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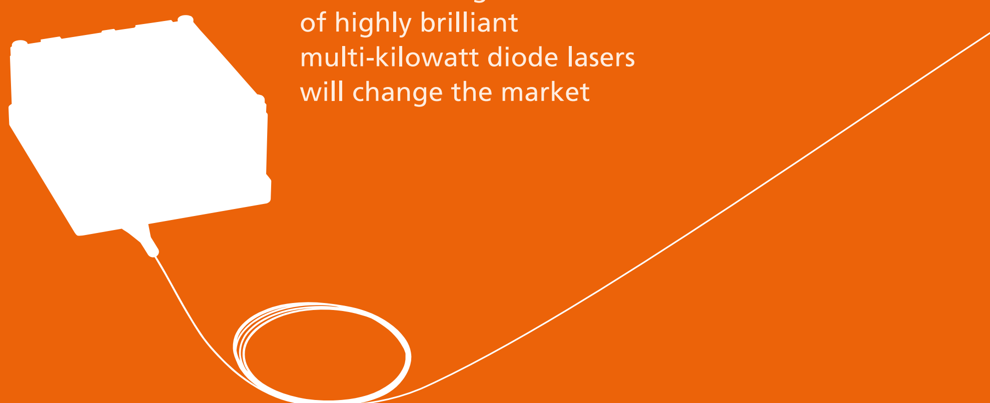
Laser Community

THE LASER MAGAZINE FROM TRUMPF

ECONOMIC MIRACLE

How the first generation of highly brilliant multi-kilowatt diode lasers will change the market



WWW.TRUMPF-LASER.COM

WHAT WILL BE

PROF. HANS JOACHIM EICHLER LOOKS AT THE FUTURE → Page 30

Cool Wet

Laser perforates watering hoses

Stress Test

Philips put laser marking to the test

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Let's talk money. Technology companies prefer to talk about the quality and functionality of their high-tech products; however, we can get some surprising insights when we look at them from a financial perspective. For example, the cost per kilowatt of laser power has almost been cut in half in the last four years. One reason for the cost savings is due to the simple fact that there is large number of lasers on the market. The greater benefit occurs, however, because innovation makes the lasers more efficient.

These innovations mean that users don't have to deal with the complexity of the high-tech machines. Only those who are interested in the technology need to dive into the secrets of laser physics. Those who are not can simply switch the laser on and start working — without giving a second thought to what makes it work.

Laser systems for material processing are achieving up times of over 99 percent — with considerably reduced maintenance costs. And behind these machines is hidden technology that

Count on the Laser !

will pay off. Such innovations greatly reduce energy consumption, relieve the budget and allow for efficiencies of 30 percent with the highest beam quality in the disk laser — and more than 40 percent in our new diode lasers.

Let's look a little more closely at the money aspect of all this. The cost of acquiring the equipment is actually only one side of the coin. Looking at the laser processes, you can easily see beyond the initial investment costs. This is where things become very clear. Generally speaking, more benefits are achieved with lasers than with "conventional" manufacturing solutions. Benefits of working with lasers include gains in productivity, process dependability, and quality and design freedom as well as weight and material savings. These advantages also frequently apply to applications for which there had been no such expectations — resulting in the proverbial pleasant surprise! Count on the Laser. It will be worth your while.

JENS BLEHER

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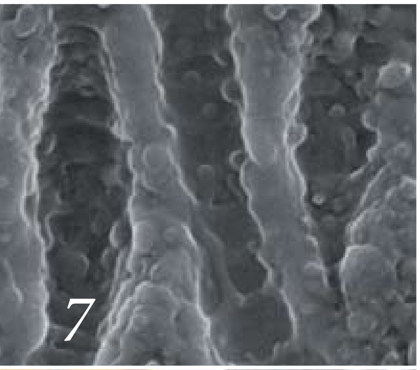

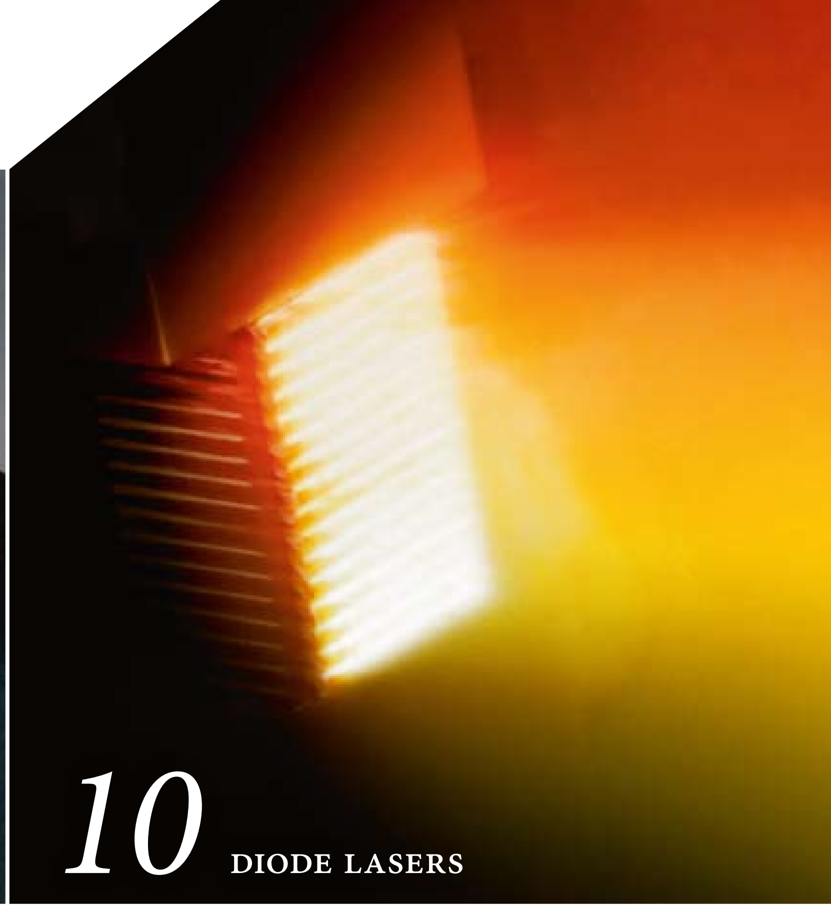

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2009

REPORT

SCIENCE

PEOPLE

S P O T

--- CLEAN THE BEAM

The **Laserzentrum Hannover** plans to determine the emissions caused by laser welding and soldering. The result will help plan more reliable and cleaner processes. *www.lzh.de*

--- INTERNATIONAL BRIDGE BUILDING

For the first time, the **OptecNet Deutschland e.V.** has provided information on optical technologies from Germany in Moscow, Russia, to aid bridge-building for small and medium-sized companies. *www.optecnet.de*

--- CALL FOR PAPERS

The **work group Lasertechnik e.V.** and the **European Laser Institute ELI** are calling for papers for the Innovation Award Laser Technology 2010. To be in the running for an award, the benefits of the work must be identified and proven. *www.innovation-award-laser.org*

--- MORE LASER WELDING

The trade publication **Industrial Laser Solutions** plans to actively promote laser welding as a welding method. Unlike other laser methods, welding is still behind in terms of its potential. *www.industrial-lasers.com*

--- PULSE MONITOR

A new technique, developed by the **Max-Planck-Institute for Quantum Optics,** allows for a complete characterization of single ultra-short laser pulses by measuring energy and direction of electrons released in xenon. *www.mpq.mpg.de*

--- LASER DEFENDS AGAINST MOSQUITOS

Researchers from the **University of Houston,** Texas, rely on lasers to fight malaria and yellow fever. Small lasers set up around threatened villages detect and shoot at mosquitos. *www.uh.edu*

--- STANDING ON ITS OWN TWO FEET

The Singapore Chapter of **SPIE** spun itself off from SPIE. The new **Optics and Photonics Society of Singapore (OPSS)** plans to intensify exchanges between science and industry. *http://opssg.org*

“Optical technologies are the key for sustained energy savings”

Martin Goetzeler, chairman of OSRAM GmbH and a spokesperson for the Photonik 2020 initiative

Light is the future

The Photonik 2020 initiative is to strengthen Germany’s leading position

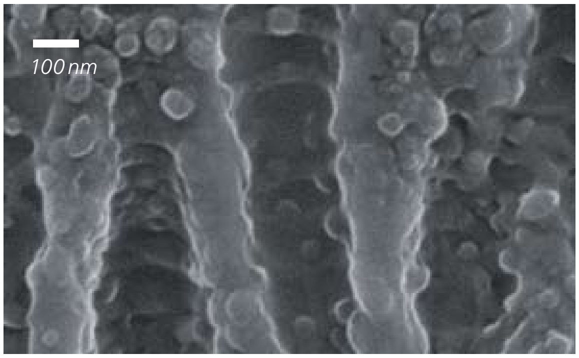
Germany is the international leader in optical technologies. Representatives of German business and science intend to further reinforce this position with the **Photonik 2020** initiative. **Martin Goetzeler** is chairman of the board of **OSRAM GmbH** and a spokesperson for the initiative. “Optical technologies are the key for sustained energy savings,” he says. In a memo to members of the German parliament, representatives of the Photonik initiative expressed the need for a process to be introduced in business, science and politics that takes optical technologies to new horizons. In light of the current economical and political challenges, the German photonics industry has underscored its readiness to continue the public-private partnership model that began between industry and the German government in 1999 / 2000. Members of the initiative are **OSRAM GmbH, Robert Bosch GmbH, AUDI AG, Carl Zeiss AG, TRUMPF,** the **Max-Planck-Institute for Quantum Optics,** the **German Physical Society** (Deutsche Physikalische Gesellschaft – DPG), **BASF SE,** the **Fraunhofer Institute for Applied Optics and Precision Engineering IOF** and **Daimler AG.**

The aim of SOLASYS is to create parity between conventional and solar power by 2015.

Sunny outlook

More affordable solar power with laser technology

The key to lower cost solar power lies in solar cells that can be manufactured more efficiently for less. A cooperative effort between 10 companies and institutes, coordinated by the **Fraunhofer Institute for Laser Technology ILT,** intends to make this happen by increasing the use of lasers in production. The alliance’s project – **Solar Cell Laser Processing Systems of the Next Generation** (SOLASYS) – shows how current methods can be improved and new processes integrated into industrial production. The goal is to create parity between conventional and solar power by the middle of the next decade.



Gaze into a future world: Laser created nanosized ripples on steel seen through a scanning helium ion microscope.

At the University of Twente Prof. Bert Huis int 't Veld decodes nanostructures.

"In the sub-100 nm-range there is an explosion of methods"

Tiny parts – giant challenge. Professor Bert Huis in 't Veld discusses short pulsed lasers for nano-machining

How small can it get in nano-machining?

