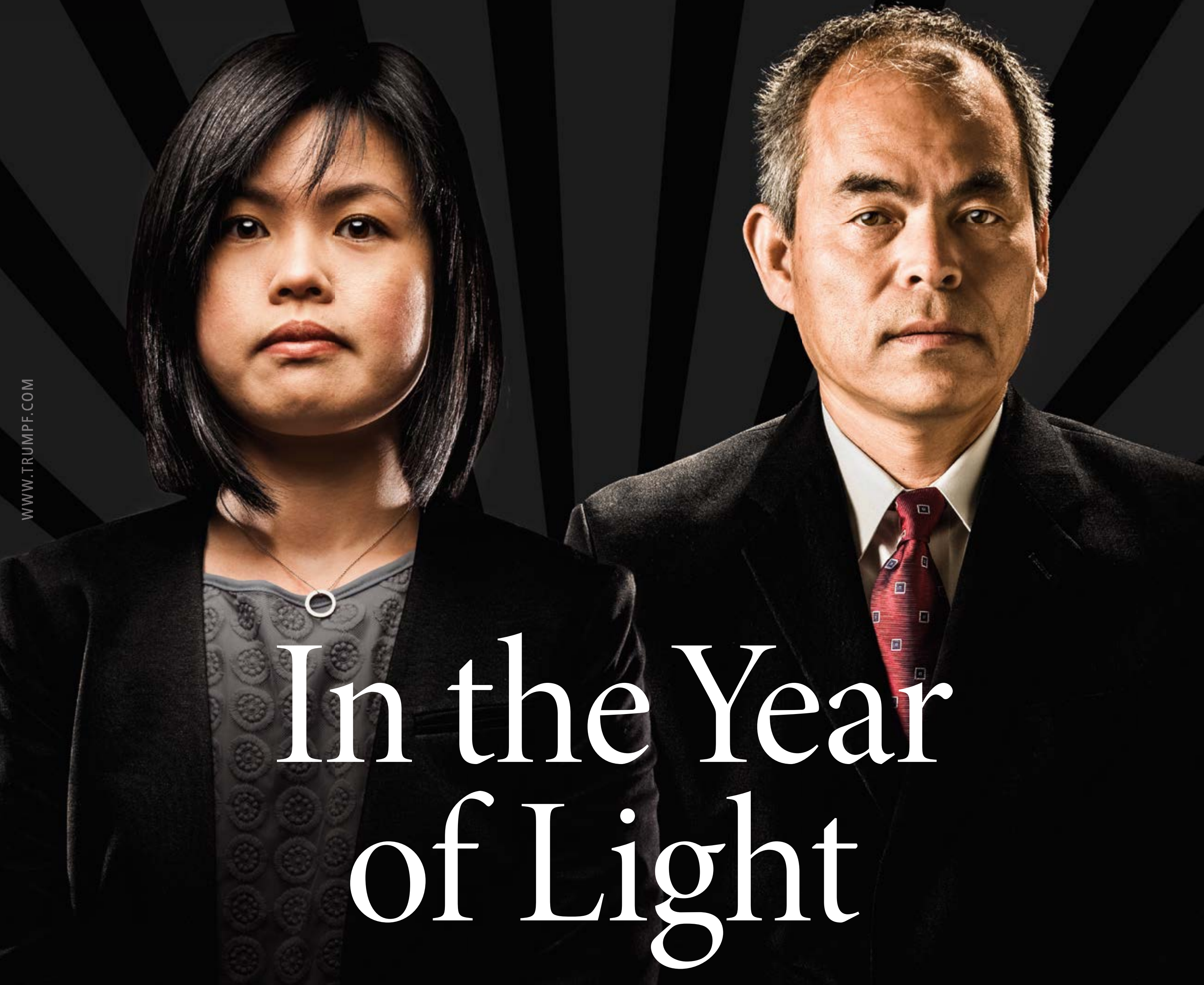
Laser *Community*

THE LASER MAGAZINE FROM TRUMPF

20/2015



In the Year of Light

Light as seen through the eyes of a recent graduate and a Nobel laureate.

ALSO: GKN's production planners. Mechanical engineers at Nexans. Developers at LCR Systems, TRUMPF and Probeam. Research on surfaces—in Münster.

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#20

June 2015

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With the Year of Light now well under way, we are using it as an opportunity to take a fresh look at light in numerous articles and publications. That's why we're so pleased that Nobel laureate Professor Shuji Nakamura has shared with us his thoughts on the meaning and effects of light on our lives. Professor Nakamura shared the Nobel Prize in Physics 2014 with Isamu Akasaki and Hiroshi Amano for their work with blue light-emitting diodes (LEDs). This achievement has paved the way for more efficient lighting, since blue LEDs are essential for creating LED lamps that can produce white light efficiently.

It's fascinating to consider all the technical applications of light, and Nakamura's light-emitting diodes are just one example among many. In industrial production, for instance, we use lasers to cut, weld and mark a wide range of materials, as well as when creating components in additive manufacturing processes. The rise of digitalization and networking in the world would be unthinkable without light, since that is what transmits data over fiber-optic cables across the globe in just fractions of a second. And the list of examples goes on and on …

Out of the comfort zone!

INTERNATIONAL
YEAR OF LIGHT
2015

Such technological advances send shock waves throughout the value chains of the industries affected. Just as Professor Nakamura's blue LEDs are changing the entire lighting industry, many of the examples given above are having a major effect on other sectors. Light is a disruptive technology, and poses serious challenges for the industries concerned. So even if at first your own industry doesn't seem to be affected, it is still worth taking a look at the technical uses of light.

TRUMPF history bears witness to this. In the 70s, TRUMPF was the world leader in nibbling technology. Lasers didn't seem to pose a threat; they were too unreliable, too expensive, and a punched hole was necessary to start the cut anyway. Nevertheless, we started working with this new tool, and today we are the world market leader in laser technology. Without lasers, our sheet metal processing machines wouldn't be possible. This experience and mindset is part of our DNA: we are constantly challenging and questioning what we do today. Will it still be the right choice tomorrow? It's this way of thinking that allows us to guarantee innovation, a promise our customers and the whole industrial sector can rely upon.

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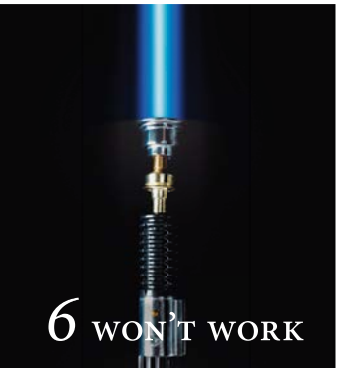
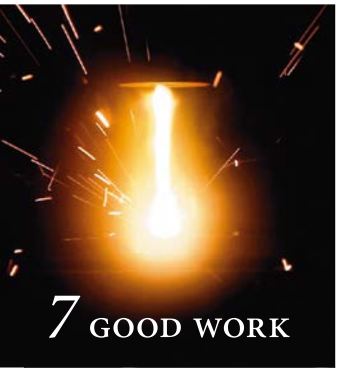
Laser *Community* #20



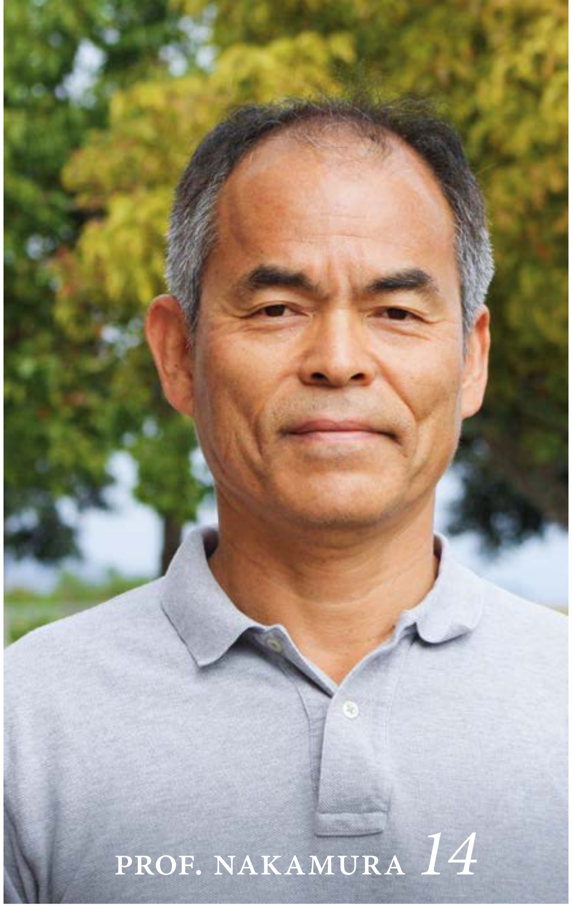


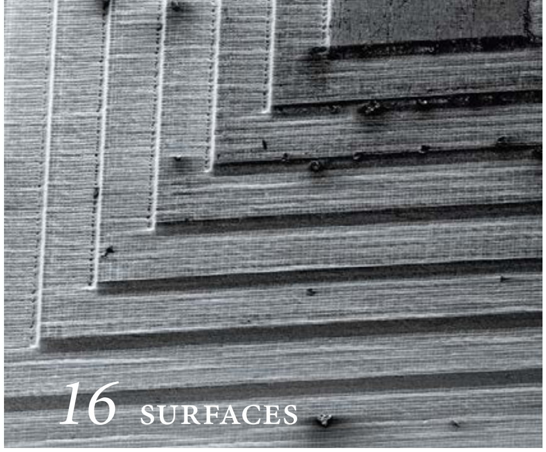
2015 – YEAR

COMMUNITY

TECHNOLOGY

Gernot Walter, ifs Braunschweig, David Jackson, EDAG





OF LIGHT

APPLICATION

On point!

Paint stripping

Recipe for success

OPINION

"Lasers will shape our future"

PROF. SHUJI NAKAMURA

More light!

Shuji Nakamura / UCSB Solid State Lighting & Energy Electronics Center, LFM Laserzentrum Münster, Detlef Göckeritz

Won't work: The lightsaber

THE LIMITS OF SCIENCE FICTION

When you think of *Star Wars*, lightsabers come to mind. George Lucas' space saga and the legendary weapon are inextricably linked, with the high-energy blade featured in countless battles and duels between Jedi knights and the Sith, between the forces of good and evil. Pure science fiction, right? Pretty much. But what if … Let's say we wanted to build one of these lightsabers. There'd certainly be a number of challenges to overcome first!

