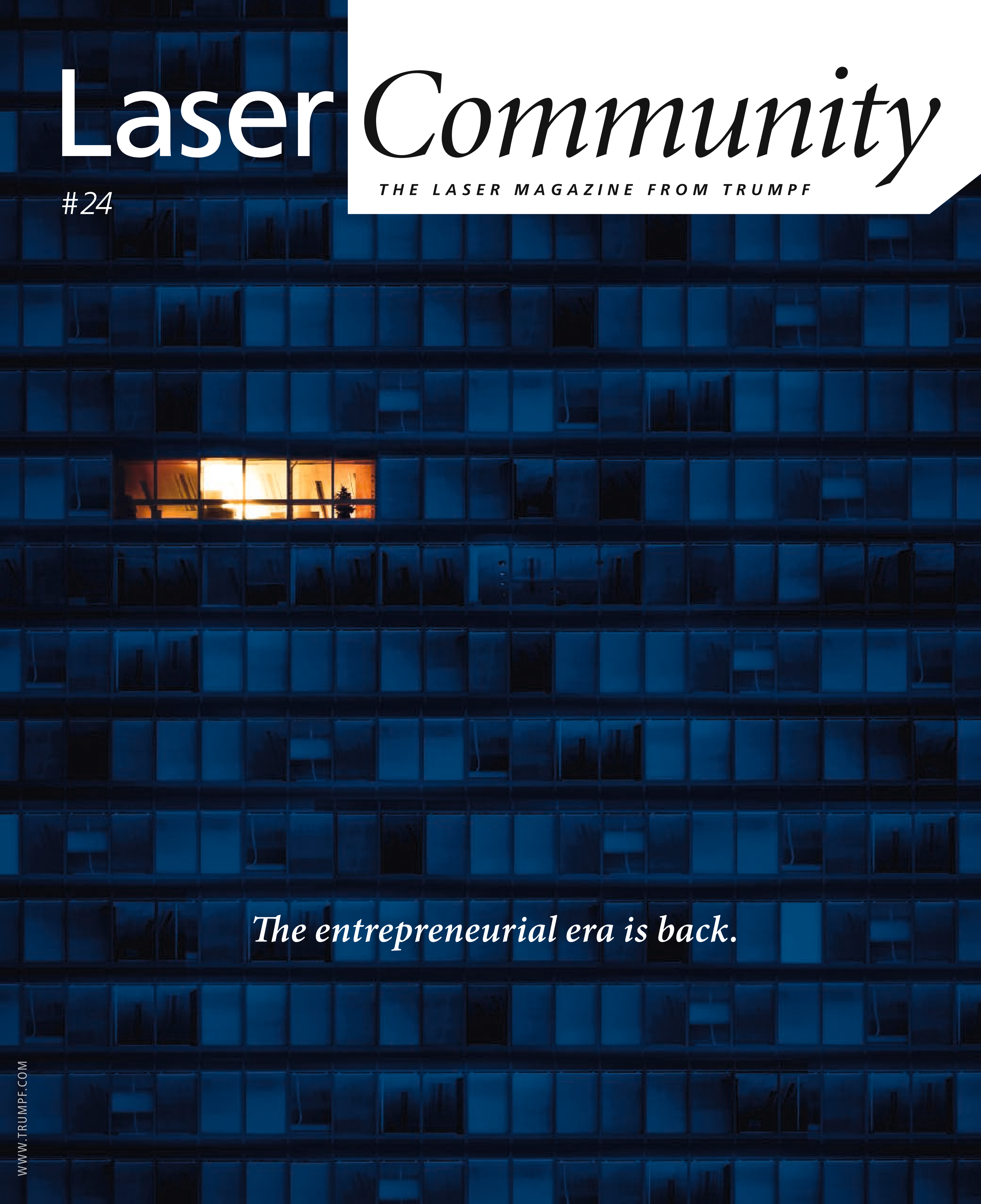
Laser Community

THE LASER MAGAZINE FROM TRUMPF

#24



The entrepreneurial era is back.

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#24

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The cover of this issue boldly proclaims that we are entering a new entrepreneurial era—and you only have to glance through the magazine to see why.

This isn't really surprising. After all, the laser is a fairly recent technology that still has huge potential for innovation. Anyone like me who has the good fortune to be a fly on the wall of the TRUMPF development departments can confirm that! The development projects under discussion right now would have seemed utopian just five years ago. Lasers are developing fast—and optical technologies, or photonics, are speedily evolving from enablers into game changers. From flexible manufacturing and Industry 4.0 to microlithography, semiconductor manufacturing and self-driving vehicles, none of today's megatrends would be possible without photonics.

It's not just Germany that has recognized the huge potential of lasers and photonics. Countries all over the world are now following suit, as I saw on my visit to the Laser World of Photonics fair in Shanghai this March. The Chinese laser industry is evolving at a tremendous pace. And the industry as a whole is thriving thanks to a plethora of national initiatives, all of

A new era of entrepreneurs?

which draw heavily on German photonics research. Europe's "Photonics21" and the "National Photonics Initiative" in the U.S., for example, are very much in the same mold as Germany's "Agenda Photonik 2020." What all these initiatives have in common is their fixation on a path that Germany has been forging for years: the decision to provide support for photonics not only in well-established businesses, but to also pay special attention to start-up founders.

A similar trend can be seen in many companies that are deliberately targeting entrepreneurs and new ideas in the photonics field and in other industries. Their tactics include funding start-ups and holding competitions for ideas—and there's plenty to suggest this is a good approach to take. The fact is, entrepreneurs are special. They identify strongly with their idea and put everything they have into making it a success. That unleashes the kind of energy that leads to superior creativity and faster implementation, triggering the kind of innovations that are otherwise hard to achieve at established companies. That's what makes entrepreneurs so appealing, both to individual businesses and to the economy as a whole. They create new things, and that's a talent we both need and admire. So now you know why we decided to devote so much of this issue to start-up founders and entrepreneurs.

We hope you enjoy reading about them!