Lasers are widely used for micro machining in numerous applications whereas sub-micron laser machining or nano machining exist only in a lab. For example 40 nm-wide grooves are formed in synthetic diamond with femto second laser processing, and in glass features as small as 20 nm have been reported. And apart from removing material on a micro or nano scale, laser-assisted material deposition has great potential.

What problems currently must be solved?

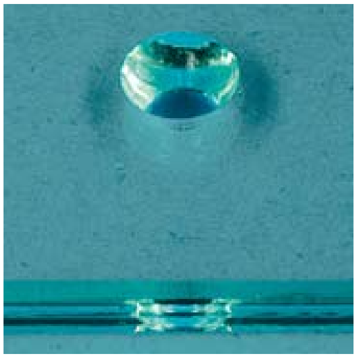
There are two major constraints for laser nano-machining. Pulses longer than about 10 pico seconds generate significant thermal effects that limit accuracy, and for real nano machining the diffraction limit must be overcome. Recently, there has been an explosion of methods to achieve features in the sub-100 nm range. A promising approach is the exploitation of multiphoton absorption: two or more photons are absorbed simultaneously. In this way only a fraction of the spot size is above the threshold fluence.

How are the future prospects of this technique?

Much work is yet to be done to increase the repeatability and throughput to make the methods attractive for commercial applications. Improved understanding of laser material interaction and implementation of advanced control techniques for working simultaneously with multiple beams must occur before lasers are declared the tools of the future for nanotechnology. At Twente University, I am studying the laser material interaction, especially the origin and growth of self-organizing nanostructures. We have obtained regular structures with a wavelength of 150 nm and an amplitude of about 10 nm. This is a good illustration of the state of the art in laser micro / nanomachining.

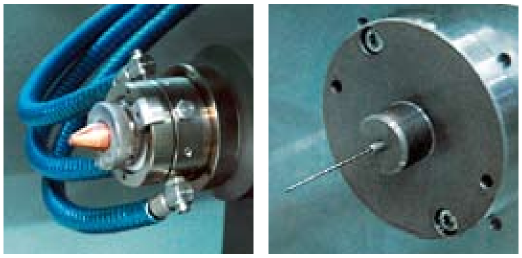
Contact: Twente University,
Prof. Bert Huis in 't Veld, Telephone +31 53 489 3596, A.J.HuisintVeld@ctw.utwente.nl

A thermal trick "breaks" the drill hole through the glass



Glass drill

A research project at the Laser **Zentrum Hannover e.V. (LZH)** addresses the laser drilling of glass as an inexpensive and environmentally friendly alternative to mechanical machining. The method is based on a thermal strain build up in the glass by the laser that leads to controlled crack formation. This crack separates out a cylindrical section of glass. Advantages: Coolant is not necessary and cleaning the glass after drilling is not as expensive or time-consuming. *www.lzh.de*



The laser (left) pre-drills; the mechanical drill (right) expands the hole.

Hot combo

For the first time ever, researchers from the **Technical University of Dortmund** have combined a conventional deep-drilling machine and laser technology. This is an unusual combination because, depending on the process, deep-drilling equipment is operated wet – with oil. Due to fire hazards, the machine processes have to be completely isolated from one another. However, this combination offers many advantages: Boring bushes are no longer necessary, process steps are saved and difficult, hard-to-machine materials can be processed better. *info@ifs.de*

NETWORK NODE

Laser technologies are among the core fields promoted by SPIE, an international optics and photonics society. SPIE advances light-based research, through conferences, exhibitions, educational programs, and publications. SPIE provides information on high-power diode and solid state lasers, commercial and biomedical applications of ultrafast lasers, and laser applications in microelectronic and optoelectronic manufacturing at conferences held annually in North America, Europe, Asia and Australia. SPIE organizes approximately 25 major events each year, including SPIE Photonics West held each January in California. Approximately 17,000 new conference proceedings and journal articles are added annually to the SPIE Digital Library, which contains 270,000 full-length articles. The online SPIE Newsroom is continually updated with technical articles authored by researchers and news for the worldwide optics and photonics community. SPIE contributes 1.6 million US-Dollars annually in scholarships, grants and other programs supporting research and education.

www.spie.org

Wave of success

MEYER WERFT Laser Center sets new standards in shipbuilding

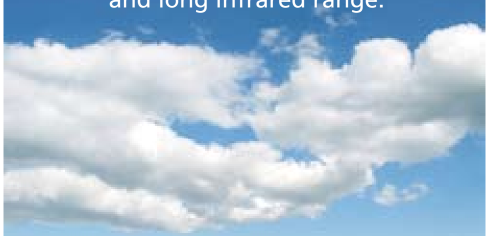
A glance at the new laser center. MEYER WERFT has a total laser output of 104 kilowatts.

"Only by using high technology will shipbuilding be sustainable for the future," say MEYER WERFT's engineers from experience. The **MEYER WERFT Laser Center** is a step into this future. The company has invested 80 million Euros into innovative laser technology that has transformed a previous steel pre-production facility into a high-tech, high output operation. With a laser output totaling 104 kilowatts, the MEYER WERFT Laser Center has become one of the largest laser centers in Europe. Steel parts will also soon be cut here in heavily automated serial production using disk lasers. "Our laser center will manufacture even more innovatively and efficiently than before," explains **Bernard Meyer,** managing director of MEYER WERFT. The machine fleet also includes two TruDisk 10003 lasers and one TruFlow 12000 from **TRUMPF.** The disk lasers are being used for laser hybrid welding. They make the process more flexible and offer considerable advantages in processing larger and larger sheets for shipbuilding. *www.meyerwerft.com*

Quantum Leap

Everything clean?

Quantum cascade lasers facilitate very fast and sophisticated gas and liquid analyses in the medium and long infrared range.

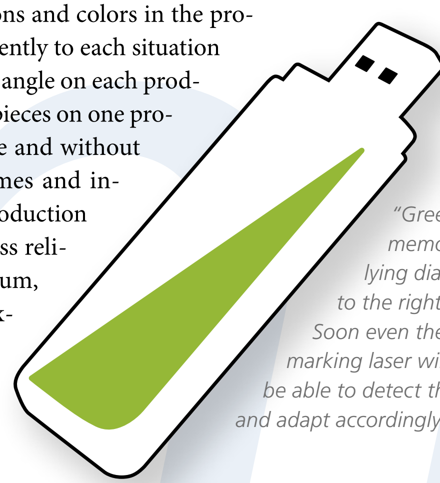


1994

The marking laser sees it all

TRUMPF Brazil sponsors study of sensor-supported laser marking

Through the sponsorship of **TRUMPF Brazil** and **Siemens**, students at the **Universidade Paulista** in Brazil h ave developed a process in which a marking laser detects various objects, their positions and colors in the production line. The laser adjusts itself independently to each situation and places appropriate lettering at the correct angle on each product. With this system, different kinds of workpieces on one production line can be marked at the same time and without hands on retrofitting. This reduces downtimes and increases machine productivity and therefore production capacity. A monitoring system ensures process reliability and quality. "With this process, aluminum, steel and also polymers can be marked," explains Anderson Oliveira Ferreira, TRUMPF Brazil employee and one of the students involved in the study. *www.unip.br*



"Green memory stick, lying diagonally to the right": Soon even the marking laser will be able to detect this and adapt accordingly.

Dr. Jochen Schneegans at the EALA would like to see "more presentations from integrators and plant builders."

Fresh air

Dr. Jochen Schneegans, director of process development at **FFT EDAG Produktionssysteme GmbH & Co. KG** explains why he likes to attend the **EALA (European Automotive Laser Application),** but would like to see a breath of "fresh air."

What could make the EALA even more interesting?
Because we produce numerous laser systems for the automobile industry, I have been a regular visitor and have also given many presentations there. The EALA offers an excellent platform for sharing information and I will definitely attend again. In general, the EALA should raise its profile more in the future because it holds an increasing number of conferences and congresses on lasers. In addition, suppliers as well as integrators and plant builders should be encouraged to give lectures and presentations. They are currently the missing link in the chain.

WORTH A TRIP

LASER 2009

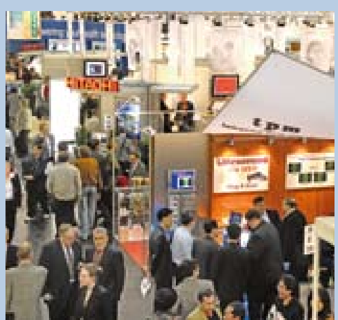
Already the 19th time — but always new, the **LASER. World of Photonics** trade fair will once again be held at the **Neue Messe München,** Germany, from June 15 to 18, 2009. The technology trade show exhibits the complete range of up-to-date applications for laser technology and is the meeting place for international market leaders, decision-makers and users from industry, research and development. The comprehensive conference and accompanying events, combined with examples of applications that can be tried at the show, has turned the unique trade show into one of the leading events for optical technologies worldwide.

FFT EDAG Produktionssysteme GmbH & Co. KG; COMPAMED / Messe Düsseldorf; PRODUCTRONICA / Messe München; Meyer Werft; Gernot Walter; WIP-Renewable Energies

CALENDAR

EU PVSEC: The 24th European Photovoltaic Solar Energy Conference

PRODUCTRONICA: Presentation and communications platform for international electronics production



COMPAMED: High tech solutions for medical technology

MACH TOOL
June 15–17, Posen, Poland
Machine Tools
www.machtool.mtp.pl/en

LASER
June 16–19, Munich, Germany
World's leading trade fair for optical technologies, www.world-of-photonics.net

SCHWEISSEN & SCHNEIDEN
September 14–19, Essen, Germany
World trade show for cutting and joining technology, www.schweissenundschneiden.de

EU PVSEC
September 21–25, Hamburg, Germany
www.photovoltaic-conference.com

FAKUMA
October 13–17, Friedrichshafen, Germany
International trade show for plastics processing
www.fakuma-messe.de

WORLD PHOTONICS EXPO
October 09–November 05, Gwangju, Korea
"Light, opening the Future." The Expo will be the first of its kind in Korea.
www.photonics-expo2009.org

ICALEO
November 02–05, Orlando / Florida, USA
28th International Congress on Applications of Lasers & Electro-Optics, www.icaleo.org

PRODUCTRONICA
November 10–13, Munich, Germany
www.productronica.de

FABTECH
November 15–18, Chicago, USA
North America's largest metal forming, fabricating and welding trade show.
www.fmafabtech.com

COMPAMED
November 18–20, Düsseldorf, Germany
www.compamed.de

BLECHEXPO
December 01–04, Stuttgart, Germany
International trade show on sheet metal processing, www.blechexpo-messe.de

ECON

Diode stack: Once they became a pump source, laser diodes initiated the first efficiency revolution for solid state lasers. Now as a highly brilliant diode laser, laser diodes are entering a second revolution.

Lawrence Livermore National Laboratory / Gernot Walter

Tiny and cost-effective laser diodes have been around for 20 years. Since their inception, one thing has become clear: If we are successful in achieving the beam quality necessary for key industrial applications using diode lasers, everything will change.