One of the less tricky aspects is the question of the power supply. How much power does a lightsaber require and, more importantly, where would it come from? Let's work on the assumption that we need to generate one kilowatt of laser power. This requires a powerful battery, and we could incorporate it into the grip. A cell phone battery would certainly fit the bill in terms of size and shape—but with an average output of 1,500 mAh, it would not nearly be powerful enough. What other options are there? A car battery, perhaps? If we decide to worry about ergonomics later, then 40 ampere-hours and a high-efficiency diode laser might be enough to generate a laser beam … for a few seconds. Well—at least it's a start!

Second problem: What would make the beam of light come to a sudden stop, after 100 cm or so? In reality, this wouldn't happen. Unless we had a mirror to reflect the laser beam back on itself after it had travelled a specific distance. But that raises the question of how to attach and position a mirror at the end of the lightsaber without physically connecting it to the grip.

Which brings us to the third and most troublesome issue: What is there to keep two lightsabers from passing through each other? Nothing! In the movies, we see fighters striking their blades against each other, but the laws of physics make this impossible. Photons don't exert forces on each other; in reality, the light beams would simply become superimposed. So if two lightsaber-wielding opponents were to cross blades, nothing would happen. They would simply cut holes in the air. Unfortunately, this means that lightsaber duels could never happen in real life.

These may be the three most obvious arguments that snuff out the idea. There are undoubtedly far more reasons that restrict lightsabers to the realms of science fiction. And even if we were able to overcome the laws of nature, we couldn't build one anyway: George Lucas holds the patents.

What other physical facts conflict with the principles behind the lightsaber? Or do you have ideas for how we could build one after all? Please drop me an e-mail to the following address:
athanassios.kaliudis@de.trumpf.com

Replica of a lightsaber. Theoretically, it would be possible to surround the high-energy "blade beam" (infrared, presumably) with a ring-shaped, focused, low-energy beam in the visible spectrum. If the combatants were then to kick up enough dust during fight scenes, it would at least explain the variety of lightsaber colors we see in the movies.

Gernot Walter, pro-beam AG

Good work: Farewell to sparks!

It's a lot less spectacular than it used to be! A solid-state laser cuts a 4 mm deep seam, at a rate of 6 meters a minute, at air pressure one-hundredth of atmospheric pressure

For ***videos and more information*** *on low-pressure welding in the industrial environment, visit laser-community.com/en/5172*

WELDING AT LOW AIR PRESSURE

It's an age-old love. Ever since people first saw sparks reflected in a companion's eyes, a crackling flame has been a primeval passion. So it came as no surprise that even seasoned viewers felt a hint of regret after this particular laser welding demonstration — even though it was, by all counts, a huge success. First, a 6 kW disk laser welded a seam at atmospheric pressure, causing sparks to fly behind the vacuum chamber's observation window and producing a glaring plume of vaporized metal above the seam. But now, at a pressure just one-hundredth of atmospheric pressure, nothing remained but a faint glow.

So it's farewell to the fireworks — and farewell to the unwanted side effects of deep welding with solid-state lasers: sparks, and spatters deposited on the workpiece surface. These effects become more noticeable as process speeds and welding depths increase. At the same time, modern high-brilliance beam sources tempt users with better energy efficiency and the option of routing the beam through laser light cables.

Earlier research work suggested that the vacuum could have a beneficial effect on the process. In 2011, researchers from Braunschweig University of Technology together with pro-beam, a manufacturer of electron beam welding systems, and laser manufacturer TRUMPF decided to pursue this. The assumption: something that helps one technique might also benefit another. The assumptions of the partners in the project turned out to be true. The cause of the fireworks turned out to be the metal vapor ejected from the capillary. It intermingles with the ambient air, producing a luminous metal vapor plume around the turbulence. This plume dances around, repeatedly striking the molten layer at the rear wall of the capillary. The deeper the beam penetrates and the faster it advances, the more spatter is produced. Drop the pressure to a hundredth of atmospheric pressure, however, and the vapor jet escapes virtually unhindered. No more fireworks.

Just three years after the pioneering project began in Braunschweig, two industrial systems made by pro-beam with laser technology from TRUMPF are welding seams in perfect quality, several millimeters deep, in gear components subject to heavy strain, without showers of sparks. The only downside is the potential disappointment of visitors who can no longer see laser power in all its glory!

Can you imagine using laser welding and low pressure in a combined process? Please drop me an e-mail: hakan.kendirci@de.trumpf.com

Vadym Tynenko / Fotolia.com

"I feel that laser welding will become increasingly competitive with traditional welding methods in the future and will even replace conventional welding techniques in many application areas."

Dr. Shuang Liu (28) earned her doctorate in the laser processing of materials. We asked her what drew her to light.

"Lasers will shape our future"

Ms. Liu, do you actually use a laser pointer in your everyday work?
Yes, I do. And it gets a lot of use!

Lasers had an almost magical quality for the first generation of laser scientists in the 1970s and 80s. Is that a feeling you can still appreciate today?
Absolutely! There's definitely something miraculous about lasers. But I think my generation sees the laser more as a tool that has become an essential part of our everyday work. Light is used as a tool by just about every carmaker—and virtually every single smartphone screen is cut by laser. The first generation of lasers focused on a much narrower range of applications, largely because lasers were still very expensive and there wasn't much research. Today we have a much better understanding of how lasers work and ready access to many different types of laser.

Do you think it's important to study laser technology in the country where it originated? Is that what prompted your move from China to America?
Moving to Dallas was a major life change which I saw both as a challenge and a great opportunity. I had already had some contact with using the laser to process materials as part of my three-year master's degree in mechanical engineering at Suzhou University. That's when I realized that lasers will shape our future. That thought fascinated me, so I decided to delve deeper into laser technology. And the birthplace of the laser seemed like a good place to start.

What was the subject of your dissertation?
The core themes for my research were laser cladding, laser welding, rapid prototyping, and using the laser to remove paint. In my dissertation I examined two different laser cladding methods and carried out experimental studies with powder injections. To compare and contrast the two methods, I observed the powder feed behavior and the thermal behavior of the hot melt tape. Laser cladding is a key application in industry when it comes to optimizing surfaces and protecting them against wear, corrosion and tremendous heat.

What was special about your studies?
I had an outstanding doctoral advisor, Prof. Radovan Kovacevic. He gave me all the support he could and showed me that it's not just about the research. He taught us to take a disciplined approach to our work, to develop perseverance and to resolutely pursue our goals. At the end of the day, getting your doctorate can be quite a solitary affair because you are researching an area that's almost entirely new. That makes it exciting—but sometimes also frustrating. So it felt even more special to finally hold my doctor's degree in my hands after all that long and arduous research work!

Talking of solitary work: When laser technology was still in its infancy, laser users felt they were part of a community, even though they were each working on completely different things. Does that sense of solidarity still exist?
Definitely. I would even say that the community pulled together even more tightly. International laser conferences and conventions have increased people's ability to share and exchange their ideas.

What led you personally to become a laser engineer?
After seven years in research I was intrigued by the idea of working in industry. Up until that point all my work had been academic, on-campus projects. By chance I heard that Miller Electric had an opening for a laser engineer, so I applied and got the job.

Your company specializes in arc welding. What role will lasers play in the future?
I think that laser welding will become the welding method of choice in the future, gradually superseding arc welding. Lasers weld perfect seams with minimal thermal injection and at a constant level of quality. Arc welding won't be able to match that in the future.

Almost a year has passed since you joined the company. What are you working on at the moment?
Right now we're expanding the laser business at Miller Electric. We obviously want to develop and broaden our skills as specialists in arc welding. The ITW Group is helping us do that. If we get a customer who is interested in laser welding, we take them into our laser laboratory and show them the tremendous precision that lasers can achieve. Then we work closely and actively with the customer to find an automated turnkey solution that best matches their needs. The actual welding technique is really just a means to an end within the complex overall automation solution.

Contact:
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Miller Electric: www.millerwelds.com

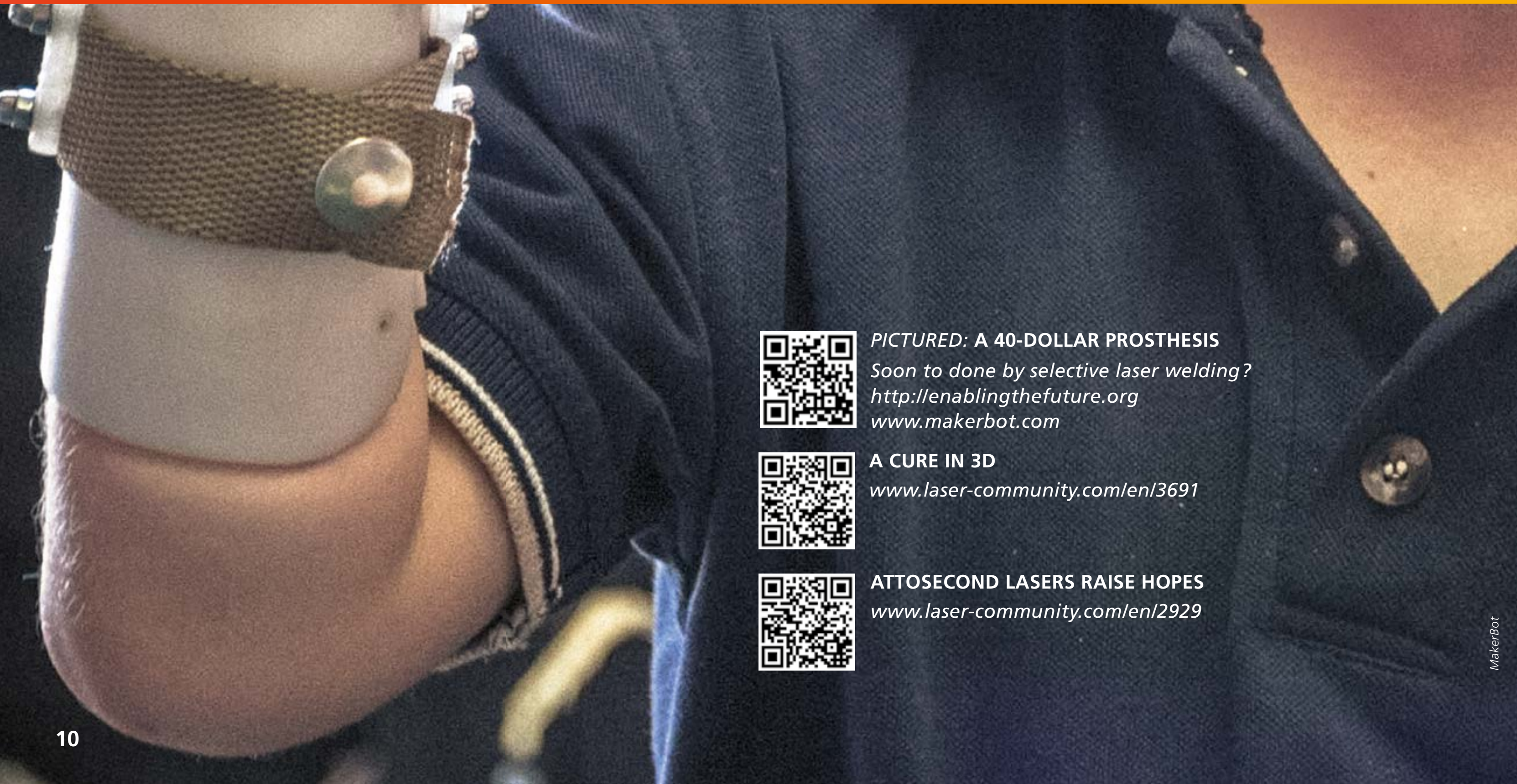
David Jackson

TO THE RESCUE: NOW IN 3D!