PETER LEIBINGER, D.ENG. H.C.
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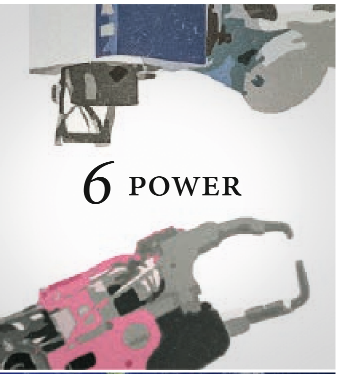


COMMUNITY

TECHNOLOGY

Gernot Walter, SPIE, janrysavy / iStockphoto, Craig Ferguson, Michael Mazohl

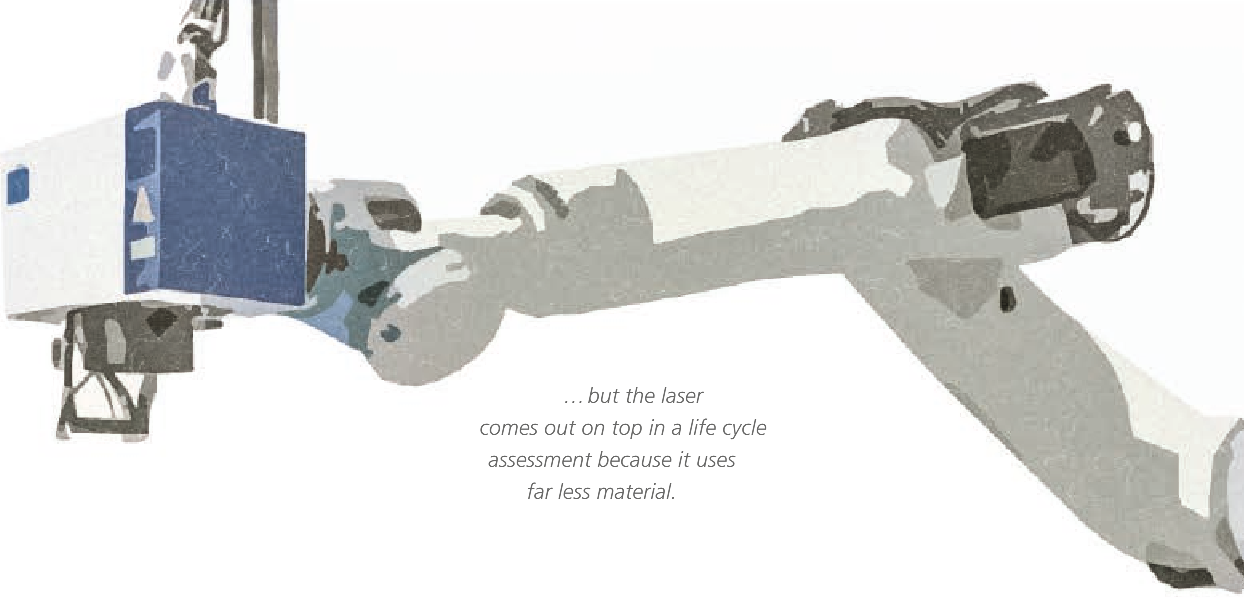
24/2017

OPINION

APPLICATION

Markus Mainka / fotolia, Gernot Walter; Tom McKenzie, Björn Behrens, Tim E White / Alamy Stock Foto

POWER



… but the laser comes out on top in a life cycle assessment because it uses far less material.

LIGHT IS GREENER THAN ELECTRICITY

Back when resistance spot welding was just starting to catch on, people still saw environmentalists as hippies in knitted pullovers toting hemp backpacks. Today, environmental life cycle assessments are a key element in the battle for customers and the future of the automobile.

Laser welding versus resistance spot welding: the flange makes all the difference. Both methods are very fast and can be highly automated …

Finally, we have a definitive answer as to whether resistance spot welding or laser welding is the most energy-efficient and eco-friendly option in car body manufacturing. The Federal Institute for Materials Research and Testing (BAM) recently carried out a comparison of the environmental impacts of using these two methods to weld deep-drawn body panels, a project that was led by Prof. Michael Rethmeier in collaboration with Prof. Matthias Finkbeiner from the Department of Environmental Technology at TU Berlin.

The results clearly show that the amount of sheet metal used is the predominant factor in the life cycle assessment of both methods—and lasers significantly reduce the amount of sheet metal required by fulfilling the same design specifications with far narrower flanges. Overall, this means that laser welding consumes nearly 50 percent less energy than resistance spot welding.

One caveat is that this only applies if you exploit the engineering opportunities offered by laser welding. If you leave the design unchanged, then the laser's benefits decline.

Even then, though, they don't disappear altogether. In fact, using a laser to weld deep-drawn panels in car body manufacturing still uses less energy than resistance spot welding even if you completely exclude the factor of materials from the equation. In other words, *lasers rule.* ■

Prof. Michael Rethmeier, head of the division Welding Technology at BAM

Prof. Matthias Finkbeiner, head of Sustainable Engineering, Technical University Berlin

Prof. Rethmeier talks about different methods and their consequences: laser-community.com/en/7119

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GLORY

WHITE LASER FOR CLIMATE RESEARCH

The company Thorlabs has developed a new kind of supercontinuum laser that can measure greenhouse gases in the atmosphere. The laser won one of this year's Prism Award.

In the last 15 years, the output power and spectral characteristics of supercontinuum lasers have improved steadily. Now Thorlabs—a manufacturer of photonics equipment based in Newton, New Jersey—has gone one step further by developing a femtosecond-laser-pumped MIR supercontinuum source based on a fiber laser. This novel design allows Thorlabs to achieve a high repetition rate of 50 megahertz with an average power output of 300 megawatts and a broad wavelength coverage of 1.3 to 4.5 micrometers. These parameters make the supercontinuum source a suitable tool for optically detecting the status of chemicals in the atmosphere using absorption spectroscopy. The idea is to help researchers measure greenhouse gases in the air, improve their understanding of global warming, and detect dangerous chemicals at an early stage. What makes the device particularly useful for researchers in the field is its diminutive size, roughly as big as a shoe box. Pumping with a femtosecond laser reduces output noise to just 0.025 per cent RMS, resulting in very high pulse-to-pulse output energy stability. These two key advantages were singled out for particular praise by the Prism Award jury when Thorlabs collected its award in the "Scientific Lasers" category at a gala in San Francisco in February.