OMIC MIRACLE

To explain the significance of this technology, let's take a look at a salt shaker. It is shaped like a cylinder, is about 30 millimeters in diameter and about 70 millimeters high. It has a volume of about 50 cubic centimeters. Now let's shake the salt out and fill the shaker with high performance laser diodes. Sitting on the table encased in this salt shaker is about one megawatt of laser power that we can simply stick in our pockets and take with us. Theoretically, of course. We would also need to include in the shaker the power supply, cooling system, beam guidance and all the other unavoidable trappings. One megawatt in a salt shaker. No wonder the laser diode has kept researchers and developers in the field of materials processing busy since its inception. This is because this tiny laser holds a mighty potential: miniaturization. Each diode is an independent laser source. If the diodes are successful in eliciting enough power to weld and cut sheet metal, a new beam source would emerge for these key industrial applications. Even with all those invisible components, this would be one source that would be so uncomplicated, compact, efficient and inexpensive that it would call into question many of the prevalent conventional methods and even existing laser technologies.

The charm of the diode Laser diodes are the most compact design for a laser beam that there is. They generate laser light from within themselves and directly from the electrical power. With modern chip production, they can be manufactured inexpensively in large quantities. They are solid-state and therefore robust. They have an immense service life that is continuing to lengthen. Laser diodes are tremendously efficient because they convert the power used directly into laser light. Fifty percent energy use is the rule, but over 80 percent is possible. A lamp-pumped rod laser converts about 5 percent of the power from the socket into performance on the workpiece. The very efficient disk and fiber lasers create 30 percent power, mainly due to the diodes that pump these laser types.

So far, the beam quality has limited diode lasers to niche markets

Two disadvantages come up directly against these benefits which are, unfortunately, critical for industrial materials processing. One is that the output of the diodes cannot be increased arbitrarily. Like all semiconductor components, they heat up. All at once, along with the emissions output, the charge from the resonator mirror dissipates directly onto the tiny diode surfaces. Though they are the only power emitters, the high performance laser diodes nevertheless achieve up to 20 watts of output. If the diodes are arranged in bars and stacked together, they can be used to construct high performance beam sources; these function primarily as the pump sources. In niche applications, as direct diode lasers with several hundred watts of power, they can also weld plastics or remelt metal surfaces — with a broad focus mark and a high output — as well as solder sheet metal. But for deep welding or even cutting metal sheets, diodes have not worked very well so far. Their beam quality is not good enough. As a rule, deep welding requires about 30 millimeter *millirad or more. For precise cutting, single digit beam parameter products also are a requirement. The beam of a high performance laser diode, however, has two different beam parameter products, depending on the viewing direction, of which one amounts to several hundred millimeters *millirad.

The cross with the beam quality The "difficult" beam quality of the diodes is directly rooted in its wonderful, miniscule size. The view through the magnifying glass shows a narrow strip of gallium arsenide (GaAs) that has the approximate proportions of a package of chewing gum. Like that package, it consists of several layers. On the border between two layers — between the silver gum wrappers, so to speak — positive and negative charge carriers meet and release the photons. These "flow" along the layer borders through the GaAs strips, are partially reflected and exit on the face as a laser light. The efficiency with which the power is converted into light greatly depends on the thickness of these layers. For high performance diodes that are required for direct diode lasers, the entire active

Thorge Hammer is responsible for beam welding techniques at Volkswagen in Wolfsburg, Germany.

"In 10 years, a multi-kilowatt laser could be as small as a DVD player"

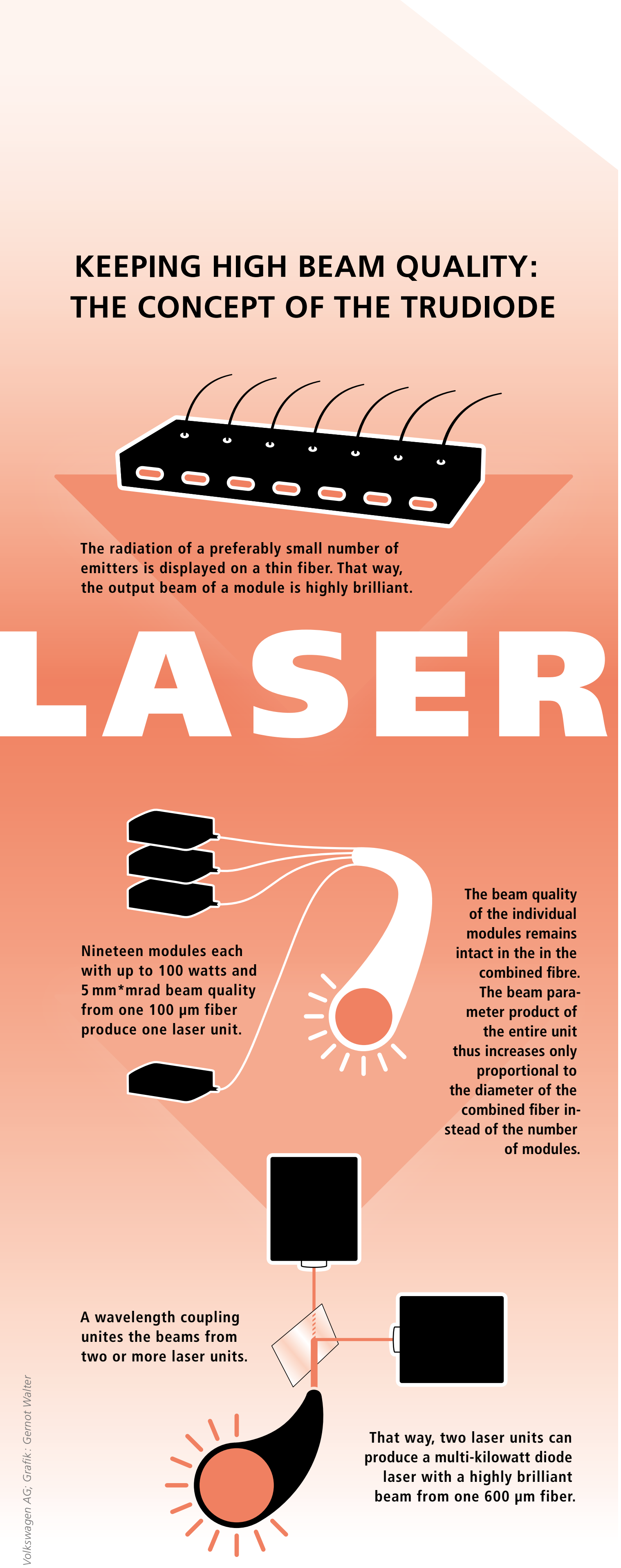
DIODE

You have been working with diode lasers for a long time. Why?
For our laser soldering applications, the beam quality of diode lasers is good enough. But, in contrast to the Nd:YAG lasers, we save considerable operating costs because the high efficiency of the diode laser's source helps to save energy.

Do you see potential for new laser applications?
In the high performance range, replacing established lamp-pumped laser sources is under discussion. Due to the diode laser's high level of efficiency and the accompanying savings in operating costs, the diode laser is an attractive replacement for existing laser sources.

What role will diode lasers play in 10 years?
The last 10 years have shown that the development of laser sources was always good for surprises. The power, beam quality and investment costs of Nd:YAG lasers have been developed in unimaginably low ranges. The same can be expected of diode lasers. Due to this development, the diode laser will also be able to prevail over well-established joining methods such as resistance spot welding in body construction.

What features still have to be developed to achieve this goal?
The greatest challenge is reducing the initial investment costs for a diode laser source. Today's manual manufacturing process will give way to automation. In 10 years it should be feasible to install a 4,000 watt laser beam in a housing not much bigger than a DVD player.



Volkswagen AG; Grafik: Gernot Walter

range of the diode is only a maximum of one micrometer high; where it stretches along the entire range horizontally the diode is from 50 to 500 micrometers high — depending on design. This allows the beam to develop an elliptical cross section: It has two different diameters and two different qualities as a result. In the vertical short "fast axis," though the beam fans out with an opening angle of about 45 degrees, the very low height of the active zone has the effect of a pinhole camera. At the same time, this very low height also means a very small beam diameter and a resulting beam parameter product of only 0.3 millimeters*millirad. The horizontal "slow axis," on the other hand, barely fans out with about six degrees. In this case, the beam diameter corresponds to the width of the active zone. Despite the low angle opening, this results in a very unfavorable beam parameter product of often several hundred millimeters *millirad.

Macaroni and flashlights The arrangement of individual emitters to bars and, if applicable, stacks adds an additional challenge to the equation. On the one hand, there is a multitude of individual beams of unsymmetrical quality that have to be shaped into a single symmetrical beam. One way is to use the energy of the diode beams to generate a new higher quality beam. This is the concept of the diode-pumped solid state laser. However, because the process costs energy, it reduces the efficiency. Another way is to have direct diode lasers form the light of the diodes directly on the fiber optics. However, those who want to transport the light of a bar or even a stack using fiber optics are confronted with the same challenge as someone who directs a square flashlight beam on macaroni: The macaroni may be illuminated, but some of the light around the macaroni is lost. On the other hand, the end face of a bar has a lot of "dead" area meaning non-radiating space between the emitters. If these dark spots are also shown on the fiber optics, this reduces the efficiency and brilliance.

> The key lies in coupling the diode beam into the fiber

The higher the output quality of the beam and the less the emitters are reproduced on a fiber, the more the "macaroni" fiber optic absorbs the light in relation to their diameter and the smaller these turn out. But along with the number of displayed emitters, the output of the beam drops, too. Only those who can make do with low output can achieve high beam quality. With high output, though, users also must accept a thick fiber, reduced efficiency and put up with mediocre to bad beam quality.

However, there is no longer any question that the large key market of welding and cutting applications in sheet metal processing is on the verge of a breakthrough. First of all, diode direct lasers are penetrating

The diode represents a new challenge to conventional welding methods

into higher and higher output classes and are increasingly becoming a point of interest for sheet metal processing. That is how in June 2008, 10 kilowatts of power output was produced from a 1.5 millimeter fiber with a beam quality of about 165 millimeters*millirad for the deposition welding of a laser in the Fraunhofer IWS. The deep welding of sheets requires a higher brilliance by a factor of 25. In early 2009, TRUMPF demonstrated a diode laser module with only five millimeters*millirad beam quality and 100 W output. However, this is only one hundredth of the output of the Fraunhof laser. Yet the module can be grouped with additional larger units. This makes it the foundation for future multiwatt diode lasers whose beam qualities make it possible to deep weld sheet metal and even, to a limited degree, cut thin metal sheets.