Additive laser manufacturing is taking the world of surgery by storm. Highly accurate 3D models of tumors help surgeons prepare for operations; prostheses mimic damaged bones only to disintegrate as the bone grows back; tiny hollow bodies facilitate the targeted transport of drugs to the afflicted area; delicate implants "remember" their shape in the body after surgery… Perhaps in the future, even the most remote clinics and disaster teams in will carry a "miniature 3D factory" as part of their standard equipment.

40 $

FOR A HAND



PICTURED: **A 40-DOLLAR PROSTHESIS**
Soon to done by selective laser welding?
http://enablingthefuture.org
www.makerbot.com

A CURE IN 3D
www.laser-community.com/en/3691

ATTOSECOND LASERS RAISE HOPES
www.laser-community.com/en/2929

MakerBot

WE ARE HERE

PROCESSING AT

14 nm

Light is the most revolutionary tool that human beings have harnessed since they first chipped knives out of stone. Four examples of where we're at—and where we're heading.

A BRAIN THAT FITS IN THE HEAD OF A PIN

Any discussion of digitalization typically involves limitless increases in processing power and transmission capacities. Laser technology is used to fabricate and separate chips, drill and cut circuit boards, cut display glass and help produce displays. Light has got us this far—and only more light can take us further.

PICTURED: **INTEL'S BROADWELL**
Revolutionary in 2013, now in mass production. What's next?
http://bit.ly/LC_intel

BEYOND 13 NANOMETERS
www.laser-community.com/en/4852

EVERYTHING DEPENDS ON THE PCB
www.laser-community.com/en/3792

Intel

225,000,000 km FROM HOME

THERE'S MORE BEYOND THE HORIZON

Microscopes reveal structures that are smaller than the wavelength of light. Laser tools manipulate tiny particles in the microscope's field of vision. High-power lasers accelerate elementary particles to aid the study of quantum electrodynamic effects. Guidance lasers help observatories capture incredibly sharp images out in space. Terawatt lasers illuminate materials for analyses, while attosecond pulses photograph electrons in chemical and biological processes. Whenever modern researchers try to catch a glimpse of the unknown, they almost always rely on photons—either directly or indirectly—even if just to manufacture the tools they need.

PICTURED: **CURIOSITY'S TRACKS ON MARS**
Laser technology is pushing the boundaries of research
www.nasa.gov/mission_pages/msl

THE MAN FOR WHOM SECONDS LAST AN ETERNITY
www.laser-community.com/en/2929

THE WORLD'S MOST POWERFUL RESEARCH LASERS
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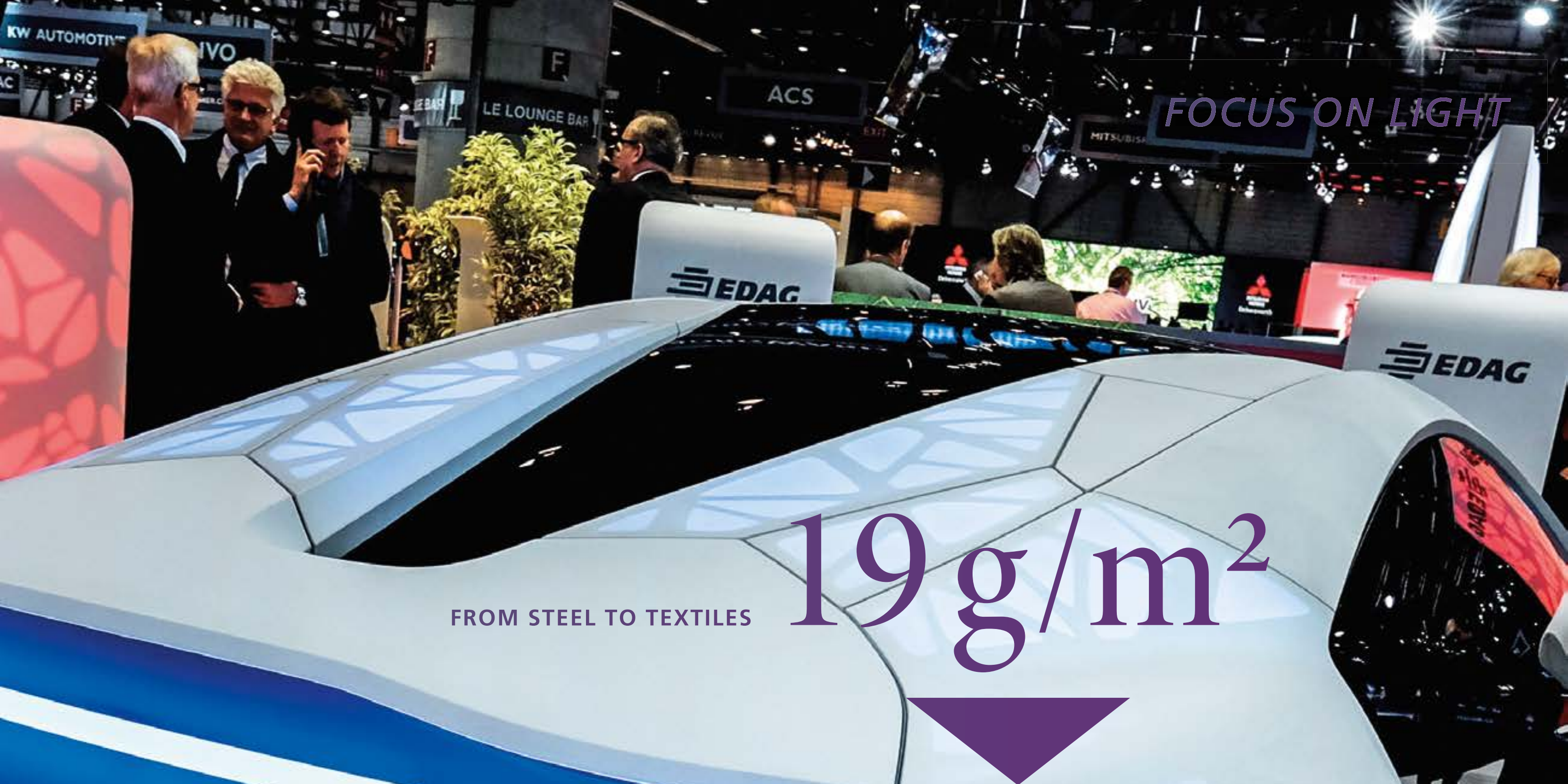


FROM STEEL TO TEXTILES 19 g/m²

CARS IN THE LIGHT OF THE FUTURE

At some time between 2008 and 2010 the public began to see the automobiles as being doomed. CO_2 legislation, fears of peak oil, and then a full-blown economic crisis all played their parts. But automobiles did indeed have a future—it's just that nobody wanted to see it. Major investments had already been made in new materials, technologies, manufacturing techniques, design changes and drive concepts—and they were just starting to bear fruit. Light was—and continues to be—one of the key tools in this transition. Today, it's crystal clear that the automobile will be an integral part of our future. And questions about what it will look like and how it will be produced are turning up some absolutely fascinating answers.

PICTURED: **THE EDAG LIGHT COCOON**
EDAG shows what could be technically feasible
http://bit.ly/LC_EDAG-Cocoon

TURNING POINT FOR THE AUTOMOBILE
www.laser-community.com/en/4604

THE AUDI REVOLUTION
www.laser-community.com/en/4925

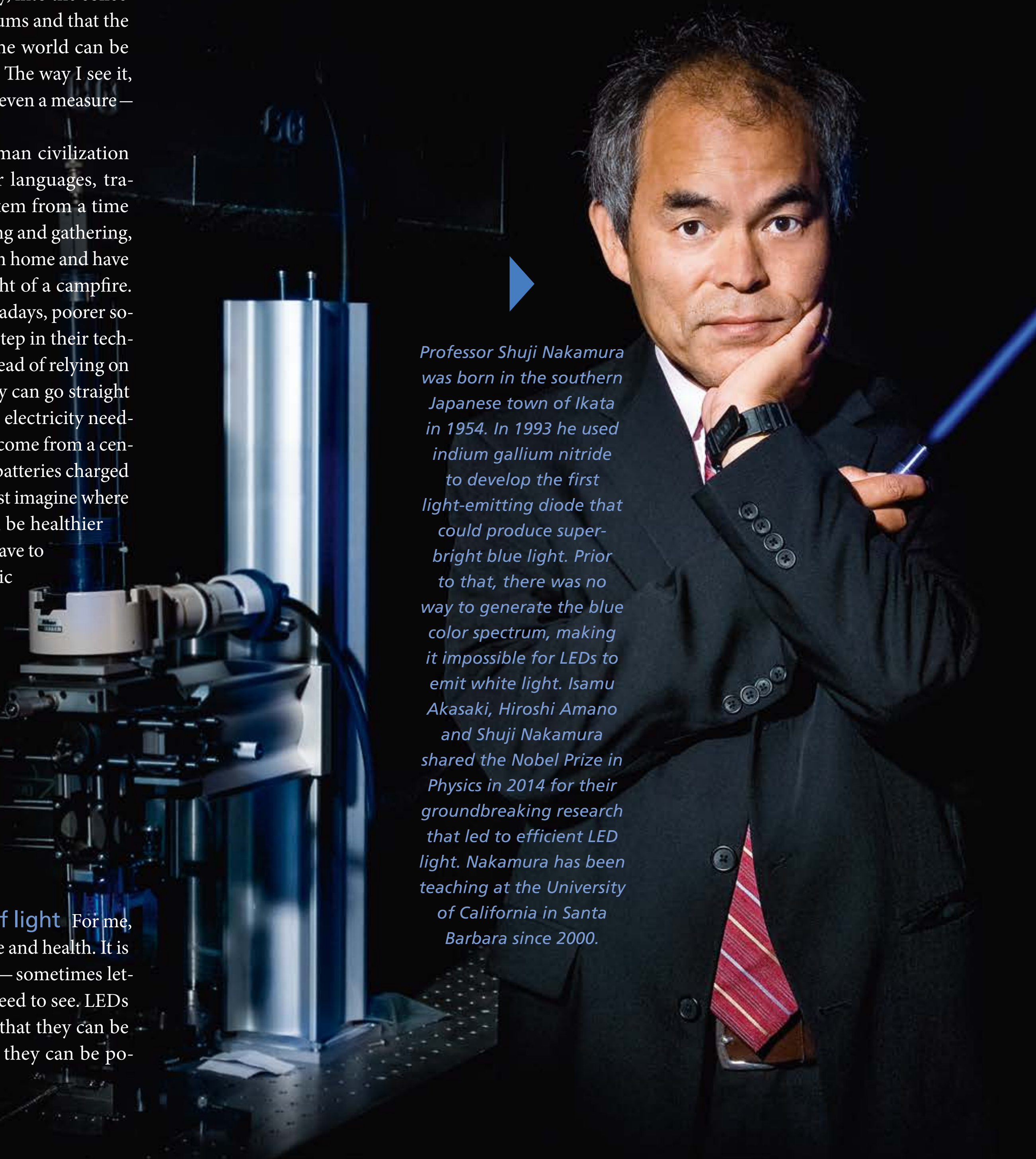
NASA/JPL-Caltech, Auto-Medienportal.Net/Manfred Zimmermann

More light!