Supercontinuum or "white light" laser sources are used to generate a super-wide continuous optical spectrum. They make use of nonlinear effects such as those produced when high-intensity laser light is propagated through optical fibers. Spectroscopy is one of the primary applications of white laser light. ■

Contact: sales@thorlabs.com

The Prism Award for a new type of supercontinuum laser was presented to Reza Salem, Lead R&D Scientist at PicoLuz and the Thorlabs Team of Anjul Loiacono, Head of Business Development; Peter Fendel, Head of the Laser Division; and Michael Mohammadi, OEM Sales Manager (from left to right).

SPIE, janrysavy / iStockphoto

“LASERS ARE THE BEST WAY TO COMBAT STAGNATION“

Taiwan’s economic miracle is also a laser miracle. Dr. Fanghei Tsau, General Director of the Laser & Additive Manufacturing Technology Center at the ITRI, and his team are at the forefront.

When the Industrial Technology Research Institute (ITRI) was founded in 1973, Taiwan’s per capita GDP was just a few hundred U.S. dollars. That figure now stands at 23,827 dollars. Has ITRI played a role in this growth?
Yes, absolutely. ITRI is a nonprofit organization for research and development. It was designed to help Taiwanese industrial companies become and remain competitive and sustainable. Over the years, the institute has incubated more than 240 companies — including global semiconductor leaders such as TSMC and UMC. Some 140 CEOs in the Taiwanese high-tech industry once worked at our institute. Our economic miracle in the past few decades consisted of Taiwan shifting from a labor-intensive economy to a value-added one driven by innovations. And our research institute has played a key role in this transformation.

How important is laser technology to the Taiwanese economy?
Very important. For companies in Taiwan, laser technology has been the driving force to avoid low-wage competition and prevent stagnation in all our key sectors of industry—from mechanical engineering and metal processing to automotive and aviation. For the next 30 years, lasers will play a key role with respect to innovations in intelligent manufacturing. That’s also what Apple is thinking, according to its patent applications. Apple is, by the way, an important company to Taiwan.

Why do you believe that lasers will play a key role in production?
There are clearly several trends in manufacturing: multi-task machines, higher production speeds, more large-scale production but with greater customization, automation and diversification of materials. And then there are megatrends, such as Industry 4.0, the Internet of Things and intelligent production lines run by software. These trends pose several challenges; laser technology and additive manufacturing, being both digital and precision processing by nature, have played and will certainly continue to play very important roles in every case.

What role does additive manufacturing play in Taiwan?
It’s becoming more important every day. The government is providing the Taiwanese aviation industry with major funding. There are some 200 companies in our aviation industry, generating annual sales of approximately 3.3 billion U.S. dollars. Additive manufacturing holds great appeal, as it helps these companies address challenges such as small-scale production, custom manufacturing, weight reduction and design of complex components. ITRI, an early adopter of metal additive manufacturing technologies in Taiwan, stands ready to work with the aviation industry supply chain, from material processing to components manufacturing. In this way, we add value not only to the Taiwanese economy, but also to society.

Could you please give us an example of a joint endeavor with a company?
There are plenty of examples. We helped Tailift, a forklift manufacturer, develop a laser-texturing machine. We mostly focus on pilot production and opportunities for integrating laser processing into manufacturing. As for additive manufacturing, we do a lot of work in laser metal deposition and 3D-printing. Just as an example: we recently helped two companies, Aurora and Tongtai, im-

Craig Ferguson

AHEAD

"Lasers will play a key role with respect to innovations in intelligent manufacturing —that's also what Apple is thinking."

Dr. Fanghei Tsau, General Director of the Laser & Additive Manufacturing Technology Center of ITRI

plement 3D-printing. We have expertise in alloy design and powder production, design analysis, laser processing, post-processing and software. This enables us to continue our development work in medical devices and molds in automotive applications. And when it comes to LMD, we recently began offering our customers a tremendous upgrade: a test platform featuring a 6,000-watt disk laser source. It's the only one of its kind in Taiwan! We linked the platform to robotic arms and a five-axis CNC machine. This allows us to conduct customer-required works with regard to rapid manufacturing of casting molds, repairs of surface defects and functional surface coatings.

What do you have planned for the next few years?

All signs point to continued robust growth in the global market for laser applications and additive manufacturing. Taiwan anticipates appealing new jobs in these fields—and ITRI will help out here. In fact, we regard ourselves as pioneers in additive manufacturing. We hope that this technology becomes widespread and thrives in Taiwan. In addition, we want to hire more in-house staff. I am committed to making the center a launching pad for up-and-coming entrepreneurs and a great place for young and ambitious people to work. ■

Contact: www.itri.org.tw

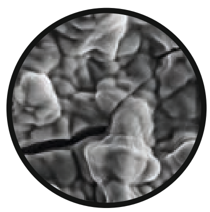
ITRI: The Industrial Technology Research Institute in Hsinchu, Taiwan, is a publicly financed research and development institute that employs around 6,000 people. It develops and commercializes technology applications in close cooperation with companies. ITRI is a multi-disciplinary research organization across several fields of interest, including laser technology and additive manufacturing.

Marcel Schäfer

A CRACKING IDEA

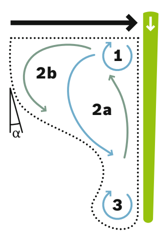
High-strength steels and laser welding are increasingly popular in car body manufacturing. But combining those two things leads to a significant risk of hot crack formation. Now there's a solution.

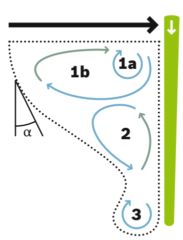
Classifying steel as a lightweight material may seem like a contradiction in terms. Yet, more than almost any other material, steel enables users to tailor its mechanical properties by selecting the right alloy composition and applying heat. That gives it huge potential, such as the ability to make smaller, lighter and thinner-walled parts from high-strength steels that are capable of absorbing the same forces as far heavier, thicker-walled parts made from conventional steels. At the same time, however, these materials make the joining process far more challenging because of their susceptibility to cracking. This is especially true of axisymmetric, round parts—a typical example being the joint between a toothed wheel and a shaft in a transmission—which pose particular problems at the end of weld seams where the laser power drops to prevent the formation of end craters. These cracks reduce the long-term strength of the seam under operating conditions and are therefore ruled to be inadmissible in the DIN EN ISO 13919 standard.