Lights out The first victim of this breakthrough is already certain: the lamp-pumped solid state laser. Diode technology may replace it in a few years, and as diodes develop further they may even encroach upon the market shares in the fiber and disk laser segment. The diode laser has the potential to evolve into the dominating laser technology among solid state lasers in the long term. Long before we reach that point, the charm of diodes will shuffle the cards mainly among the competition with conventional systems for materials processing. All the benefits of the laser as a tool combined in a compact, robust and highly efficient system. And this is already available for simple applications at incredibly competitive investment costs. ■

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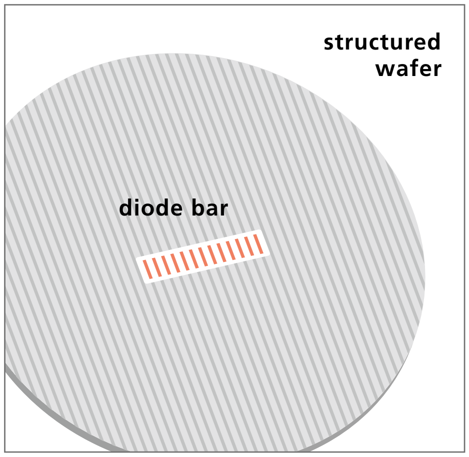
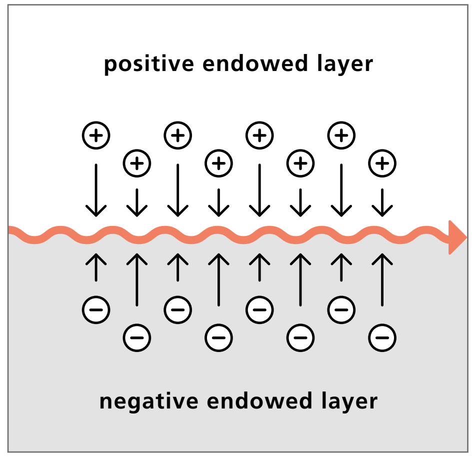




1 SEMICONDUCTOR COMPONENT *Diodes are made of gallium arsenide, which is enriched with other elements. One bar consists of numerous diodes cut from a wafer.*

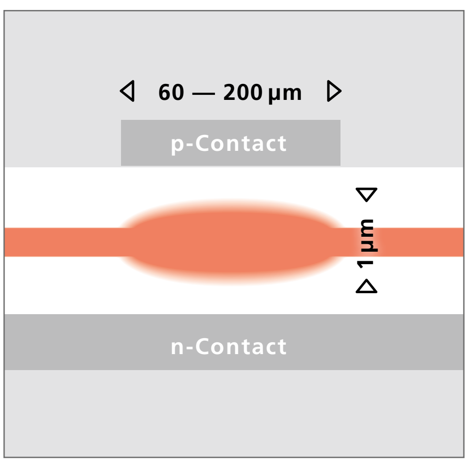
2 BEAM GENERATION *The charge carriers meet between positive and negative endowed layers of the diodes in the bar. Photons are released and reflected between the face of the diode.*

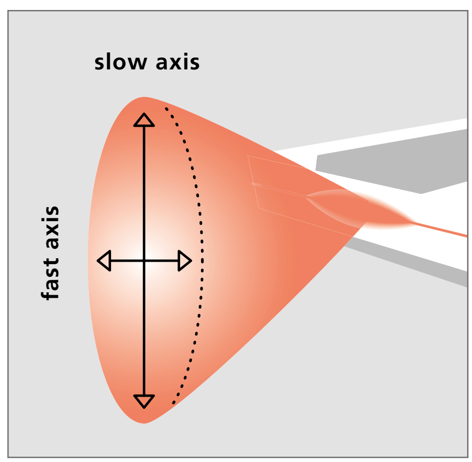
A TRIFLE ?

Though miniscule, diodes convert power directly into laser light and have an 80 percent degree of efficiency. This incredible tininess, however, is also the root of its weakness — difficulties with beam quality

3 OUTPUT *The tiny mirror surfaces quickly achieve the critical power densities. They can only be made wider. The height of the beam surface specifies the active layer.*

4 BEAM QUALITIES *The beam surface of high performance diodes has a large length-width ratio. Accordingly, the beam has an elliptical profile with two "quality axes."*





Grafik: Gernot Walter

"Understanding must precede application"

Application research drives technical advancement. However, the energy for revolutionary findings comes straight from basic research. Jörg Erselius, president of Max-Planck-Innovation, is convinced of this.

Economic and business experts have no doubt: Without highly effective basic research, a country cannot sustain a leading competitive position among other nations. Future economic growth and the long-term assurance of highly-skilled jobs and their related purchasing power is nurtured by the work and the findings from knowledge-oriented science in universities and independent research institutes. Max Planck said so himself with the words: "Understanding must precede application."

Why? This question has to be allowed — especially in a time in which sound bites often count for more than content and reasoning. Why, for example, does a country, or to be more specific, Germany, invest in its own basic research when, in a time of total globalization and the Internet, any kind of information is available worldwide in just fractions of a second — from Berlin to New York to Tokyo. Even if this image of the "global village" is circulated day in and day out via all media, it does overlook the most important information carriers: people. People are essential carriers of information; the direct, personal exchange of knowledge between individual people is the most effective means for connecting basic research and business applications. As long as this is the case, there has to be a local connection between the place of research and the place of its application. This can be seen in practice. For example, an analysis of about 400,000 patents indicated that American companies disproportionately cite American scientists, German companies cite German scientists, and British companies cite British scientists. Even cluster concepts, widespread now, rely on scientists and engineers, research facilities and companies being located near one another — with success.

The second "why" takes into account an even more fundamental aspect: Why basic research at all? Ultimately, business benefits to a greater extent from application-oriented research because the path to the product is more direct, shorter and less expensive. The answer to this question can only be: You can't have one without the other! Naturally, application-oriented research is an essential requirement for a modern economy. Yet at the same time, its strength is its weakness because such research is geared to existing applications. But the long-term future — and our entire day-to-day experience shows this — lies in the complete unknown. Here, basic research plays off its strength by offering the opportunity to discover things never before seen, never before conceived of, thereby making it accessible for the first time. It thus creates completely new spaces in which we can shape our future. This can only be achieved under the total freedom of research that does not peer at what is already known, rather dares to take paths into the unknown.

Today's key industries based on semiconductor, biotechnology, and (future) nanotechnology would never have been able to evolve by simply improving existing technology. They required the creative energy from revolutionary ideas that originated from basic research to be able to come to life. Even Einstein tried to make this point, though provocatively, when he said: "If you leave research up to only the engineers, you would have perfectly functioning kerosene lamps, but no electrical power." In the spirit of unity and the complementarity of natural and engineering sciences, you can add: "But without engineers we wouldn't even have the kerosene lamp — let alone potent power plants, without which our modern life would not be conceivable."

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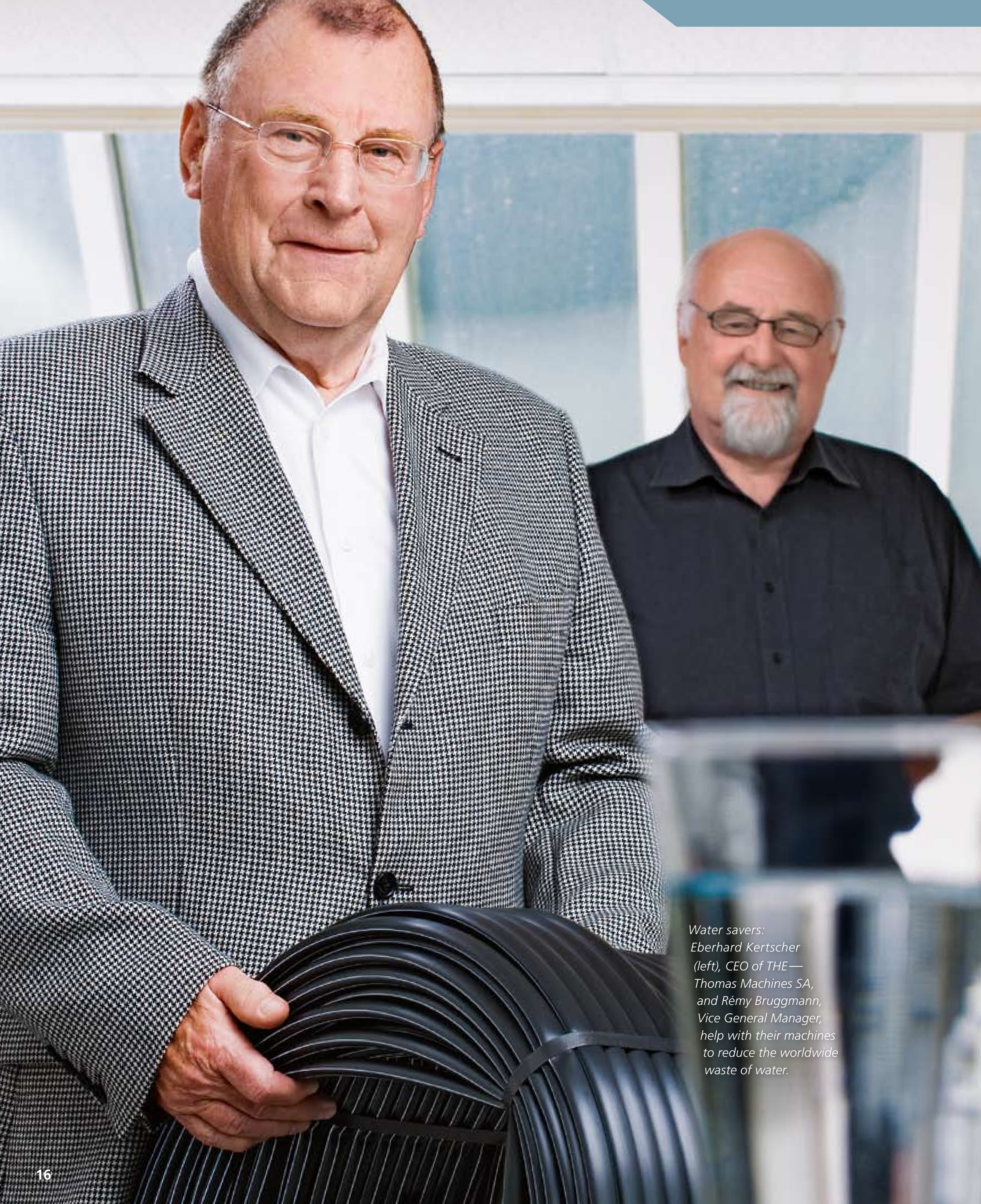


Water savers: Eberhard Kertscher (left), CEO of THE — Thomas Machines SA, and Rémy Bruggmann, Vice General Manager, help with their machines to reduce the worldwide waste of water.