Professor Shuji Nakamura was awarded the 2014 Nobel Prize in Physics and has devoted his entire research career to light. In this essay, he explains why inexpensive light is invaluable.

Finally! The age of incandescent and fluorescent lighting that eats up electricity is drawing to a close. I have spent countless hours of my life developing and researching solid-state light sources — in other words, LEDs and laser diodes. My goal was to provide efficient and custom light sources. So I'm thrilled that light bulbs and fluorescent tubes can now start making their way, slowly but surely, into the collections of technology museums and that the job of bringing light to the world can be given to solid-state lights. The way I see it, cheap light is a driver — or even a measure — of civilization.

Can you imagine human civilization without light? Surely our languages, traditions and heritage all stem from a time when, after a day of hunting and gathering, our ancestors would return home and have stories to share by the light of a campfire. That's still true today. Nowadays, poorer societies can skip an entire step in their technological evolution — instead of relying on inefficient light bulbs, they can go straight to efficient LEDs. And the electricity needed to power them doesn't come from a central grid, but rather from batteries charged by affordable solar cells. Just imagine where this will lead! People will be healthier since they will no longer have to light their rooms with toxic kerosene lamps. School children and adults will finally be able to read and study by night as well as by day. This will considerably improve literacy and the level of education in poorer countries — and with it people's chances for a better life.



Professor Shuji Nakamura was born in the southern Japanese town of Ikata in 1954. In 1993 he used indium gallium nitride to develop the first light-emitting diode that could produce super-bright blue light. Prior to that, there was no way to generate the blue color spectrum, making it impossible for LEDs to emit white light. Isamu Akasaki, Hiroshi Amano and Shuji Nakamura shared the Nobel Prize in Physics in 2014 for their groundbreaking research that led to efficient LED light. Nakamura has been teaching at the University of California in Santa Barbara since 2000.

Shuji Nakamura / UCSB Solid State Lighting & Energy Electronics Center

The healing power of light For me, light is also a symbol of life and health. It is a great help to physicians — sometimes letting them see what they need to see. LEDs offer the great advantage that they can be made very small, so that they can be positioned at the tip of tiny handheld surgical instruments. This means that light can be shone precisely were the surgeon needs it and, because LEDs give off very little heat, they can be positioned very close to where the surgeon is operating. In the future, our bodies will be home to more and more artificial materials that have undergone some reaction caused by light. Dentists, for example, model implants out of artificial resin that hardens in seconds when exposed to a certain type of UV light. Even fractures heal faster with the help of photosensitive materials..

Light will also help protect us. Colleagues of mine are currently working on UV LEDs that will help us disinfect surfaces. Others are using a certain type of UV light to activate medications the patient has already been given. This means that the medications target the cells or pathogens when and where they're supposed to and the patient is protected from unwanted side effects. All these applications benefit from our ability to control the wavelength of light from solid-state sources with a high degree of precision.

Finding clever uses for light is also a key factor for success in medical research. The winners of the 2014 Nobel Prize in Chemistry even managed to use light to examine structures and movements that are smaller than half the light's wavelength and make them visible. This work by Eric Betzig, Stefan Hell and William Moerner opened up a type of nanoscopy that allows us to see how molecules form synapses. The technique will help us better understand diseases such as Parkinson's and Alzheimer's.

I feel there's considerable room for improving the way solid-state light sources are used in medicine and biology. It should be possible to push wavelengths even further into the ultraviolet range, which in turn would open up a wealth of potential applications.

Mood lighting Light will help us to feel better. For a long time now, I've been fascinated by discovering what effect light can have on our moods or, even more so, on our physiology. Any parent living in an industrialized country will know that it's a good idea to send their children outside for some fresh air every now and again. Of course there are a number of benefits to doing this, but one is that our skin needs to absorb UVB rays from sunlight to generate vitamin D.

"I regard inexpensive light as a measure of civilization."

Light also controls our circadian rhythms — in other words, our inner 24-hour clock. We can turn this to our advantage by installing suitable blue light in our offices; this has been shown to improve people's mood and productivity. The lighting in some airplanes is programmed to help passengers experience as little jetlag as possible. In countries with long winters — Sweden, for instance — there are "daylight showers" at bus stops. This kind of simple light therapy has been scientifically proven to have a profoundly positive effect on people's moods. Doctors around the world are using light to treat depression and sleep disorders.

Feeding the soul I take frequent walks in the countryside and find that doing this stimulates my creative process. Once I was thinking about how most of us take light for granted. But what is light? I'm not talking about the age-old debate of wave vs. particle. I'm more interested in what light means to us. For plants, light means food. But for us, light is primarily a way to transmit information — a medium for feeding the mind and spirit. Just look at the words we use: Teachers illuminate their subjects, human understanding of the world exploded during the Enlightenment, and the police are tasked with shedding light on situations.

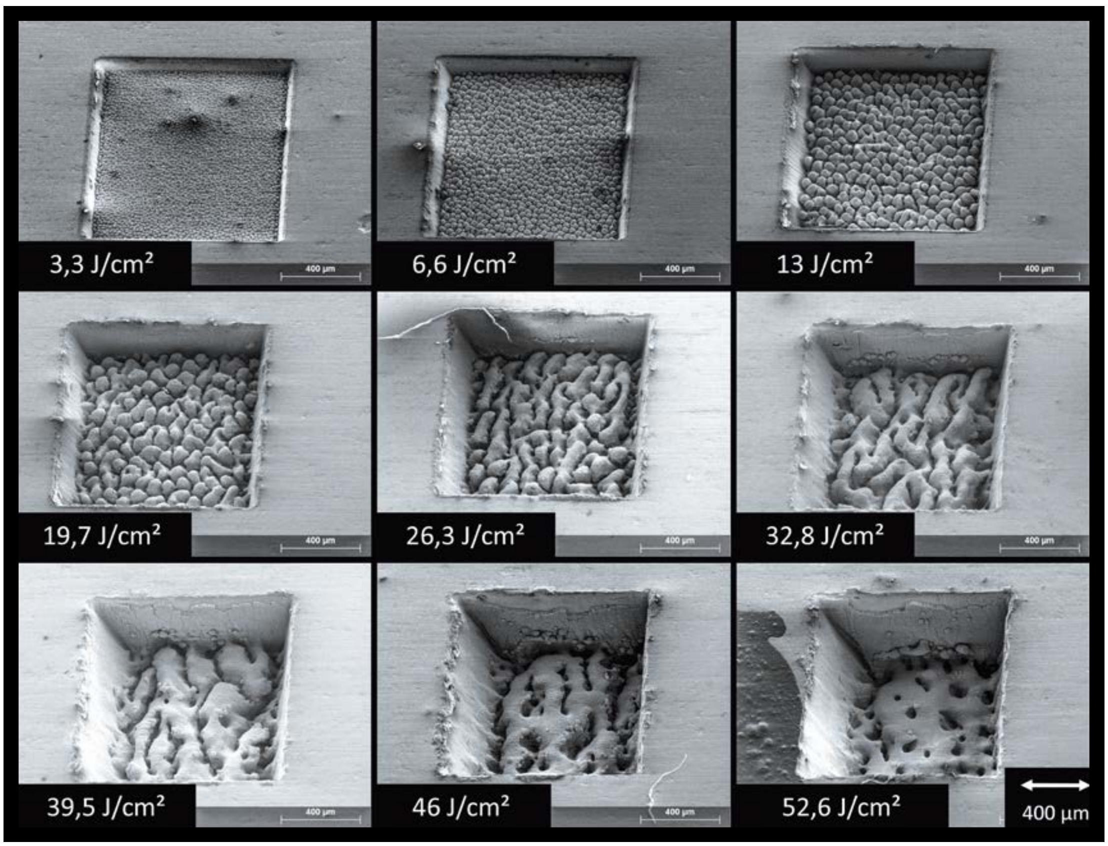
Your smartphone's small, illuminated screen uses light to deliver information to your brain. You can tell which sculpture in an exhibition is the most important by how it is lit. The tiny light mounted on the tip of your drill allows you to better see where you are drilling. Light also carries information from a technical point of view: the backbone of the internet is made up of massive fiber optic cables, your Blu-ray player allows you to watch the latest season of your favorite TV show. And LiFi systems are increasingly being used to transmit information across open spaces: a photodiode converts the flashing light of a light diode into electrical impulses. We already have the first LiFi cell phone.

"Tony, turn off that laser and go to sleep" What will the future bring? More light! We've by no means exhausted the potential of efficient light sources. At the Solid State Lighting and Energy Electronics Center in Santa Barbara, my colleagues and I are working on using lasers in lighting systems. LEDs still suffer from what we call droop — they become less efficient when powered by higher currents. Lasers don't have this problem. This is why we want to use lasers to create a smaller, brighter light source, which means that we'll also be able to simplify the design of the heat dissipater and optics. We hope that sometime in the near future, a mother will be telling her son, "Tony, turn off that laser and go to sleep." ■

Contact the author: shuji@engineering.ucsb.edu

Microstructuring of materials using brilliant laser light is one of the key topics now being investigated by the Laser Center (LFM) at the Münster University of Applied Sciences. The center's founder and director, Professor Klaus Dickmann, specializes in structuring surfaces and lending them new functions.