Top: Freely solidified dendrite surfaces visible under a scanning electron microscope—a typical characteristic of hot cracks.

Below: Changes in fluid dynamics while welding with a shifted focus position.





HOT AND COLD CRACKS There are currently two mainstream methods of avoiding cold cracking. One option is to add another material to the weld as a filler wire to produce localized changes in the composition of the alloy. The other technique is to pre-heat the part to a sufficiently high temperature. The idea behind both methods is to generate less martensite—a very hard constituent of steel—in the seam, because an excessive amount of this crystalline structure leads to a high degree of hardening as well as significant tension in the joining zone due to the increased volume.

In contrast, hot cracks are formed by a complex interplay between the alloy composition, the structural design, and the position of the seam on the part. They are also influenced by weld process parameters that determine the thermal load on the workpiece. Hot cracks form in the welding process during the transition of the liquid metal melt into a solid state; in other words, during the cooling process. This leads to stress and expansion of the material at the same time, with breaks running along the grain boundaries (intercrystalline), some of which exhibit an accumulation of low-melting phases.

Hot cracks are small and rarely extend more than a few millimeters. This study focused on hot cracks that form in the actual weld deposit. These solidification cracks are often buried deep below the surface and are difficult to detect. In contrast to cold cracks, hot cracks are characterized by freely solidified dendrite surfaces that can be seen under a scanning electron microscope (SEM).

THE KEY IS IN THE KEYHOLE
In deep-penetration welding, energy delivery in the welding process occurs when the laser beam vaporizes the material. The resulting vaporization pressure leads to the formation of a deep, vapor-filled hole known as a keyhole. Due to the dynamic behavior of this keyhole, fluid motion occurs within the pool of molten material created by the laser beam as it advances along the weld joint. The molten metal flows around the keyhole, generating eddies in the rear section of the melt pool that affect the three-dimensional geometry of the pool. The correlation of these three factors—keyhole, melt flow, hot cracks—lies in a periodicity: the frequency of the oscillations of the keyhole and melt pool correspond to the frequency with which hot cracks form.

The formation of hot cracks can be influenced by modifying the way in which energy is delivered to the keyhole.

This also applies the other way around; in other words, the melt pool eddies and weld pool geometry can be influenced by the way in which energy is delivered to the keyhole. Various measuring techniques were used to analyze these melt pool motions. A new method was developed to obtain a kind of footprint of the process by creating a median image of the flow phenomena within the weld pool. This technique introduces additional particles into the melt pool to observe and track their trajectories with the help of x-rays in order to gather information on the flow conditions. One of the phenomena the scientists observed was that the direction of rotation of the eddies in the upper part of the melt pool reverses when the focal position is shifted by one Rayleigh length. At the same time, it was also observed that this same shifting of the focal position led to lower hot crack susceptibility.

Thermo-mechanical simulations were used to examine the connection between modified flow phenomena and modified geometry of the melt pool on the one hand, and reduced crack formation on the other. These revealed that the location of maximum strain also shifted in tandem with the focal position as a result of the changes to the melt pool geometry. These findings can be used to influence the conditions that are required for hot cracks to form. As a result, the "only" thing that needs to be done to avoid hot cracks is to exert a sufficiently strong influence on the flow characteristics and thus on the geometry of the melt pool.

Researchers came up with various options for modifying the way in which energy is delivered to the keyhole. In one approach, lasers of differing brilliance (beam parameter product 2 mm * mrad to 24 mm * mrad) were used with different focusing conditions. In another, scientists investigated the effects of the laser's wavelength (1.03 µm and 10.6 µm) while maintaining the same optical and mechanical boundary conditions. Unfortunately, none of these approaches were successful. In both cases the team succeeded in modifying the form and characteristics of the cracks but were unable to eliminate crack formation entirely. They also detected a significant increase in crack susceptibility as soon as higher welding speeds were used.

DOUBLE BREAKTHROUGH The breakthrough was achieved by applying multiple methods simultaneously. The first way of preventing cracks is dual beam welding, which involves splitting the output power of the main beam into a primary beam and a secondary beam at a ratio of 72 : 28. As long as the beams are arranged in tandem—i.e. with the secondary beam following the primary beam as it advances—and the secondary beam is directed at a specific point in the beams' shared melt pool, then cracking can be avoided entirely. This does, however, require the spacing to be adjusted to the melt pool length in each case, which is dictated by the selected laser output power.

The second technique is to carry out welding using a time-modulated laser beam. By carefully selecting the amplitude of the continuous modulation, it is possible to eliminate cracking entirely across a broad spectrum of the modulation frequency, regardless of weld depth and welding speed.

Analysis of the flow characteristics in the melt pool and their geometry has revealed that time-modulated power makes a significant difference. It is also possible to carry out thermodynamic surface measurements of fluctuations in melt pool length during the welding process and to significantly reduce these fluctuations. This yields a measurable parameter that can be used to monitor and stabilize process behavior. Several series of tests on real parts have shown that this method offers considerable potential for welding high-strength steels without cracking in the future. ■

Marcel Schaefer

Marcel Schäfer *studied mechanical engineering at Stuttgart University, majoring in laser technology. Part of his upcoming doctorate focuses on joining high-strength steels. He carried out his experiments at the TRUMPF Laser Application Center and at the Institute of Beam Tools (IFSW) at the University of Stuttgart.*

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Three entrepreneurs tell the story behind their success

→

Here they come again:

Photonics and especially laser technologies have turned generations of inventors and engineers into entrepreneurs. Now a new era of entrepreneurs is emerging.