Constant dripping

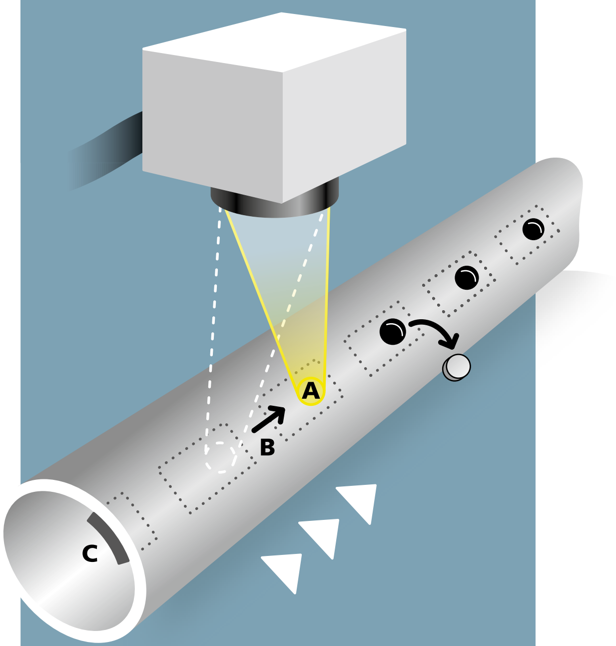
A 50-worker company on Lac de Neuchâtel, Switzerland, is revolutionizing the production of highly efficient irrigation systems with Helvetic tenacity and modern laser technology.

Using conventional irrigation systems like surface flooding or sprinklers, more than 60 percent of the water used goes off the mark. Drip irrigation systems bring almost 100 percent to the target: the roots of the plants.

And go! In one one-hundredth of a second intervals, the laser beam bores one cylindrical hole after the other in the wall of a plastic hose 0.15 to 1.2 millimeters thick. The drop emitter on the inside of the drilled hose wall, a type of valve made of fine plastic labyrinth, does not even get hot in the process. In this operation, future irrigation hoses rush through the system at up to 250 meters per minute. In order to hit the fast moving target at precisely the designated spot, a moving mirror directs the laser beam. The mirror itself moves to compensate for the speed of the hoses, precisely positioning the beam and ensuring the hole is really a hole and not a slit. The hoses' intended use is contingent on that. The finished hoses represent the core of a modern irrigation system that ensures high crop yields worldwide with the lowest possible water consumption. But only if every hole has the right shape and is positioned in precisely the right place. That is the task that the small company THE — Thomas Machines in Yvonand, Switzerland, has been committed to for years.

Saving water, march Fresh water is the crude oil of the 21st century. It is becoming scarcer and ever more expensive. About two-thirds of the world's fresh water consumption is directed to agriculture and farming. But up to 60 percent of the water used to irrigate crops is wasted because it comes through archaic irrigation sources such as flooding or rain. The water — including the manure frequently mixed in — evaporates or trickles away before it can reach the crops. Efficient drip irrigation systems with specially equipped hoses have long been available, but their high production cost makes them unaffordable to farmers, especially farmers in developing countries. However, the inventive minds at Thomas Machines have developed methods and machines that, with the aid of laser technology, can easily double the manufacturing productivity, thus making high-tech, water-saving hoses affordable.

Expensive technology makes inexpensive products possible Drip irrigation systems are based on pipes and hoses with special control valves for the water flow. These "emitters" or "drippers" ensure that the water is discharged constantly, across many hundreds of meters and even up to several kilometers. The idea is so simple, but implementation is so complicated. A special lance inserts up to 1,000 drippers per minute into the freshly extruded and still hot hose. Then a laser beam bores the actual exit hole above each dripper. If the hole is too close to the dripper, the water flows uncontrolled from the hose, breaking the irrigation chain. If the beam penetrates the dripper, irrigation is also disrupted. This can result in major crop losses. First of all, the hose has to be



extremely reliable and efficient; secondly, for farmers in drought-prone countries, it has to be affordable. This Catch-22 situation has occupied Eberhard Kertscher, managing director of Thomas Machines, since he learned about the principle of drip irrigation at an Israeli kibbutz when he was a young engineer. The solution for high-end, but nevertheless, affordable hoses means for him: Productivity! Productivity! Productivity! For years, Kertscher has been tenaciously tinkering on increasingly productive machines. It has been a long and rocky path. Though he was encumbered by patent-related legal hurdles and periods of economic drought, he has worked his company into the leading market position thanks to his inventiveness, doggedness — and modern laser technology.

Competitors of Thomas Machines drill or punch the holes only mechanically. The Swiss from the Neuenburger See (Lake Neuenberger) region have found their own path and are relying on the laser for their high-end machines. The challenge of positioning the laser beam on the fast moving hose was solved by Kertscher and his team by means of an elaborate control system and a scanner (Figure A). A further problem is caused by the energy distribution of the beam. The light output density corresponds to the Gaussian distribution principle that says the beam of a laser is conical. This means the drilled hole is not cylindrical; moreover, the underlying emitter is also drilled through and therefore unusable (Figure B). The solution to this problem came from a ring focal unit that changes the laser beam into a ring shape that permits cutting out small slices like a punching machine (Figure C).

Productivity and quality The most powerful machines from Yvonand, Switzerland, turn out up to 60,000 kilometers of perfect watering hoses annually — about twice as many as machines with a mechanical drill. In order to meet the necessary quality and 100 percent zero defect rate while ensuring high system speed, Eberhard Kertscher and his employees developed and patented a complex laser scanning system. This checks the drill hole relative to the emitter in real time. If a defect is discovered, the relevant piece of hose lands automatically in a separate roll. Eberhard Kertscher has registered 15 patents in the last few years. Not all have been completely integrated into production, but he does still have a few aces up his sleeve with regard to technical improvements. “The market is big and we are small — many competitors have gotten wind of new opportunities. In this context, our technology always has to be one step ahead.” However, the chiseled expression on the face the company’s head shows no fear. “With today’s short-sighted, quarterly report frame of mind, you cannot pull a rabbit out of a hat in this market. Those who want to harvest a good crop in this niche market need a lot of experience and staying power.” ■

PUNCHING WITH LIGHT

The focus mark (**A**) is turned into a ring. So the hole has a precise cylindrical shape. In order to place the hole precisely, the scanner mirror tracks the light with the precise hose speed (**B**). The pulse duration is matched to the wall strength of the hose, allowing the beam to cut precisely on the drop emitter (**C**). Pulsed solid-state lasers from the TruPulse series are the beam source.

THE COMPANY

THE Thomas Machines SA has 50 employees and posted sales of 20 million Swiss francs (18 Mio. US-Dollar) in 2008. In addition to the machines for producing drip irrigation hoses and tubes, the Swiss company forms and cross-cuts thick sheet metal up to 0.08 millimeters using laser technology.

Contact:

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Grafik: Gernot Walter

He saves weight, material and costs for his customers. Reinhard Aumayr, founder of LASER & more.

Simon Koy

"The design is decisive!"

Scarcely anybody produces stainless steel components as precisely and in such a material-savings manner as LASER & more in Wels, Austria. Company founder Reinhard Aumayr reveals the secret of the company's success.

Mr. Aumayr, how did you get to the top of Burj Dubai?
By welding 3.6 meters dead straight. We attended the Big 5 trade show in 2007 in Dubai. We met an employee from Arabian Aluminum there who was working on the building's entire facade. The construction company had tested other suppliers and was frustrated because none was able to produce the prototypes in the required quality. The weld seams were often twisted and the housing contorted. After the trade show, we contacted him again and offered to do another test using our laser welding method. Our prototype impressed the architects immediately. The weld seams up to 3.6 meters long are now dead straight. The complicated shape of the housing is 40 percent lighter than originally planned thanks to narrower wall thicknesses. The last 4,000 elements were delivered at the end of January 2009. The customer is very satisfied. The last stainless steel housing will soon be mounted four meters below the top of the skyscraper at 814 meters high.

This puts you at the top of the world in a dual sense. What is the secret of your success?
We are the only company in Austria to offer the complete production chain, from laser punching to laser welding. This allows for a level of precision and engineering possibilities that no other manufacturer has reached. There are only a few com-

panies in the world that can do this. Other bid invitations for new high rise projects are in the works and we are expecting excellent opportunities in this field.

Why haven't your competitors hit on this?
Because it's not so easy. It's not enough to purchase just a laser welding machine; you also have build on your skills and knowledge. When I founded the company in 2000, we were a pure job shop for other companies. We cut stainless steel sheets using laser machines. The competition has caught up quite a bit, and by now almost every local foundry has a laser cutting machine. It therefore became clear to me that we would only get into a leading position if we offered our customers added value. And so in 2005, we began laser welding with two welding cells from TRUMPF, we invested a total of one million Euros in this machinery. During the first few months, we produced a lot of scrap because we first had to learn how laser welding worked, how to clamp the parts and what the machines can actually do. Now, for example, we have learned that the gap has to be as narrow as possible, under 0.2 millimeters because otherwise the laser burns away the metal only instead of joining the sheets. This does not matter with traditional welding because you add material to it so that the gap closes. But this limits the design freedom and makes the component heavier, and that is just what we want to avoid.

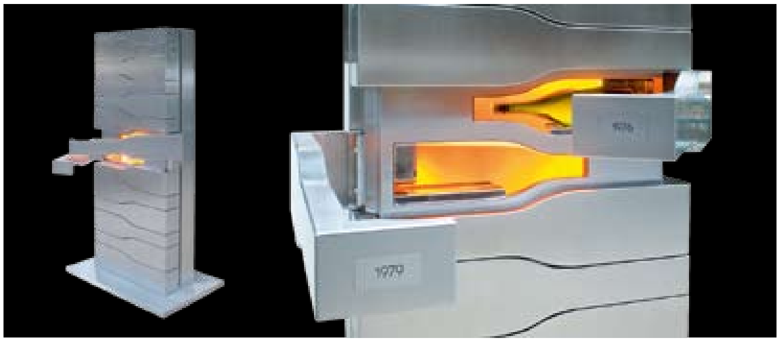
> "Customers frequently design parts to be too complicated because they are only familiar with conventional welding processes."

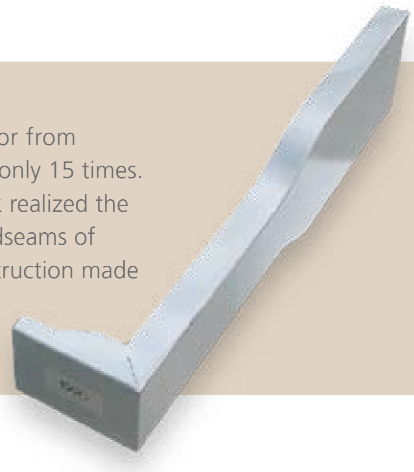
And where is the added value for the customer?
The customer gets better quality. The parts have less warping and require less refinishing work. Also designs are possible that hadn't even been thought of before. But above all, the customer saves money. The largest savings potential are the material costs that we normally reduce by 10 to 50 percent. We achieve this because we can process thinner sheets without sacrificing stability. But it is not enough to replace a traditional welding process with laser welding. You only reap the benefits if you optimize the entire production process. So what we sell is not just a welding service, but value engineering, as we call it.