Adding depth



Modifying the surface of stainless steel at a structural level by varying laser parameters—in this case, laser fluency. This makes it possible to achieve different functional effects.

LFM Laser-Zentrum Münster

to surfaces

1 PAST / *From a barebones tool to a diagnostic system*

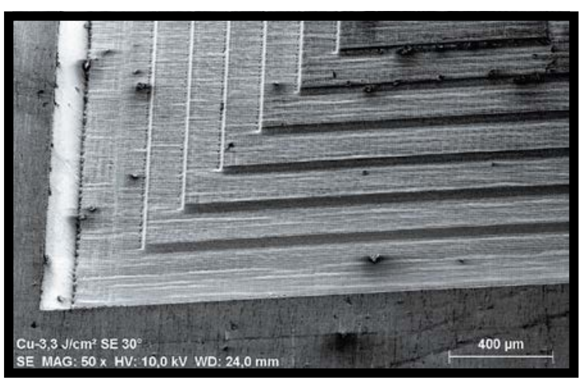
2009. After a decade of research, the ultra-short pulsed (USP) laser was about to experience an industrial breakthrough at the Laser World of Photonics—the world's leading trade fair for the laser and photonics industry, held in Munich. Professor Klaus Dickmann had come to the exhibition seeking the best USP laser for his laboratory. At that time, USP still had an almost mythical status—a tool that could process material without heating it up. Dickmann had his eye on the brand new TruMicro 5000 series of lasers made by TRUMPF. Using extremely short laser pulses lasting just 0.00000000001 second, the TruMicro 5000's laser beam could vaporize material in tiny, highly accurate portions, leaving no residue behind.

"Ultra-short pulsed lasers? From my very first encounter I saw them to be the perfect tool for microprocessing materials and structuring surfaces. A picosecond pulse ejects virtually no melt, so you get a uniform surface, right down to the submicron level."

Münster. The TruMicro 5000 arrived at the LFM's 600 square meter lab facility as a barebones system, a beam source in its purest state. But Prof. Dickmann had a whole lot more in mind for the empirical processes at his laboratory in Steinfurt. Conducting research with lasers means running through a virtually endless series of tests, especially if you are dealing with exotic materials. And that's precisely where USP lasers really come into their own. The team led by Dickmann is familiar with just about every type of material, including copper, stainless steel, piezoceramics, glass and many, many more.

"Automation? That's just as essential in research as it is in other fields. By bringing industrial processes into the lab setting, we can achieve valid results faster. Empiricism is a prerequisite for determining the behavior of a surface exposed to different amounts of energy. All the calculations and simulations can only provide approximate values."

Dickmann and his team got to work on transforming the beam source into a rather intelligent production system—boasting special optical features, technical optimization of the control system, and an in-line monitoring system. They even added high-resolution cameras to detect and correct processing deviations during processing. And they never lost sight of their primary goal: to investigate the capabilities of ultra-short laser radiation in real-life applications and to channel their findings into industrial practice. This would ultimately enable clients to select the perfect production parameters so as to achieve optimum results in their manufacturing process—in terms of both quality and quantity.



Generating a pyramid in copper through layer-by-layer rendering of a 3D model

The empirical approach to the objective involved plenty of automation—for tasks such as gradually shifting the laser fluency or energy density. The sample surface was divided into individual fields, creating separate segments, which were then processed with different beam parameters. The system painstakingly documented all the parameters and results to ensure that the test setup could be replicated. And it generated results that would go on to prove their worth in industrial settings.

2 PRESENT / *Searching for applications*

So who benefits from this research? Applications for medical technology are inevitably right at the top of the list. These range from film perforation and microcomponents for medical instruments to absorbable coronary stents that can be produced at significantly higher quality levels using ultrashort laser pulses. But the application that reigns supreme in Dickmann's mind is the adding functions to parts of surfaces in combination with microstructuring—and the process of generating microstructures using picosecond pulses (ps pulses) has already been implemented on an industrial scale. But there is so much more that is possible when researchers apply their imagination. For example, a picosecond laser can also be used to lend a functional structure to surfaces. This might involve a "lab-on-a-chip", a tiny laboratory the size of a fingernail, which acts as a blood analysis platform. After taking a blood sample, it channels it to a tiny testing station and immediately displays the results. Inside the mini-laboratory, the beam of a picosecond laser has carved hydrophilic channels in a hydrophobic environment. Interfacial forces drive the fluid sample along these channels to target destinations in the various reaction and analysis zones. By now the researchers at the LFM can not only measure the flow resistance; they have also succeeded in setting all the parameters with absolute precision. This opens the door to multiple applications in medical diagnostics.

A fascinating effect already inspiring researchers—and which will benefit manufacturers in the future—is the ability of materials to form self-organized microstructures under the influence of ultra-short laser pulses. The size and shape of the nano-ripples and periodic microstructures produced in this manner have a direct impact on the properties of the surface and can be controlled by modifying the laser parameters. The effect of material-specific self-organization under the influence of ps laser irradiation can further simplify the task of structuring functional surfaces. Researchers at the LFM laboratory are now busy investigating what exactly happens when you vary the laser parameters.

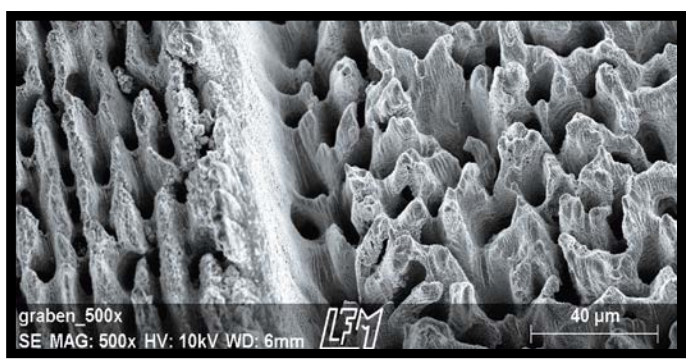
"Why niche applications? Because that's where interesting things are happening and where we can make our mark. And that's why we're not focusing on photovoltaics, because that market is very crowded right now."

One example of a niche application is the work currently being carried out by researchers in the field of tribology. For example, microscopically small lubrication pockets or freestanding microcones can reduce frictional resistance in mechanical drive systems and enhance performance. LFM researchers are seeking the most suitable parameters to optimize the speed and quality of the process.

Microsieves and filters are another promising field. The LFM specializes in developing methods used to produce microfiltration membranes from stainless steel. These microsieves are then used in biomedical and food technology, for instance. The primary goal in this case is to understand exactly how the process works and determine how USP laser radiation interacts with a wide range of different materials. Researchers hope that the results of these studies will lead to enhanced drilling speeds and quality at reduced hole diameters.

"Patents? They require tons of work and often clog up the process rather than yielding benefits. That's why we're not focused on patents and haven't applied for any. We're more excited about showing people the fascinating new technical possibilities for using the laser as a tool—and venturing into uncharted territory. And our partners in industry are only interested in methods that offer clear cost benefits over conventional techniques."

The LFM is also hard at work at the boundary between picosecond and femtosecond processing. They have already completed a project on microprocessing temperature-sensitive components. That was done in collaboration with the University of Applied Sciences at Mittweida. A novel ps laser system with an optical scanner was developed for the study, catering to several microstructuring processes using a variety of metallic and dielectric materials. A chromatic sensor first recorded the topography. The team then used a scanning electron microscope to analyze aspects of specific applications. At the end of the study the researchers compared their findings with those of parallel studies on femtosecond laser processing, carried out at University in Mittweida. The results were astonishing. With parameters optimized specific to the application, ps pulses achieve a level of quality that in many applications is barely distinguishable from the quality achieved by femtosecond processing. The project results made it possible to accelerate ablation processes for ps laser processing by up to 400 percent and significantly increase the level of precision.



Laser structured and functionalized microchannel with hydrophobic (left) and hydrophilic (right) surface properties

LFM Laser-Zentrum Münster

Functionalized matrix on a stainless steel surface, intended to fix water droplets in place

3 FORECAST / *Virtually unlimited opportunities*

Material processing with ultra-short pulses has been gaining ground for a long time, making its way into more and more high-volume production applications and supplanting conventional methods such as mechanical drilling, EDM and chemical etching. The laser offers multiple benefits—it can be configured with absolute precision to ensure reliable processes, and it is often the only tool that provides the option of selective processing. It also offers potential in fields such as security technology by incorporating counterfeit-proof structures inside materials, for example.

Right now the LFM is working on the topic of beam forming for USP lasers. The team figures that it can optimize processes by using adaptive optics to vary the geometries of the focus spot, exploiting the fact that the material is photonically activated in a different way. The researchers hope this will enable them to achieve faster process rates.

The LFM is also involved in fascinating work for the LACONA (Lasers in the Conservation of Artworks) organization. Every two years LACONA organizes a scientific exchange between restoration experts and laser physicists. Klaus Dickmann has been a permanent member of the international conference committee for a number of years. He and his team use the appropriate lasers to restore valuable parchment and old frescoes.

"Limitations? What limitations? As Peter Leibinger said: 'With the the ultra-short pulse laser we've opened a door into a new realm—and we won't know its precise extent or all its details for a very long time'."