Vienna, AT

Michael Mazohl

LISTENING WITH LIGHT

Xarion Laser Acoustics GmbH, Balthasar Fischer

It was the laser microphone that prompted me to set up my own business. The idea came to me after I obtained my doctorate in physics while studying for my second degree in sound engineering at the University of Music and Performing Arts in Vienna. The first one I built filled a whole table and cost 300 euros: it was while I was writing my thesis for my sound engineering degree and I made it out of materials from the local hardware store. It was all very rudimentary, but it worked! Now, 10 years later, I'm managing director of the technology company Xarion. My invention has shrunk to just a few millimeters in size and it's fantastically high-tech, with a small sensor that measures sound waves using light. We use a laser beam to replace the membrane you find in conventional microphones. When a sound wave hits the laser light of our laser microphone, the pressure causes slight changes in the light's velocity, and the laser beam propagates more slowly. So, we measure the sound wave indirectly by measuring the intensity of the light. The sensor has no moving parts, which makes it resistant to external influences. What's more, it can measure sounds ranging from deep infrasound to ultrasound in the megahertz range, covering a frequency range 50 times larger than that of the human ear. We're hoping this will open new doors for process and machine monitoring in industrial manufacturing. By applying it to a laser material processing machine, for example, we can accurately determine whether the nozzle is blocked or how deep the laser beam is penetrating the material. We acquire that information by listening with the microphone at very high ultrasound frequencies. The sensor even works underwater and in radioactive liquids, so that opens up potential applications in the fields of medical devices and non-destructive material testing. In Geneva, it's helping CERN to monitor metal absorbers that are fired at with highly energetic protons.

Runcorn, UK

Paul Cooper

WAR ON THE DEVIL PARTICLE

LPW Technology, Phil Carroll

Seven years ago, I realized something essential. Like all industrial production processes, additive manufacturing (AM) comprises the three key pillars of machine, process and material. Yet while AM specialists were always talking about machines and processes, hardly anybody was focusing on metal powders! Which is odd, considering that the production of metal powders back then was still plagued by a thousand teething problems. If you're using low-quality materials, even the best processes and the best machines aren't going to do you any good. In other words: garbage in, garbage out. So, we made it our mission to understand metal powders, to view the AM process from the perspective of the powder, better than anybody else does. To this end, I hired more and more people; there are over seventy-five of us working here now. Together, we conduct research and implement stringent control and processing to be certain that we have complete control over the specification of shape and size of powder particles. The worst enemy of AM remains the devil particle, or contamination particle. There are two billion particles in just one kilogram of powder. How can you make sure that every single particle is perfect? We invest a great deal of time and effort to keep devil particles at bay from the point of powder purchase and throughout the customer manufacturing process. I've always sought out customers in the two industries known for the highest standards: aviation and medicine. Simply put, if we satisfy their criteria, then we can meet anyone's requirements. My company is not a megastore for metal powders. We instead see ourselves as a technical "upscale boutique".

HEIFER NICE BUSINESS

Engender Technologies, Prof. Cather Simpson

One of the biggest problems in the dairy industry is sex. Essentially equal numbers of male and female calves are born—but only females will ultimately produce valuable milk. Three years ago, we had an epiphany based on the fact that 90+ percent of all dairy calves in industrialized countries are the outcome of artificial insemination. Sperm cells that have an X chromosome produce female offspring. The DNA of these sperm cells is slightly larger than the DNA of a sperm cell with a Y chromosome. That means we can use a fluorescence method to distinguish sperm cells and sort them into two groups. We introduce the sperm cells into a channel on a microfluidic chip. Detection of the sperm's fluorescence emission triggers a short flash from a Yb:YAG laser, depending on sex. The scattering power of the pulse nudges the intact sperm cell to the edge of the channel, which splits downstream for superb sorting: the X-bearing sperm cells flow to the left and the Y-bearing cells to the right. All this happens in a system about the size of an office printer. Venture investment company Pacific Channel and the University of Auckland helped us found Engender Technologies, Ltd.—which is commercializing our idea. The market for artificial insemination in the agricultural industry is worth $1.5 billion U.S. annually, and we are certain that high-quality sperm sorted by sex will always sell better than unsorted sperm.

Auckland, NZ

Alex Wallace

"Disruptive technology" Is a popular term in today's tech world. Industry experts and economic analysts apply it to photonics in general and to laser systems in particular, perceiving these as disruptive technologies that will have far-reaching effects on every aspect of our lives. This radical transformation has received solid political support for a number of years. Back in 2005 the European Union created the Photonics21 association of industrial representatives and research organizations. In 2012 U.S. President Barack Obama followed suit, founding the National Photonics Initiative to bring all the key institutes and industry associations under one roof. The stated goal of both alliances is to play a pioneering role in this highly promising field.

Light-based technologies are currently transforming every industrial sector, including aviation, medicine, automotive, research, biology, electronics, and many more. This process of upheaval presents entrepreneurs with the perfect opportunity to make their mark with a single, brilliant idea. Right now, young men and women on every continent are founding companies based around laser light. Laser technology may be a fairly recent development, but this marks the second era of entrepreneurs over the course of just 60 years.

— The first gold rush —

The history of the industry really began with a legendary figure in the laser world, Eugene Watson. In 1961, he founded his first company, Quanta-Ray, in California—the oldest laser manufacturer still up and running today. Just five years later he took another bold step, setting up a number of other photonics companies. He built one of his first lasers in a laundry room. With the help of his lifelong friend Earl Bell, Watson was one of the first people to see that lasers with sufficient average power could be used to machine materials. When the first CO_2 laser was invented with the power they needed, the two scientists realized that their hour had come. Boeing pioneered the use of CO_2 lasers for titanium cutting and welding.

Eugene Watson was part of the first generation of entrepreneurs in the laser industry. The production of laser beam sources for research purposes was already underway when various entrepreneurial inventors and developers began to realize just how profitable laser material processing could be.

In 1974, Jürgen Held decided to take the plunge and launched a start-up called Held Systems based on laser technology in West Germany. Just one year later, his company sold its first industrial laser, a 200-watt system for manufacturing glass fibers. Later on, when the first industrial-scale, high-power lasers became commercially available, Held Systems focused on building special-purpose laser machines, a segment they are still flourishing in today.

But it was in the 1980s and 1990s that the first laser technology gold rush really picked up pace. New laser machine tools revolutionized various sectors, particularly the manufacturing industry. In 1992, Bernhard Lang founded the company Lang-Laser-System in Germany to build his own laser machines for processing packaging materials. In 1995, Thomas Kimme set up a contract manufacturing business offering laser metal deposition. Today, Laservorm also produces its own laser processing machines. In 1999, Erhard Hujer set up a job shop for 2D and 3D laser material processing and has been opening a new location every few years ever since.