Can you give an example?
For the Öresund Tunnel between Denmark and Sweden, we produced the brackets that hold the piping to the tunnel wall. Instead of bending the parts twice as specified by the customer and welding once, we redesigned the part such that we bent it once and welded it twice. By doing this, we saved 13 percent on the material. We slimmed a similar part for the Felbertauern Tunnel from 8.5 to 3.5 kilograms and reduced the costs from 125 Euros to 80 Euros.

How is such a major savings possible?
The customers frequently design parts to be too complicated because they are only familiar with conventional welding processes. In order to benefit from all efficiency potential, you have to be very familiar with the laser welding process and also keep the design process in mind at the same time.

Simon Koy, METAGRO Edelstahltechnik AG, LASER+more





The champagne refrigerator from Veuve Cliquot will be built only 15 times. METAGRO Edelstahltechnik realized the venturous design. The weldseams of the fiddly doors are a construction made by LASER & more.

Does this mean that you offer design engineering as a service?
It's part of our service and we want to further expand it. As a rule, we receive design drawings from customers that we redraw using our CAD program so that the benefits of laser welding are fully brought to bear. Herein lies the actual unique selling point of LASER & more. But first we have to enlighten the customer. Because customers do not think about laser welding, they don't bring it up on their own. That is why I often take a traditionally produced part, visit customers and show them how it can be redesigned and what they could save by doing business with us. Technicians are easier to impress because they see the entire process chain. Buyers are more skeptical and require proof, which we, of course, deliver. In this case, TRUMPF should do more to enlighten the industry and, for example, advocate for the inclusion of laser welding in technical courses and in trade schools. Even when it comes to standardization, laser welding has not been given very much consideration so far. If it were, the static layout of a component would change considerably if thinner sheets were used.

What are your plans for the future?
In the next five years, we want to move away from the job shop operation, which still makes up the largest part of our sales. Instead, we want to lengthen the value added supply chain and deliver more finished parts as we did for the Burj Dubai or as we did for the doors of a spectacular refrigerator for champagne bottles. This refrigerator was built by METAGRO Edelstahltechnik AG for Veuve Cliquot and is limited to 15 units. Today, we want to further process the sheets that we frequently cut and punch to produce the end product ourselves. I estimate that we will purchase a handful of laser welding machines to achieve this goal. ■

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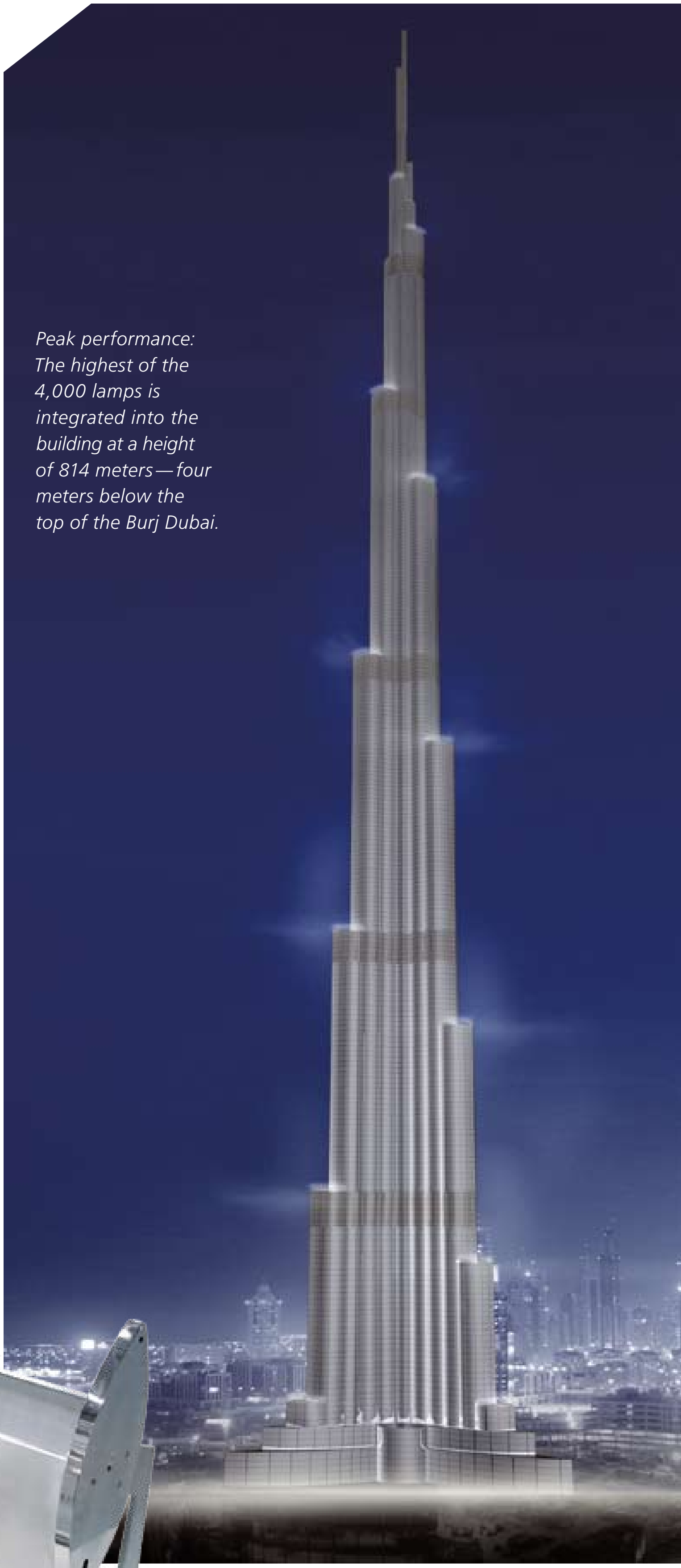

Peak performance: The highest of the 4,000 lamps is integrated into the building at a height of 814 meters—four meters below the top of the Burj Dubai.

Four thousand stainless steel lamps make the Burj Dubai gleam at night. LASER & more focused production on laser welding and saved another 40 percent in weight by using thin sheets.

Putting the laser to the acid test

Pad printing, etching, embossing or laser marking? Philips Lighting Electronics went for the answer.

White letters and numbers appear like magic on the gray plastic housing. In between, brief flashes of light can be seen and fine swirls of smoke rise up. Then everything stops moving. The process takes 10.94 seconds. The result: Two laser-marked control gears.

Since March 2008, Philips Lighting Electronics has been using the laser to mark two of its approximately 400 different products manufactured in Pila, Poland. But this is just the beginning. Starting soon, laser marking is set to expand considerably. The reason: With pad printing and labeling — procedures that Philips has used so far — "there have been constant process quality problems," says project manager Marcin Prus. The print smudged, was askew, rubbed off or was simply incorrect. "The imprint is so small — a nine could easily be mistaken for an eight," explains Tomasz Kopyść, process engineer. Correcting the incorrect settings on the machine was time-consuming. This resulted in the pad printer being unusable for nearly 15 hours per month — the printer that printed the labels was out of commission for twice as long.

When Philips decided in February 2007 to manufacture two new products in Pila, which is about 100 kilometers north of Poznan, Poland, Marcin Prus and his colleagues lobbied to introduce a new marking and labeling method at the same time. They quickly established the important criteria: high quality, flexible and easy to operate, very short retooling times, low ongoing costs, minimal defect rate, work safety and environmental sustainability.

The Test In looking for the best procedure, Marcin Prus and his colleagues first compared the existing methods. The unit costs for labeling turned out to be twice as high as with pad printing. Marking 100 control gears with labels cost 4.57 Euros; pad printing cost 2.23 Euros. "The process loss for pad printing was 98.5 percent — an unbelievably high number," recalls Marcin Prus. With labeling, the rate was 19.7 percent. The team began to explore laser marking, mechanical engraving, etching, ink jet printing, embossing and other marking procedures. They evaluated all issues, such as quality, consistency, stress of the material, flexibility, investment costs, look and feel,

1 Looking for a new solution: Marcin Prus (left) and Tomasz Kopyść ran the trials at Philips Lighting Electronics.

2 The marking procedures in question: labels and pad printing along with the newcomer — laser marking.

3 Marking in progress: Marking results and overall cost made the day for the laser.

4 A close look on the results.

as well as environmental friendliness. Their findings all clearly pointed to laser marking, but the high investment costs were an equal disadvantage. A major plus, on the other hand, were the operating costs. At 1.60 Euro per 100 pieces, they came out low in comparison to the other procedures. In addition, Marcin Prus believed it was better to make the right investment once and have a high-quality marking procedure for the long term. In the end, these were investment costs that would pay off in the medium term: low operating costs, flexible operation, low reject rate, little reworking.

The Outcome

Until the decision was made in favor of laser marking, Marcin Prus and his colleagues had to work hard to convince upper management of its benefits. And they succeeded. At the same time the new products were introduced, two TruMark Station 5000 R marking laser systems with a rotary indexing table for loading and unloading parallel to production went into operation right on schedule. The operators had no trouble making the transition to the new machines: "You turn the machine on and everything works the way it is supposed to." While the operator is talking, she loads the outer half of the machine's rotary indexing table with two new plastic housings. She places them on a workpiece holder that secures the housing so that slipping or incorrect placement is prevented. The laser meanwhile marks the two workpieces on the other half of the rotary table. Another reason operators are pleased with the new machines is that they are no longer exposed to ink fumes. The machine rotates the table, the new parts go under the laser and the operator then removes both completely marked control gears. The marking is flawless. If you move your fingers over the characters, you find they are slightly raised. The laser beam generated a white foam from the plastic in the focus point. In order to retool the machine for a different housing type, the operator only has to replace the holder on the rotary indexing table and retrieve a different file on the connected monitor. "It takes about two minutes and the machine is retooled and ready," she explains. With pad printing, it took 20 minutes to retool and about five minutes for labeling.

Marcin Prus and Tomasz Kopyść are satisfied with the machine. They are planning to expand the use of laser marking to other products, new and already existing. "On the other hand we have to continue to introduce laser marking," says Tomasz Kopyść. "Barcodes for clear traceability are becoming mandatory, and for this purpose, laser marking has many advantages for us." ■

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KD Busch

By Prof. Shoji Maruo

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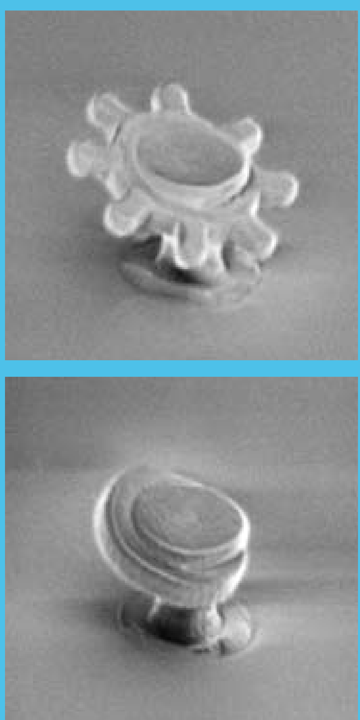
Multiphoton microfabrication allows for creating the smallest devices with the help of a laser and chemistry. First efforts at large-scale production show the process to be successful.