The key challenge continues to be the task of discovering new applications. Thanks to the non-linear absorption processes, ps pulses can be used to process transparent materials, too. And the new class of coating systems and composites offers as much food for researchers' imaginations as does the structuring of ceramic surfaces. ■

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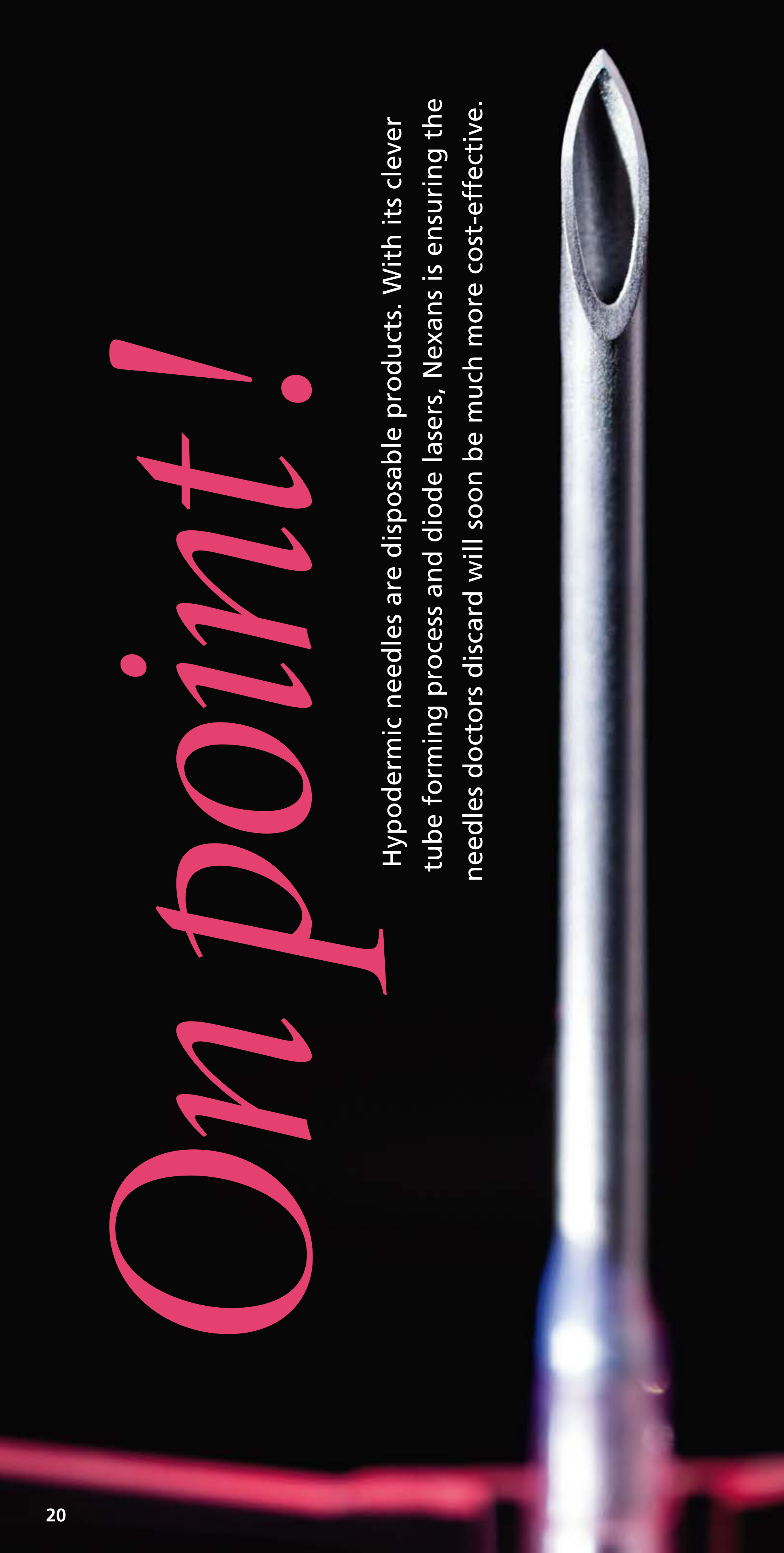
__Prof. Klaus Dickmann, D.Eng.,__ is the founder and director of the Laser Center at the University of Applied Sciences at Münster (LFM). He studied electrical engineering and physics and obtained his doctorate from the Hannover Laser Center (LZH), in the Institute of Production Engineering and Machine Tools (IFW) at the University of Hannover. His dissertation was on "Using Lasers to Cut Sheets of Electrical Steel." He not only focuses on research into material processing with the laser; he is also passionate about safety. As a publicly appointed and certified expert in laser safety and laser technology, he spends much of his time working on unresolved safety issues, including those relating to ultra-short pulsed laser radiation. www.fh-muenster.de/laserzentrum

On point!

Hyperdermic needles are disposable products. With its clever tube forming process and diode lasers, Nexans is ensuring the needles doctors discard will soon be much more cost-effective.



28 minutes into the episode: Dr. House leans on his cane, his patient convulsing and twitching in front of him. The TV physician is annoyed that his initial diagnosis turned out to be wrong (he gets it right second time round). His assistant yells for a drug with a complicated name, and a nurse prepares it, flicking the syringe with her finger. The "sharp" costs all of 6 cents — not that it interests anyone here on the set. In the real world, it's a different story. Developments in metal forming and welding processes sent the price of hollow stainless steel needles plunging during the middle of the last century. Doctors and hospital staff could now afford to use needles once and throw them away, instead of having to sterilize and reuse the same one over and over. This advance in hygiene has probably saved almost as many lives as the medication the needles are used to inject.

A billion needles While no official statistics are available, we know that in Germany alone millions of hypodermic needles are discarded daily after being used by doctors, caregivers and patients to pierce the skin. On a global scale, that figure probably amounts to over a billion. Every day. Which suddenly turns a few cents per needle into a very hefty sum indeed.

Ralf Egerer, Director of Machine and Cryogenic Systems at Nexans, tells us how he sees it: "Medical technology is expensive, even for what appears to be such a cheap product. We're working to reduce the costs. Our aim is to halve the price of hypodermic needles in the near future!" Egerer intends to achieve this goal using NanoWema, a machine set up at Nexans in Hannover. NanoWema rolls extremely narrow stainless steel strips into ultra-thin tubes and then welds them with a laser beam.

Ralf Egerer of Nexans believes that efficient diode lasers are the way to make injections cheaper.

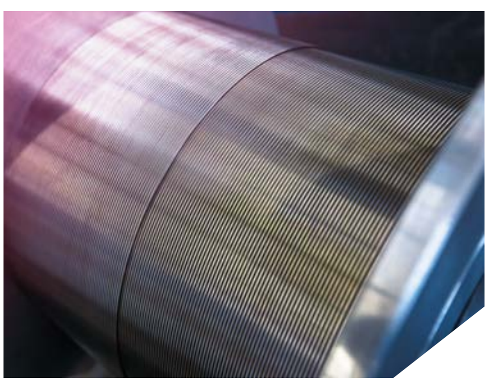
Nexans is primarily a cable manufacturer, and a pretty significant one at that. The company, based in Paris, has over 25,000 employees and is deemed to be one of the cable giants, providing the deep-sea cables, industrial wiring and telecommunications lines that connect our world. With its NanoWema concept, Nexans is applying its core business expertise to a new market. "It's actually not such a great leap from cables to hypodermic needles. To shield the cable bundles inside deep-sea cables against the effects of water pressure, we wrap them in thin-walled sheaths made of copper or aluminum. And so we're used to producing long, thin metal tubes. With NanoWema, we've managed to refine the process so we can make even narrower, finer tubing," says Egerer. The tubes he is referring to are 1.8 millimeters in diameter, with walls 0.05 millimeters thick.

This kind of tubing is usually manufactured using TIG welding processes. Egerer explains: "TIG systems have technical limitations in terms of the amount of steel that can be processed and the wall thickness that can be achieved. TIG-welded tubes are usually twice the diameter of tubing that has been joined with a laser, and have walls that are three times as thick. Intensive reworking is required after the TIG welding process to make the walls thinner and reduce the diameter." This involves pulling the thin tubing over a mandrel and forcing it through a narrower ring. The stainless steel hardens, becoming more dense and brittle. But the steel has to remain malleable for subsequent finishing processes, so the metal has to be relaxed again. To do this, the kilometer-long length of tubing is pulled through a red-hot oven and heated right through. "Five reductions and three annealing steps are the norm for tubes produced conventionally, which involves a tremendous amount of energy and labor," says Egerer. "With the diode laser, we make tubes that are already close to the required dimensions, saving our customers the expense involved in subsequent processing and the large amount of space the finishing process requires."

A welding seam five kilometers long

The NanoWema process starts with the machine unwinding a thin, five-kilometer strip of metal from the spool and applying a lubricant to it. In a series of steps, the machine shapes the metal into a perfectly round, open tube using forming rollers. At the end of the shaping process, the outside edges of the strip have been brought together to lie in parallel, side by side.

So fine is the gap between the edges that the laser has to be incredibly precise, focusing its beam to an accuracy of 0.2 mm. Instead of tracking the seam with the laser, Nexans has developed a system for mechanically fixing the gap in place so that it is forced to pass exactly through the beam's focal point. The machine pulls the tube-shaped metal strip through a narrow ring called the closing die. A small fin sticking out inside the ring rests in the gap, acting as a guide that keeps the seam centered as it passes along the line. The laser beam can now weld the five-kilometer seam from above in one go, without once having to adjust its focus. As soon as the tubing has been welded, the NanoWema system immediately winds it onto a spool. After four hours the diode laser gets a short break. "We turn the laser on, pull kilometers of tubing beneath it, and then switch the laser off again. It's that simple," says Egerer. "But Nexan's years and years of processing experience form the basis for making sure that it actually works. There's no way anyone will be doing something like this any time soon."



This hollow section of tubing will later be used to make hypodermic needles, capillary tubes for thermostats, or protective shields for communications electronics.

The NanoWema system produces ultra-thin tubes that are nearly the right size and shape, thus eliminating many of the finishing steps usually required to achieve the needed thickness and diameter.

The laser can continuously weld kilometers of tubing at rates of up to 20 meters per minute, which is twice the speed that a TIG welder can manage. What's more, there's no dirt build-up on the material, which has to be removed later. Welding lubricated tubing with TIG technology causes impurities due to the crusted grease that forms on the welding wire. The laser, meanwhile, simply burns the grease off.

"Laser technology has become much cheaper in the last ten years. We're able to get significantly more kilowatts of power out of every euro we spend, with far greater efficiency," says Egerer. "Taking all these factors into account, using diode lasers and the NanoWema process lets us produce ultra-thin tubing with unit costs that are half of the current market rate. So in the future, Dr. House's successors won't have to worry about the cost of their hypodermic needles. ■

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PAINT STRIPPING

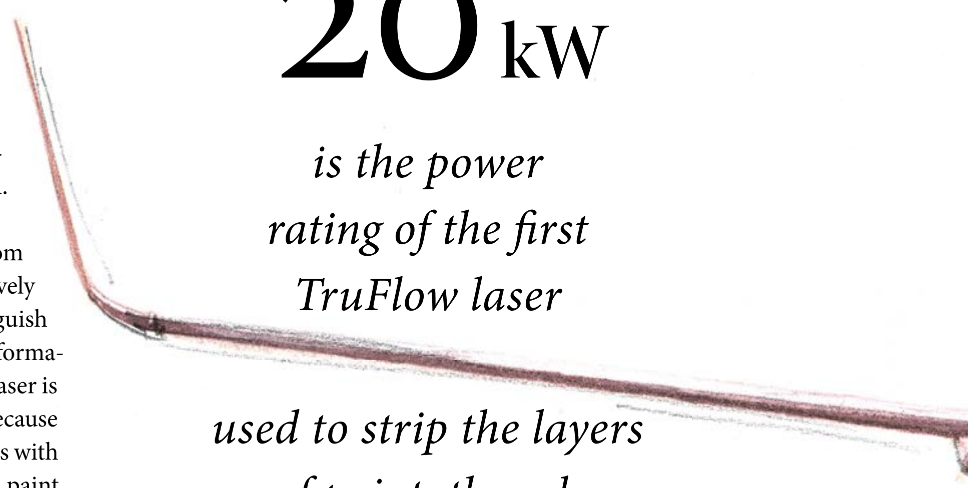
LCR Systems is planning to use lasers as a gentler and more efficient means of removing paint from aircraft.