> *Laser technology often inspires people to start up their own companies.*

For the most part, these entrepreneurs are practical people, typically engineers and technicians from the manufacturing industry. Not always experts in laser technology, they understand how much laser cutting and welding are transforming sheet metal processing. This new era of entrepreneurs also encompasses integrators who delve deep into the realm of laser technology to develop methods and machines for material processing. In the USA, Mark Plasse opened the job shop and integrator Litron in 1997. Today, Litron is the leading U.S. provider of laser cutting and fully enclosed laser welding systems for the medical and aerospace industries. In the Netherlands, Martin Langkamp set up the company IMS in 1999 as an offshoot of Texas Instruments. Since then he has been building laser manufacturing systems designed for microprocessing in the medical device and electronics industries. So laser technology is once again prompting people to establish new companies.

— Here comes the second wave —

In 2012, Balthasar Fischer from Austria had an idea he couldn't get out of his head. The qualified physicist and sound engineer was determined to build a functional microphone without any moving parts—in other words, without a membrane. He was tired of trying to measure sound and having to deal with interference such as wind noise, the noise of water flowing, vibration, and membrane reverberation. His groundbreaking solution was to detect sound waves directly by measuring the changes in light intensity in a laser beam. Fischer founded the start-up company Xarion while he was still studying at the university. That makes him a good example of today's second era of entrepreneurs, many of whom started out in research institutes. The more researchers discover about laser light and how it works, the more these findings give rise to ideas for applications and business concepts. Similar to the famous "Stanford boys" of Silicon Valley, many of this latest batch of start-up founders are post-grads and post-docs who spin off a marketable idea from their research work and then team up with venture capitalists who have their eye on a profitable investment. The fact that these ideas stem from general research rather than a narrowly-framed user problem makes them more diverse than ever before. Cather Simpson is a university professor of physical chemistry in New Zealand and an expert in laser technology in her area of expertise. In 2015, she heard about the problems involved in selecting the gender of dairy cattle and immediately realized that a laser might offer the perfect solution. Now her start-up company Engender is on the verge of launching a viable sperm sorting machine.

— Digital photonics —

Two key technological trends that reinforce each other—and arguably even depend on each other—

are photonics and digitalization. Many observers in the media and business world consider the digitalization of production in the form of Industry 4.0 and smart manufacturing to be the defining disruptive technology of our time. That may well be true, but it's only part of the story. The fact is that fully digitalized factories still need a tool that can actually perform the required steps on the workpiece in a fast, automated, direct and versatile fashion. Light is the perfect choice. It is physically unconstrained and can be formed in real time using lines of code. Laser light can be modified and adapted from one set of data to the next, and that makes it an excellent tool for bridging the digital and physical worlds.

Photonics is going through a gold rush phase

Its benefits are particularly striking in the field of additive manufacturing. In 2016, the Swiss start-up UrbanAlps redefined the concept of a key, adding additional security features within the key's hollow interior that make it impossible to forge. Producing a key in this way would be impossible without laser-based 3D printing. People say data in the future will be like gold, but perhaps it will actually be more like the gold pan. Because in many cases it will ultimately come down to using streams of data to create, move or modify real things that you can touch.

A further trend in digitalized photonics is automation, another area where entrepreneurs are making major strides. Take Walter Sticht in Germany, for example. In 2011, he decided that even at 64, there was still plenty more to discover. He sold his old company and started afresh with the idea of creating ultra-fast automation for flexible small-batch production—using lasers of course!

— *Everyone's on board* —

Jörg Jetter from Germany took a very different approach. In 2006, with an MBA under his belt, he decided to start his own company. He began searching for a worthwhile technology that could form the basis of a business. He analyzed markets and potential demand and eventually founded the company Firma 4Jet. The idea he settled on was to build mass-market laser machines to ablate surfaces. The applications soon snowballed, and 4Jet machines are now used to vaporize rubber residues in tire molds and remove photoactive layers around the edges of solar cells.

This willingness to see the laser as a problem-solving tool enriches laser technology enormously and broadens the scope of what we regard as feasible. With a surge of entrepreneurial momentum also emerging in a plethora of other sectors, the new era of laser start-ups is steadily gaining even more impetus. Laser technology has become a familiar and confident part of the industrial landscape. Any product developer worth their salt knows that laser light is an integral part of their toolkit, because whatever product they have in mind, lasers can almost always form a fruitful part of the production process.

New opportunities are also constantly emerging based on novel laser-based technologies, and astute engineers know how to spot these and turn them into successful businesses. For example, one of the side-effects of the recent surge in 3D printing is the huge demand for high-quality metal powder. UK-based LPW Technology is a one-man company that decided to tackle this challenge head on. In 2012, Phil Carroll hired a team of specialists to help him investigate every aspect of metal powder manufacturing, all before he sold a single particle. Today his company supplies powder to demanding customers in the aviation and medical sectors.

— *Lasers are cool* —

There's one more reason behind the recent surge in laser start-ups, a hard-to-pin-down factor that exerts a powerful influence: lasers are cool! They fuel the imaginations of hundreds of thousands of highly intelligent people. You would probably struggle to find any engineer or scientist who didn't lap up science fiction books or TV shows as a kid. Laser beams were a staple of that genre before they became a reality, and that's one of the reasons why they have now come to epitomize the idea of future technologies. And this isn't just a subjective feeling—more and more of today's biggest visions feature light and lasers, including star probes, space elevators, weather modification, e-mobility, factories of the future, and cancer therapy. Photonics is clearly destined to play a key role in the future of technology.

Ultimately there's one key thing that any potential entrepreneur needs to remember: if you're looking for an idea that amounts to more than just lines of code, you would be wise to take a careful look at what lasers can do. Or think carefully about what people who work with lasers need. Or at least mull over what lasers can do to help people who are planning something new—or who are simply looking to save the world.

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Christof.Siebert@de.trumpf.com

LIGHT HEARS SOUND
Read the full report on Xarion here:
www.laser-community.com/en/7054

POWDER GALORE
The big interview with Phil Carroll about LPW Technology:
www.laser-community.com/en/7117

SPERM SORTING
Read the full interview with Prof. Cather Simpson, the founder of Engender, here:
www.laser-community.com/en/7060

THE SILENT REVOLUTION

Cutting, welding, deposition welding, 3D printing … these cool kids of laser material processing hog the limelight, so it is easy to overlook the marking laser standing in the background. And yet it has transformed the marking of objects forever.

