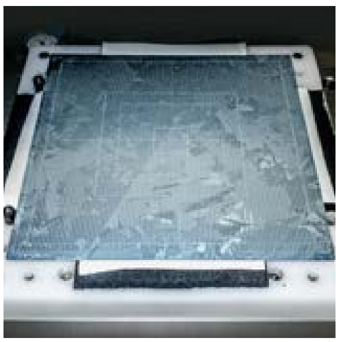
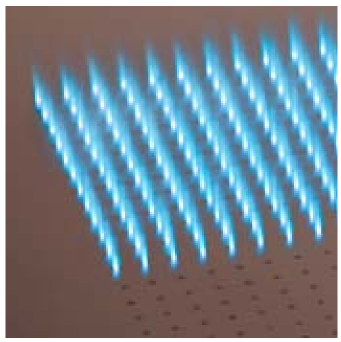
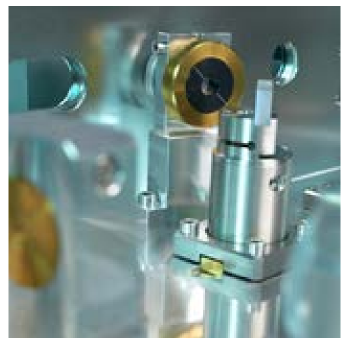


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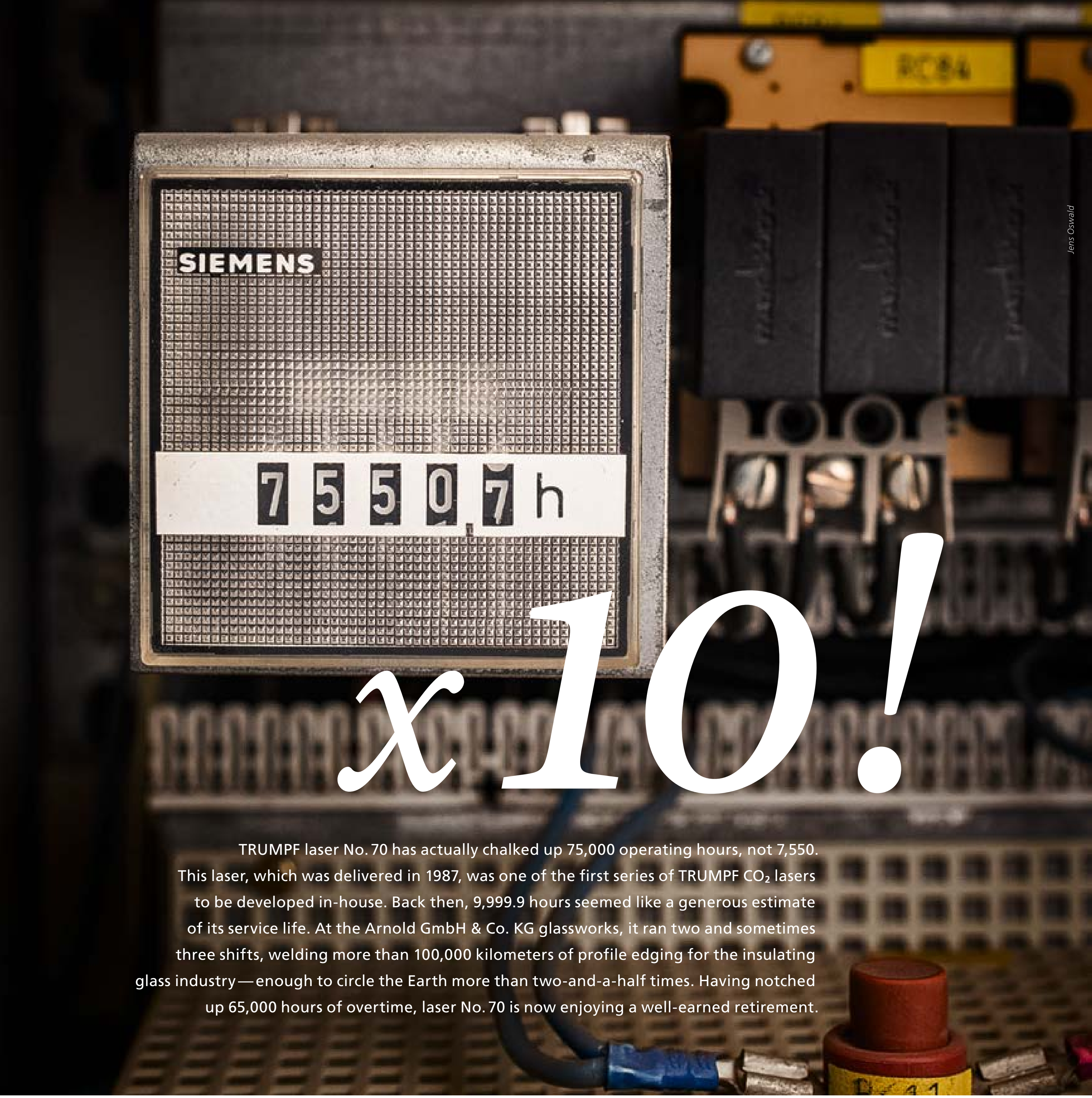
Gernot Walter

Where's the laser?

IN BEER AND COLESLAW: Imagine a beautiful summer's evening in your garden, just as the sun begins to set. Its warm rays lend sparkle to your golden glass of cold beer, topped with a foamy head. Bowls of coleslaw and potato salad are set out and ready, next to the barbecue. The role the laser played in creating this perfect setting might not be immediately clear. But wait — the stainless steel grater used to prepare the vegetables was made by Rösle, which means that those elegant, almost invisible welds were made with a laser. And bundled light also shaped the edge of your glass, now overflowing with the froth on the refreshing beer. A laser scribed the glass and then blasted it with the thermal energy of a defocused beam — without creating internal stresses and microfissures. The result is a smooth edge that complements the smooth taste of the beer — with no finishing or polishing work required. Cheers!



Jens Oswald

x10!

TRUMPF laser No. 70 has actually chalked up 75,000 operating hours, not 7,550. This laser, which was delivered in 1987, was one of the first series of TRUMPF CO_2 lasers to be developed in-house. Back then, 9,999.9 hours seemed like a generous estimate of its service life. At the Arnold GmbH & Co. KG glassworks, it ran two and sometimes three shifts, welding more than 100,000 kilometers of profile edging for the insulating glass industry—enough to circle the Earth more than two-and-a-half times. Having notched up 65,000 hours of overtime, laser No. 70 is now enjoying a well-earned retirement.

TRUMPF

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