Airlines regularly strip the paint off their aircraft and then apply a fresh coat, often using chemicals or abrasive methods such as sandblasting to do so. The problem is that these techniques are expensive, time-consuming, and produce large quantities of waste—to name just some of the disadvantages. In addition, some of the new materials used to build aircraft are very sensitive to chemical and mechanical cleaning methods, so aircraft manufacturers are increasingly seeking gentler and more precise techniques.

Mobile laser That's where LCR Systems B.V. comes in. The company, based in the Netherlands, has announced its intention to develop what it calls a "laser paint removal robot" by 2016, which would use a laser to strip all the paint off an aircraft in a completely automated process. The company says it will be compatible with all types of aircraft and markedly superior to competing products in terms of cost and performance. At the heart of the system is an extremely powerful CO_2 laser, which is TRUMPF's contribution to the project. This laser and a robot arm will be mounted on a mobile platform. The idea is that the platform will travel around the aircraft, permitting the laser to remove all the paint. A traditional laser with a tube-type HF generator would not provide reliable performance due to the movement of the platform and would also take up too much space. TRUMPF has therefore chosen a transistor-based generator for this application. The laser is significantly smaller and more rugged, making it the perfect choice for use on the mobile platform.

Faster and more economical To keep the surfaces from being damaged, the laser will be carefully programmed to selectively remove one or more paint layers. An optical sensor will distinguish between variations in the colors of the layers and transmit this information to the laser control unit to regulate the laser power. A CO_2 laser is a particularly good choice for stripping the paint off an aircraft because its long wavelength lets it remove a broad range of different paints with similar levels of ablation efficiency. LCR is hoping that its laser paint removal robot will reduce the time required for aircraft paint stripping by 30 percent. In the case of larger aircraft, this method would save two whole days of work. Other positive effects of the new technique include an 80 percent reduction in the costs for each aircraft, clean extraction of the gases, and a reduction of the CO_2 footprint by 90 percent.

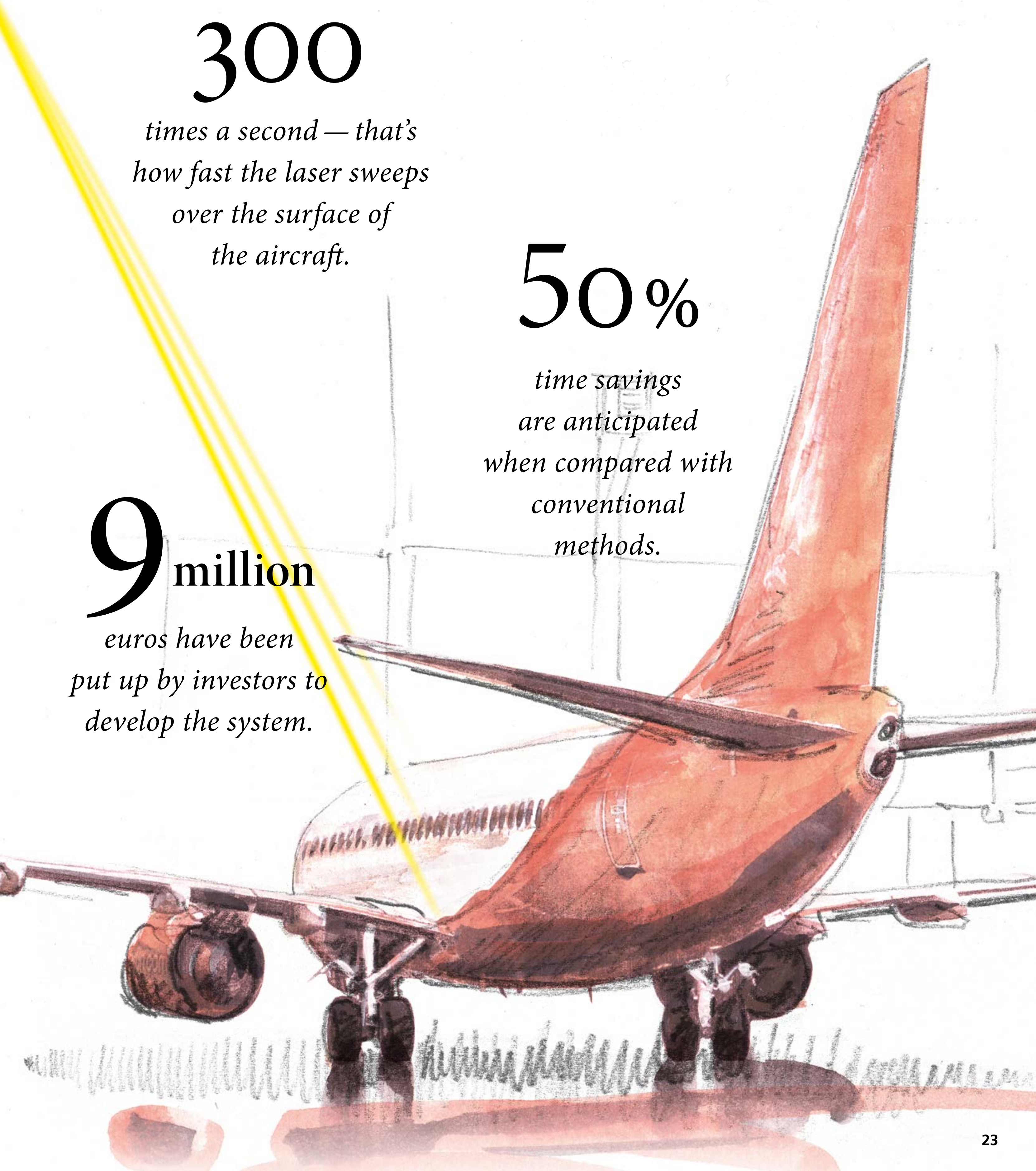
Contact: www.mowarped.com/lcr/



20 kW

is the power rating of the first TruFlow laser used to strip the layers of paint, though the company is also planning additional power classes.

Gernot Walter



300

times a second — that's how fast the laser sweeps over the surface of the aircraft.

50 %

time savings are anticipated when compared with conventional methods.

9 million

euros have been put up by investors to develop the system.

"Our customers expect us to have full mastery of laser welding technology."

Production engineer Huo Chenghui at the GKN Driveline plant in Shanghai, China

"The new disk laser welding system has significantly cut our production costs."

Zoran Bubic is in charge of central processes and operational planning at the GKN plant in Zwickau, Germany.

Mirko Hertel, Propaganda Studios, Detlef Göckeritz

"Retooling times, range of variants—we get better with every new system."

Antonio Torres, welding specialist at the GKN Driveline plant in Mexico, and his colleagues Neil Plant and Martín Sánchez

A model of *success*

Automotive giant GKN Driveline started welding drive components with lasers 14 years ago. Now the tried-and-tested system is moving to the next round—featuring disk lasers—on three continents.

A production hall in the Black Forest. Antonio Torres, welding specialist at the GKN Driveline plant in Mexico, and his colleagues Martín Sánchez and Neil Plant are watching closely to see how the machine handles the drive components they brought with them. A gripper picks up what's called a tulip cover for a flange. Shaped like an inverted top hat, the cover is slightly bigger than a fist. Flange and housing have already been joined in a press fit. They are placed in a parts holder on a carousel and are clamped from the inside. The carousel rotates to the next position, where an inductor is placed around the head of the component. The metal smokes and glows while the infrared beam of a pyrometer measures the temperature. Within seconds, the upper end of the flange is heated until it becomes incandescent. The carousel rotates into the welding cell. The light from the disk laser welds six neat seams before the part cools too far—again monitored by a pyrometer. At the final station, the gripper removes the part from the mold and inserts it in the marking laser box, where it is inscribed. The tulip cover is lowered onto the conveyor belt. The whole process takes just a few seconds.

Torres has connected his laptop to keep track of every single parameter. "I'd heard a lot about this kind of system from my colleagues, but I still find the cycle times and accuracy demonstrated here to be pretty impressive." He arrived in southern Germany from Celaya in central Mexico a couple of days ago. The purpose of his visit to KMS Automation, a manufacturing technology company, was to take a look at the machine that will soon be improving his production output.

Deep welding with disk lasers

GKN Driveline is one of the largest suppliers of automotive driveline systems, offering a wide range of drivetrain solutions. Here precisely timed mass production flow joins high quality expectations. GKN's plant in Mexico is currently being expanded and Torres is starting to manufacture a broader range of product versions. "This also means that we will be using new production technologies. From now on, solid-state lasers will play a permanent role in our manufacturing operations."

Neil Plant didn't have to travel quite as far as Torres to get to the Black Forest. He works at the main GKN plant in Birmingham, UK, as Manufacturing Development Manager Welding. As Plant points out, "Laser welding itself is nothing new for GKN. We adopted this type of CO_2 laser system for welding as the standard for many of our products 14 years ago, because it's stable, fast, and needs no touch-up work. Laser welding processes always seem expensive at first, but they have significantly reduced our production costs each and every time."

Most companies that produce welded drive components opt for CO_2 lasers. Until now, only they were capable of achieving the necessary depth for weld seams that have to hold up under constant high stress. Now solid-state lasers can do the same thing, thanks to the TRUMPF engineers who have greatly improved the beam quality of disk lasers in recent years. A tangible result of their efforts is Torres's new machine.

Drive components subjected to severe strains: countertrack joint (left) and tulip cover for flanges (right)

Neil Plant says, "The new laser welding systems have become standard in our operations, and are gradually being rolled out in more and more of our international plants." One of these will soon be in the plant at Shanghai, China, where production engineer Huo Chenghui works. "Our customers expect us to be up to date on this technology. We were so impressed with the efficiency of disk lasers that we intend to use them for all our smaller components in the future." Huo Chenghui plans to soon order the same disk laser welding system that Torres has. "Our German colleagues in Zwickau have already adopted this approach with very positive results. We want to follow their example."