Test objects: One possible way to reproduce micromachines with moveable parts is membrane-assisted microtransfer molding. It copies the complete machine from a master model and requires no additional assembling.

Whether it be nanophotonics, microelectronics or microfluidics there is a growing demand for 3D microstructures and an approach to building them in large-scale production. A promising generative technique that is gaining more importance is the so-called multiphoton microfabrication. Ultrashort laser pulses irradiate photosensitive material, which polymerizes only in the focal point. In this way, the photosensitive material is formed in three dimensions. The technique is rapid and flexible, and therefore offers great promise as a tool for generating complex microdevices for various applications in optics, medicine and biology. New materials and applications for multiphoton microfabrication emerge and the challenge of reproducing the complex microstructures is a central issue of research.

3D microfabrication using photopolymers was originally derived from stereolithography used for rapid prototyping. In this technique, thin layers of photopolymer are deposited. The area in between a 2D-cut of the desired 3D structure is irradiated by ultraviolet light according to the sliced data. The irradiated photopolymer cures in these slices. Thus layer by layer the desired part is created. However, the depth resolution of this technique is restricted to several micrometers due to the layer-by-layer nature of the technique. To overcome this drawback, my team and I utilized two-photon absorption polymerization for producing 3D microstructures. This technology employs tightly focused ultra-short laser pulses into the volume of a liquid resin — which is transparent in the visible and infrared — in order to initiate two-photon polymerization. In contrast to "classical" stereolithography, the photons can pervade the material and absorption only takes place in the focal point and not on the surface. The material polymerizes, but not before at least two photons are absorbed simultaneously in a single quantum event. And this only takes place in the focal point. So, structures with sub-100 nm resolution and relatively high throughput are created.

Materials and applications

Another important aspect for the exploitation of this technology is the material used. There is a strong demand for cheap as well as reliable materials, and depending on the application different polymers are chosen. For biological applications, proteins have been utilized for 3D direct writing with a femtosecond pulsed laser beam. For photonic applications, several kinds of photosensitive materials, including inorganic-organic hybrid polymers (ORMOCER), a negative photoresist (SU-8) and hybrid materials containing metallic ions have been used. The properties of ORMOCER can be adjusted from those that are characteristic for organic polymers to those that are similar to inorganic glasses. The material provides smooth 3D microstructures without shrinkage and deformation and is therefore suitable for making precise optical elements such as waveguides and photonic crystals.

While areas such as improved resolution and incorporation of new materials continue to attract considerable attention, this technology is

Multiphoton microfabrication allows for extremely small resolutions. Professor Satoshi Kawata's team fabricated this model of a bull.*

now at a mature enough stage to where the focus is evolving toward application. From Biological implants to photonic crystals — the range of applications is broad. Three-dimensional microelectromechanical systems (MEMS) devices are one central application of multiphoton microfabrication. The technique is also used to fabricate several kinds of polymeric micromachines such as microturbines. My research team and I focus on the fabrication of optically driven micromachines such as micropumps and micromanipulators. With an eye towards biochip applications, we developed a lobed micropump driven by light.

The way to mass production

Multiphoton microfabrication is a powerful method for creating complex, 3D micro- and nanostructures. However, before this technique can gain significant industrial relevance, a serious roadblock must be overcome. Scaling this technique up for mass production represents a considerable challenge. Different approaches are employed to overcome this limitation. One is fabrication at multiple points simultaneously: Given an efficient enough photoinitiator, fabrication can be accomplished with only a small fraction of the output power of a Ti:sapphire oscillator. However, even with improvements in photoinitiators, it seems unlikely that multipoint fabrication schemes of this sort will be able to extend beyond fabrication at a few thousand points simultaneously. And most applications for mass production will require considerably higher fabrication rates to become economically viable. Two other techniques, mulitbeam interference lithography (MBIL) and proximity field nanopatterning (PnP), are especially suitable for mass production of patterns that have local, three-dimensional periodicity on roughly the scale of the visible light. They are therefore of great interest for applications such as photonic crystals. However, the throughput of these interference lithographies must be higher for most of the potential uses.

The technique my team and I are currently working on is membrane-assisted microtransfer molding. This technique allows for reproducing a moveable micromachine, created with multiphoton microfabrication. A 3D master model with a partition membrane that holds the moveable part is immerged into polydimethylsiloxane (PDMS), which is cured to form a mold. After the mold is released from the master model, it is stretched and filled with a molding material. Following the curing of the molding material, the PDMS mold and the membrane is released, leaving a replicated master model with moveable parts. This approach is the further development of microtransfer molding. In microtransfer molding it is not possible to reproduce moveable parts since they become trapped within the PDMS mold and cannot be released. In conventional molding this problem is referred to as "mold lock." In the example described above, the membrane prevents the moveable part from becoming trapped within the PDMS. The advantage of the molding technique is that a single set of master structures can be used to create an essentially unlimited number of molds, and each mold can be used dozens of times. It is also possible to use replica structures to create additional molds.

Future prospects

Over the next few years there will be an exponential increase in the use of multiphoton fabrication in fields such as photonics, micromechanical systems, microfluidics, micromagnetics, biosciences and bioengineering. The laser sources have become more favorable, smoothing the way to industrial production. The first commercial applications are likely to be in areas in which multiphoton fabrication has clear advantages over more traditional techniques such as the creation of high-performance 3D photonic crystals and microinductors. Commercial applications are also on the horizon in other areas, such as tissue scaffolding and the creation of functional 3D components for microfluidic systems. ■

Shoji Maruo is Associate Professor at the Department of Mechanical Engineering at Yokohama National University. He earned his Ph. D. in 3D optical microfabrication with photopolymers in 1997. Afterwards he worked on the development of MEMS devices at Nagoya University.

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* By courtesy of Prof. Kawata. First published in Nature, Vol. 412, page 697 (2001).

"I want pollution-free

Almost by definition, Stan Ream is a pioneer in the business of laser materials processing. Today, his work at the Edison Welding Institute (EWI, USA) is helping to push fuel cells out of the laboratory and into high-volume production.

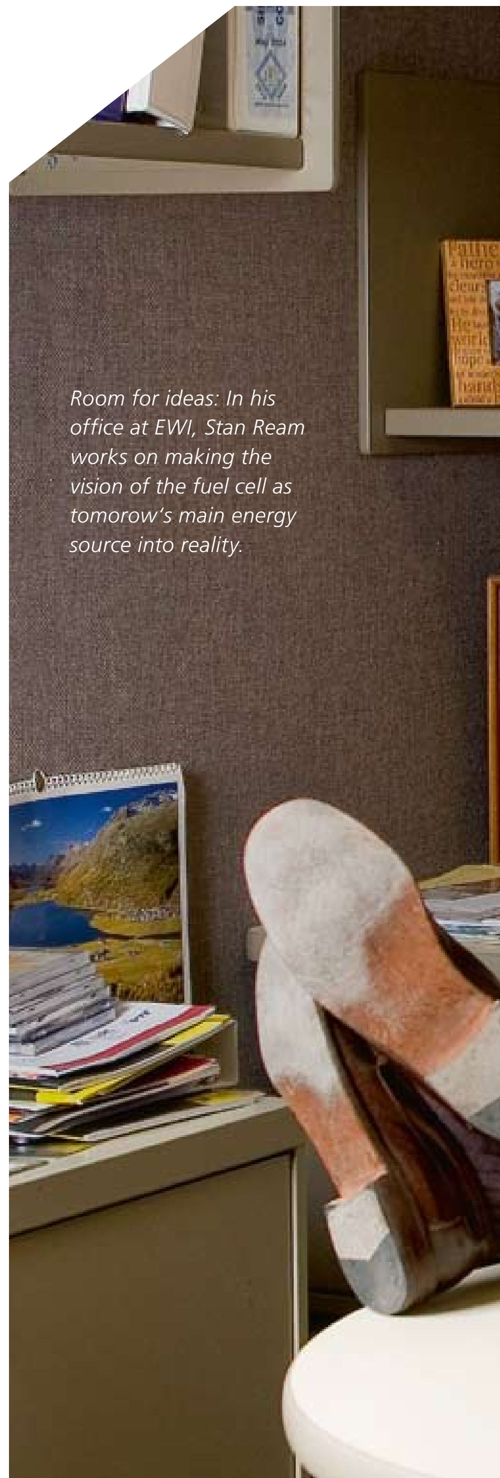
How did you get involved with laser processing of fuel cells?
I've worked with lasers since the early 1970s when only a handful of us in the whole world were able to work on laser materials processing technology. At EWI, we've been engaged with the fuel cell community for the last five years in the interest of moving it towards volume manufacturing. Fuel cells have lingered in the laboratory for decades. Only recently has manufacturing become an issue. Everyone wants long-lasting, highly efficient and affordable construction techniques, but they're still not looking at how to manufacture in volume.

What exactly is a fuel cell and how does it work?
There are literally hundreds of kinds of fuel cells in different designs, but the short answer is that the fuel cell is a device that converts hydrogen and oxygen into electricity. Hydrogen and oxygen combine to create water and at the same time liberate electricity. How this is accomplished varies from fuel cell to fuel cell, but most fuel cells, and certainly those used in automotive applications, involve many layers of thin materials stacked up in a repeating series that together create electricity.

Given the variety of fuel cells, are there any universal challenges in manufacturing them?
Honestly, in terms of manufacturing, I've seen relatively few consistent themes. The one that really struck us years ago was the number of thin metallic sheets that need to be welded at very high speed. In many fuel cell designs, solid oxide as well as PEM (polymer exchange membrane) fuel cells, that theme pops up a number of times. And until a few years ago, we didn't have a welding technology we could apply.

Is this where laser technology fits into fuel cell manufacturing?
Yes. For instance, fuel cells used in automotive applications are made of repeating layers of different components, called a "stack." One element in the stack, called a bi-polar plate, requires between 1 and 2 meters of welding. So, you can have 300 to 500 meters of weld requirement in just one fuel cell stack. The need to join these many thin sheets of metal into a stack is what we have been addressing with high-brightness solid state lasers.

How fast does the process need to be for laser welding to make sense?
EWI helped the U.S. Department of Energy create a road map on this topic about two years ago. We called for 50 meters a minute as a target speed. We've achieved that and more. If you go much faster, you run into a welding phenomenon called "humping" — sort of a technical speed limit. Speed is critical to making fuel cell technology affordable. Achieving the targeted speed means we can put affordable numbers on the cost of laser welding fuel cells. It is also happens that welding speed improves the robustness of the weld in these thin



Room for ideas: In his office at EWI, Stan Ream works on making the vision of the fuel cell as tomorrow's main energy source into reality.

transportation”

materials. High-speed laser welding actually improves the tolerance to small variations in process conditions.