Endless possibilities: supermarket chains use marking lasers instead of stickers or shrink-wrap in order to reliably distinguish organic vegetables from their non-organic counterparts. No dye is required, and it does not harm the skin of the cucumber. It just bleaches pigments in the skin.

Fotolia/Markus Mainka, iStockphoto/omersukrugoksu; composing: Gernot Walter

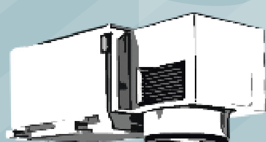
STAND-ALONE SYSTEM
TruMark Station 5000
[860 x 2.000 x 1.310 mm]
Convenient, handy marking of components

MOBILE SYSTEM
TruMark 5010 Mobile Marker
[980 x 460 x 1,200 mm]
Flexible markings for large, heavy components

01

[factor: size]

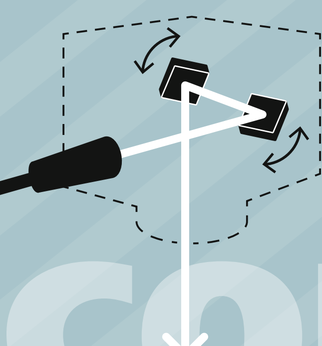
The installation space needed for marking laser systems is shrinking all the time. They can be set up like office printers, easily inserted into process chains, shuttled back and forth between cumbersome components, or integrated directly into processing machines. Moreover, they are closed, almost maintenance-free, plug-and-play systems that require practically no prior experience with laser technology. All this increases their availability as a tool.



INTEGRATABLE SYSTEM
TruMark Serie 5000 [414 x 131 x 157 mm]
Marking directly in manufacturing systems

DESKTOP SYSTEM
TruMark Station 1000 [410 x 760 x 831 mm]
Simple markings for small components and small-scale series

SCANNER
[Moves up to one million pulses per second across the workpiece]

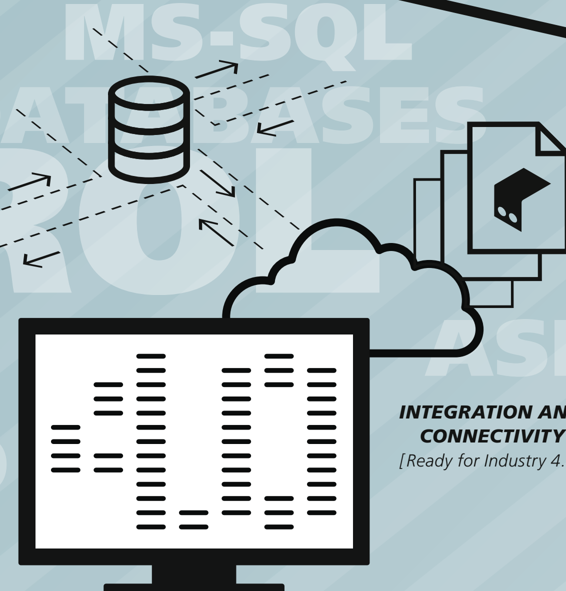


02

[factor: control]

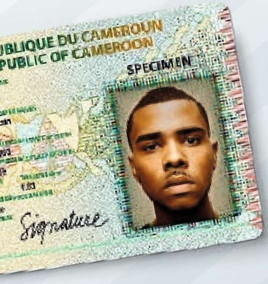
Modern scanning and control technology makes it possible to control the position of the focus and the amount of energy input with huge precision—not just on surfaces, but also in 3D space. The software supports operators or automation solutions as the case may be, calculates edges, aligns markings, recognizes and reads QR codes, creates documentation and initiates follow-up steps. It is the key to integration in manufacturing solutions, ERP systems, and database solutions—both on the road to plug and play and also on the road to Industry 4.0 and smart factories.

IMAGE PROCESSING
[Edge sensing, alignment, reading and checking of data matrix codes]

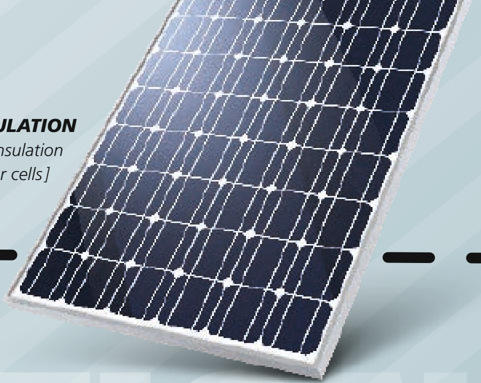


INTEGRATION AND CONNECTIVITY
[Ready for Industry 4.0]

ULTRAVIOLET
[355 Nanometer]



Individualization, security features
[forgery-proof ID cards]

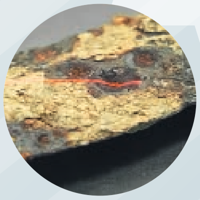


EDGE INSULATION
[Electrical insulation of solar cells]

06

[factor: Application]

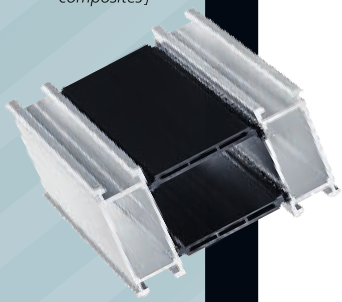
Cleaning and restoration
[ablating grease, corrosion, dirt]



Marking lasers are continually expanding into new fields of application. Because they are faster, more efficient and more productive than conventional methods, because they do not require the use of consumables and because they are more versatile—they are not limited to reproducing characters or symbols from a fixed set. They are not even limited to marking tasks. They simply use laser light to process surfaces very quickly while affording extremely tight control. This makes them a wonderful platform for application ideas in the lower power range—and for uses far beyond their original purpose.

INCREASED EFFICIENCY
[Better sliding behavior with small oil cups]

HYBRID JOINING
[Secure adhesion for plastic-metal composites]



MARKING 4.0

It began with the simple idea of engraving characters using laser light. Today it has grown into an almost universal and fully connectable technology platform for marking, surface processing, surface functionalization and material micro-processing.