Inductor as a perfect partner

In fact, it was in Zwickau that GKN started working with laser welding. Zoran Bubic, who is in charge of central processes and operational planning there, recalls: "We collaborated with TRUMPF 14 years ago on a welding process using CO_2 lasers. One of the challenges at that time was to find a clever way of preheating the workpiece." Their solution was induction heating. "It's ideal for welding as it provides rapid, localized heating and can be easily integrated into the process, which since then has produced stable, satisfactory results," says Bubic. "And then, a couple of years ago, in response to growing customer demand, we wanted to add a second welding system. It was to greatly lower the production costs but, of course, achieve the same quality level." Together with TRUMPF, the engineers at GKN Driveline Germany decided to employ a TruDisk 5302 fiber-guided disk laser in the welding process. The laser applications laboratory in Ditzingen worked with GKN Driveline to define the welding parameters, including heating temperature, laser output, focal position, welding rate and others. As Bubic explains, "Our customers are among the world's top carmakers and they have a very exact idea of how their components are to be. For instance, their specifications for welded seams cover pages and pages, defining tolerances for porosity, joining errors, undercutting, pore clusters and weld convexity. With the help of the TRUMPF laboratory, we were able to meet all the product's specifications with a disk laser solution." The system was integrated by KMS Automation, based in the Black Forest village of Schramberg. The company developed a concept that would allow the various elements to be combined into one production machine with short cycle times. TRUMPF Hüttinger is responsible for supplying the generator, process energy and inductor for preheating, while TRUMPF supplies the laser source, optical cables, optics, and the TruLaser welding cell.

Goodbye helium

"We have been using this solid-state laser welding system for two years, and it has let us, once again, reduce our production costs considerably," reports Bubic. "In addition to its smaller footprint—our old CO_2 system needed 100 square meters, its successor only 35—it also uses less energy. The new system has an efficiency rate of nearly 30 percent, which is much more than that of the previous system." Another advantage of the solid-state laser is that it operates at a wavelength that the material can absorb more efficiently. Thus it requires far less laser power. "But the biggest factor is the shielding gas," explains Bubic. "Helium is expensive right now. The CO_2 system blows some 16 liters of this gas onto the workpiece every minute in order to suppress metal vapor plasma. Since solid-state lasers don't create plasma, we don't need shielding gas at all." In the Black Forest, Torres pulls on white safety gloves and picks up the hot, freshly welded tulip cover. "We get better with every new system. This one enables us to weld a wider range of component versions using a single machine while reducing retooling times." He looks at the component and adds: "Most of the advances made in joining in the future will come from laser welding." ■

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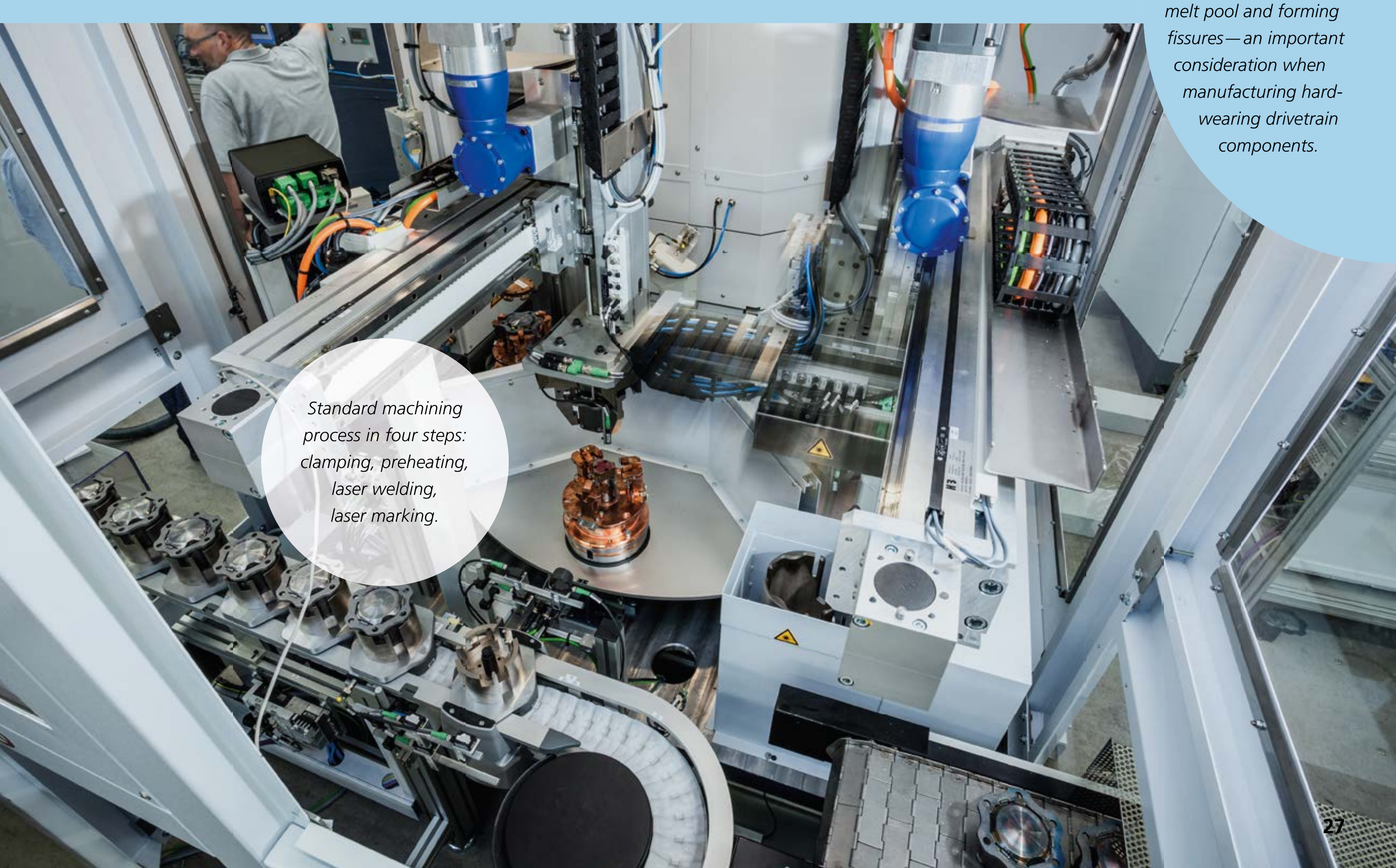
Phone: +49 (0)7156 303–36890, hakan.kendirci@de.trumpf.com

Before it enters the welding cell, the upper end of the tulip cover is heated by an inductor until it becomes incandescent—in mere seconds.

Solid-state welding lasers do not generate plasma, so GKN Driveline has absolutely no need for shielding gas.

Preheating keeps the carbon in this extremely hard metal from diffusing into the melt pool and forming fissures—an important consideration when manufacturing hard-wearing drivetrain components.



Standard machining process in four steps: clamping, preheating, laser welding, laser marking.

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RECIPROCITIES IN HYBRID LASER WELDING OF THICK SHEET METAL

Dr. Wei Liu (29) studied mechanical engineering at the Bobby B. Lyle School of Engineering at Southern Methodist University in Dallas, Texas. He wrote his dissertation on using the hybrid laser arc to weld advanced high-strength steel sheet and aluminum alloys. In separate efforts he investigated both the interactions between the laser beam, the substrate and the filler material as well as the interaction between the laser beam and the arc. You can read his complete dissertation online: *http://gradworks.umi.com/36/70/3670927.html*

OPTIMIZING METAL SURFACES USING PICOSECOND LASERS

Dr. Peixun Fan (28) studied material sciences and engineering at Tsinghua University in Beijing. He wrote his dissertation on the use of picosecond lasers to machine and enhance metal surfaces by adding microstructures and nanostructures—with particular reference to their antireflective properties. These play a key role for material surfaces in areas such as sensor technology, aeronautics and aerospace engineering, and solar energy applications. You can request the full dissertation by writing to him at: *fpx@mail.tsinghua.edu.cn* Peixun Fan's research studies are available on the following website: *http://www.researchgate.net/profile/Peixun_Fan*

FURTHER READING

So what are the next steps for light as a tool? The work done by five young researchers gives readers some idea of what is possible.

OPTICALLY PUMPED, SEMICONDUCTOR-BASED ULTRA-SHORT PULSED LASERS

Mario Mangold (28) obtained his doctorate at ETH Zurich, researching the so-called MIXSEL—modelocked integrated external-cavity surface emitting lasers. These semiconductor disk lasers have the potential to evolve into compact sources for ultra-short laser pulses used in medicine, biotechnology and metrology. Mangold achieved pulse repetition rates of between five and 100 GHz and pulse lengths of less than 300 femtoseconds. His full dissertation is available on request: *mangold@phys.ethz.ch* and his recent research work can be browsed at: *https://scholar.google.ch/citations?user=4r66gpQAAAAJ*

WELDING MAGNESIUM ALLOYS WITH ZERO-GAP LAP JOINTS

Dr. Masoud Harooni (33) obtained his doctorate from the Bobby B. Lyle School of Engineering at Southern Methodist University in Dallas, Texas. He wrote his dissertation on joining hard-to-weld lightweight alloys, focusing on a magnesium alloy that can help the automotive industry to significant reduction in mass. He also studied the application of spectroscopy to detect welding defects nondestructively, in in real time. His project was a mutual work with GM. Read more about his findings here: *http://gradworks.umi.com/36/24/3624907.html*

CONTROLLING ELECTRONS WITH SINGLE-CYCLE LASER PULSES

Dr. Matthias Kübel-Schwarz (30) obtained his doctorate from the Ludwig Maximilian University in Munich, in collaboration with the Max Planck Institute of Quantum Optics in Garching. He investigated individual atoms and molecules using ultra-short laser pulses with durations of just a few optical cycles. These laser pulses can be used to control the movement of electrons and atoms and to perform targeted bond breaking in polyatomic molecules. His full dissertation and other academic publications are available online at: *http://www.attoworld.de/Mainpages/PeoplePages/KuebelMatthias/index.html*

Dr. Wei Liu, Dr. Peixun Fan, Dr. Masoud Harooni, Mario Mangold, Dr. Matthias Kübel-Schwarz

Where's the laser?

In the light of the future: The high-beam headlamps illuminate 600 meters of the highway ahead. This is a shining example of an entirely new light source. A blue laser diode illuminates a specially structured ceramic plate doped with phosphorus. Excited by the laser, the converter emits its own wonderful white light, which, like deer caught in headlights, has captivated the automotive world. And since the automotive industry has the high volumes, enthusiasm and resources to take laser headlamps out of the lab and onto the road, auto applications just the beginning. But eventually this new "laser light" could cast everything else in shadow. Interestingly, laser headlamps rely on another beam source which is still in its infancy: the required structure of the ceramic surface can only be produced industrially using ultra-short pulsed lasers.

BMW, Gernot Walter