> "We need to move from making a few hundred fuel cells every once in a while to a few hundred a minute. That's a huge step."

Is laser welding helping to shrink fuel cells?
Actually, in some ways, yes. The ability to weld with a tiny beam allows fuel cell designers to use denser and finer features in the design and improve their device's efficiency. But that benefit is secondary to speed and process robustness.

Realistically, when do you see manufacturing of fuel cells changing?
When we move from making a few hundred every once in a while to a few hundred a minute. That's a huge step, and it has to be taken, but it's not going to happen until there's a compelling reason to do so — another sharp spike in energy prices, which could happen at any time, or a significant government subsidy, or a true commitment to reducing our carbon footprint. It won't just happen on its own.

What are the advantages of fuel cell technology?
The potential benefits for the automotive industry — the biggest market for fuel cells — are more efficient energy use and possibly a reduction in greenhouse gas emissions, although that will depend on where you get the hydrogen. If you use clean energy to make the hydrogen, fuel cells have the potential to give cars the ability to run emission-free for 300 miles. Today's batteries won't take you 300 miles.

Fuel cells sound wonderful; why aren't they a part of everyday life yet?
Because hydrogen isn't bubbling out of the ground, free to use. It's expensive to make hydrogen — that's one major issue. The other is that there are some expensive materials in fuel cells — catalysts like platinum and fancy polymers and ceramics that are required in the membrane — and we've never made enough of them to drive down the manufacturing costs.

Tell me more about the automotive applications; will fuel cells change car design?
Yes, in a lot of ways. First of all, many of the things we're seeing in current hybrids are paving a path for fuel cell hybrids. We're learning to run cars on electricity rather than gasoline. The plug-in hybrids that will hit the market in the next year or two will run primarily on electricity. The gasoline engine will only come on when necessary to charge the battery. We'll see more efficient utilization of electric power and electronics. Also, new vehicles will be smaller and lighter.

What excites you the most about fuel cell technology?
I'm attracted to the possibility of a pollution-free transportation environment sometime in somebody's future. A future where we get hydrogen from wind or solar panels and put it in our cars, where we drive around with fuel cell hybrid vehicles, and have a near-zero carbon footprint. It's a futuristic vision, but it will happen someday. I don't know if it will be in my career or lifetime, but it's got to go that way. And it's exciting to be a part of something like that. ■

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LIFE

After years of being recruited away from employer to employer, Stan Ream sought employment at EWI, "so I could make a real impact on the way things are manufactured."

LASER

Ream was first hooked on laser technology after watching a 15kW CO_2-laser weld 10mm stainless steel in 1973.

ACHIVEMENT

Industry veterans praise the length and breadth of Stan Ream's laser experience. Novices discover Ream when they Google the special laser application he pioneered.

Rycus Associated

“Given the situation, the laser was never invented?”

5 QUESTIONS TO JENIFER BUNIS

“Engineering and manufacturing would not be nearly as efficient”

Which application seemed impossible ten years ago?
I would not have imagined the global reach CO_2 lasers have today. Lasers are installed in virtually every country, often being operated by people with no formal education. Many everyday items we use or buy are now laser marked!

What do you wish lasers could do?
I would like to see a simple “plug and play” fiber optic beam delivery that will easily transmit the CO_2 wavelength with minimal losses and maximum flexibility. This would greatly facilitate the adaptation of lasers into existing manufacturing equipment.

What changes in laser technology are the most important to you?
Companies have learned how to effectively manufacture this high technology equipment on a very large scale. As a result, laser prices have dropped significantly, turning lasers into more of a commonplace industrial tool, and less of a solution only afforded by companies rich in Ph.D.s and dollars.

What event awakened your interest in laser technology?
As a freshman at the University of Rochester, I was having doubts about my choice of chemical engineering as a major. I began exploring alternatives and learned about the unique optical engineering program. I was introduced to the exciting world of lasers in my first class, and I have been in that world ever since.

Jenifer Bunis is executive vice president of Synrad, Inc. Synrad manufactures CO_2 lasers in its facility near Seattle, Washington. Prior to Synrad, she worked with excimer lasers at Questek, and with solid state lasers at MIT Lincoln Laboratory, both in the Boston area. She holds a B.S. in optical engineering from the University of Rochester and is a former board member of the Laser Institute of America.

More questions to Jenifer Bunis:
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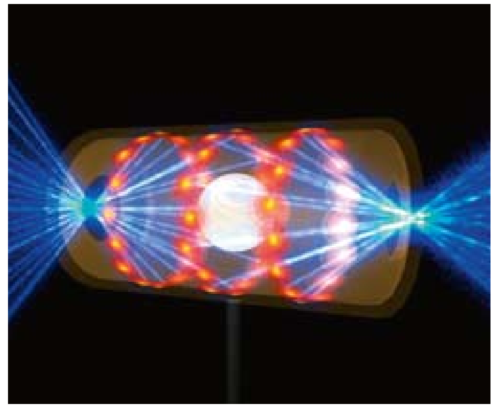

Powering fusion: In the vacuum saggar, which is only a few centimeters in size, 192 laser beams hit the fuel pellet and ignite a tiny sun.

The star maker

A super laser makes fusion energy gains much more of a reality

Fusion energy: Scientists have been dreaming for decades about creating inexhaustible energy reserves through the fusion of atoms. As early as the 1930s they succeeded in creating the first artificial nuclear fusion. However, far more energy has been invested in the process than gained. For the fusion of two nuclear atoms, a plasma temperature of 100 million kelvin is required. Keeping the nuclei stable was also quite a job at which all previous methods failed. Now the scientists of the National Ignition Facility (NIF) in California, which will go into operation in 2009, are full of hope again. They want to achieve with laser beams what has been impossible with magnetic field lines. The heart of the US $ 3.5 billion plant is an airless globe. Inside it about two million joules of laser energy come together to hit a tiny target one centimeter in size — a frozen pellet made of the fusion fuels deuterium and tritium. The enormously high heat causes the atoms to ionize; this means the electrons loosen themselves from the nuclear atoms and form plasma. Once two nuclear atoms meet in this fusion plasma, they melt together and release energy as powerful as the energy released from the inside of any star. The activation energy necessary for the reaction is generated by 192 laser beams. With output energy of only one billionth of a joule each, the laser beams are directed, divided, regrouped and reinforced by numerous amplifiers until they reach an energy output of about 20,000 joules each. The decisive energy kick occurs in the optical devices in which the laser beams are converted from long wave infrared beams to short wave and energy-enriched UV rays. They hit their target with such power that fusion is triggered, thus converting the tiny deuterium-tritium pellet into a man-made, energy-rich star. ■

Contact: www.llnl.gov

Jenifer Bunis; National Ignition Facility

The threshold is dropping

How will diode lasers change the markets? Prof. Hans Joachim Eichler risks taking a look.

With high-power, fiber-coupled, direct-diode lasers, users expect the power socket efficiency levels to be higher than with other available multi-kilowatt laser systems. Future generations of these laser systems could achieve efficiencies of up to 50 percent and beam divergence angles are possible that are less than one level above the bending limit.

Indeed, the use of fiber lasers allows even lower divergence angles with the same beam cross-section surface or even higher beam qualities to be generated. For many applications such as cutting and welding, for example, the beam quality and the focus capacity of the high-power, fiber-coupled, direct-diode lasers appear to be sufficient. With their higher efficiency, compact design and lower costs, this new generation can replace solid-state lasers as well as the classic CO_2 lasers when it comes to seam welding for joining sheet metal and deposition welding for surface refinement. The same applies for selective thermal treatment of surfaces for structural changes and for hardening.

Compared to conventional lasers for material processing, high-power, fiber-coupled, direct-diode lasers have reduced acquisition and operating costs and thus lower the entry level for "laser newbies." Due to these economic advantages, high-power, fiber-coupled, direct-diode lasers will soon be dominant in industrial materials processing up into the kilowatt range, pushing more expensive fiber or disk lasers into application niches in which excellent beam quality (e.g. basic mode) or short pulses with energies of up to one joule and peak performances of 10 gigawatts with nano- and pico-second time periods are needed.

In addition, the direct coupling of the beam into the fiber promises a higher level of efficiency compared to the latest diode-pumped fiber and disk lasers. Diode-pumped solid-state lasers always exhibit a power loss: From a pump wavelength of 940 nanometers, output wavelengths of 1,030 nanometers could develop. With the newly introduced high-power diode lasers, this loss does not occur.

Dr. Ing. Hans Joachim Eichler Professor at the Institute for Optics and Nuclear Physics at the Technical University of Berlin. Managing director of Laser- und Medizin-Technologie GmbH Berlin.

This means high-power, fiber-coupled diode lasers can emit, on a GaAs basis, even shorter wavelengths of 1,000 nanometers down to 800 nanometers. That could be advantageous, for example, for welding aluminum and separating glass panes, silicon wafers as well as other semiconductors. In this process, any wavelength within this bandwidth can generally be selected so that for each material one suitable absorption can be established for process optimization.

However, the history of material processing with lasers shows that replacing established laser systems with new ones triggers evolutionary developments. CO_2 lasers are still in use extensively. Lamp-pumped Nd:YAG lasers make up the second and further successful generation of high-power lasers. The third generation with its more effective, diode-pumped solid-state lasers appears to not yet have exceeded the peak of industrial application. Now comes the fourth generation of high-power lasers, based on fiber-coupled direct-diode lasers, which promises additional cost reductions in conventional laser welding and will now find broader areas of application. In addition to sheet metal processing, the welding of multiple plastic parts in automobile manufacturing as well as joining plastics and glasses to metals and producing solar cells are gaining in importance. In these instances, high-power lasers make high processing speeds possible. ■

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Where’s the laser?

WITH EACH CALL: Your cell phone rings and your fingers press the laser-inscribed call button. The background LED, visible through very subtle laser drilled holes, signals that there is a connection. The small housing lies lightly and comfortably in your hand. Stylish with laser engravings, the chassis parts have to withstand a lot. Laser cut and spot welded, the chassis withstands jolts just as well as it keeps dirt off. The metal components inside the cell phone that were laser cut and welded hold the electronics reliably in place, even the lithium-ion battery. The air-tight laser welded battery cover absorbs damaging electro-magnetic rays, ensuring your daily calls are reliable, clear and trouble-free.

Heike vogler; Gernot Walter


68 000 000 000
COLORS. THAT IS THE NUMBER OF COLORS THE FIRST LASER TELEVISION WILL BE ABLE TO SHOW.
THE LARGE NUMBER OF COLORS WILL MEAN COLOR DEPTHS OF UP TO 48 BITS CAN BE BROADCAST.
THE VIEW ON THE SCREEN WILL LOOK JUST AS REAL AS THE WORLD OUTSIDE.
Getty Images