03

[factor: laser light]

FREQUENCY AND POWER
[Selectable parameters]

Modern, almost maintenance-free beam sources make it possible to build systems that can be operated by users without special laser know-how. At the same time, they offer increasingly more freedom in the choice of process- and material-specific processing parameters. For individual solutions, the full range of pulsed industrial beam sources is available: for special materials, higher productivity, or applications such as ablation, cleaning, and surface structuring and activation.

INFRARED
[1.064 Nanometer]

GREEN
[532 Nanometer]

APPLICATION

05

[factor: processes]

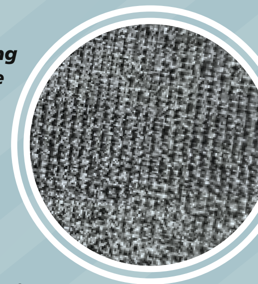
Laser marking started out with laser engraving in steel. With the evolution of beam sources and scanner and control technologies as well as its use on materials other than steel, a variety of other processes developed over time: the foaming of plastics for raised markings, heat-induced color contrasts that do not affect the surface characteristics, the manipulation of pigments in the material, or the targeted ablation of paint or other coating layers.

PROCESSES

Foaming
[plastics]

Engraving
[metals, wood, leather, ceramics]

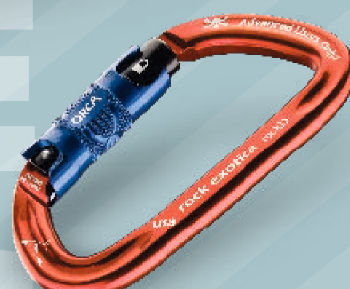
Engineering surface characteristics
[metals, plastics, wood, ceramics, leather]



Color-contrasting
[plastics and metals]

Blackmarking
[metals for corrosion-resistance]

Ablating/ de-coating
[paint/coatings]



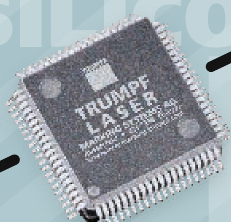
04

[factor: materials]

Pulsed lasers can leave marks on practically any kind of material. In case of doubt, it is just a matter of choosing the right laser, wavelength and pulse duration to achieve the desired result. Today's possibilities for fine-tuning individual parameters also make it possible not only to leave markings, but also, for example, to just change specific pigments in a targeted manner.

MATERIALS

WOOD GLASS LEATHER SILICON CERAMIC CHROME STEEL PLASTICS ALUMINUM GOLD



Gemalto, Heureka / Ville Eerikäinen, Markus Mainka / fotolia, Landesmuseum Württemberg, electriceye / fotolia

“I find the disk as amazing as ever”

Adolf Giesen had his head in the clouds when he came up with the idea for a disk laser in 1991. In this interview, he describes how the laser is reaching for the stars to rid the Earth’s orbit of space debris.

Y

Your plan is to vaporize space debris using a laser beam. It’s a bit audacious, isn’t it?
Not at all! It’s completely realistic. At the German Aerospace Center (DLR) we’re already using lasers with high-energy short and ultrashort pulses to detect space junk. We can calculate their trajectories down to the nearest meter.

But to vaporize pieces of debris the laser would have to be considerably more powerful!
We’ll certainly need a good few kilojoules to vaporize the surface of each piece of debris. We’ll do that using laser ablation, which will have a “push” effect, slowing the debris down and ultimately causing it to burn up in the lower atmosphere. The idea may sound a bit up in the air, but we actually already have concepts on the table.

And where will this huge increase in laser power come from?
A disk laser is obviously the best choice.

You came up with the concept for the disk laser 26 years ago. Did you realize back then exactly how much potential it had? I notice that you based your first publication on the assumption that each disk would provide just a few hundred watts of output power.
I didn’t want to stick my head out too much back then, but I had already realized that the disk could generate a lot of power. At that time, I was lucky enough to be working together with Klaus Wittig, an outstanding theoretician, as well as with Andreas Voss and Uwe Brauch. We collaborated on the design of a model that demonstrated that we could turn my idea into a scalable concept. Even then it was clear to us that the disk laser wouldn’t be restricted to the kilowatt range. In fact, that was what kept me working on the concept, because I said right from the start that I didn’t see the point if the output power was limited.

The basic concept of a disk laser occurred to you in an unusual place. So, unlike most of us, you don’t spend your time flicking through magazines when you’re on a plane, right?
(laughs): You really have done your homework! You’re talking about my flight from the USA to Japan in the fall of 1991. And you’re right, I really did make good use of it.

That’s putting it mildly! You laid the foundations for an entirely new manufacturing technology. How did it actually come about?
I had just come back from a conference on solid-state lasers. One of the sessions focused on the active laser medium Yb:YAG. The presenter was tremendously enthusiastic about this highly promising material that could be used to build beam sources for high-power lasers if only a way could be found to cool the material sufficiently, a problem that seemed insurmountable at the time. And I couldn’t get that thought out of my mind.

So, you cracked the seemingly insurmountable problem of cooling?
Yes, the idea of a disk just came to me on the plane. Because a disk that was thin enough would be particularly easy to cool across its whole area. That was the basic idea at least, and my team and I then spent the next three months devel-

oping a concept that essentially looked much the same back then as it does today.

Could you briefly explain how it works?

Well at its core, as I said, is a Yb:YAG disk that is just about a few hundred micrometers thick—the surface area to volume ratio solves the cooling problem. What's more, the direction of the temperature gradients is almost exclusively axial, which results in minimal thermal lens effects. The laser medium is pumped in a multipass configuration that consists of a parabolic mirror and a deflection system. It actually sounds relatively simple, but the technology is highly complex. The pump beam is refocused by a mirror into the laser crystal. The highly reflective coating on the back of the disk reflects back any non-absorbed radiation. Repeat that enough times and you get highly efficient absorption of the pump light, and the pump source doesn't even have to be particularly brilliant for the disk laser to exhibit good beam quality.

I suppose people welcomed the idea with open arms?

Well, first we had to overcome a few difficulties. For example, the way in which the disk is bonded to the heat sink was—and still is—a crucial issue. But we successfully tackled all those problems. And we made steady progress year after year with support from the German Federal Ministry of Education and Research and with the collaboration of industry partners. Jenoptik presented the first disk laser at the laser exhibition in Munich in 1997, and TRUMPF followed suit in 2000.

"In 1982 the experts would have been satisfied with just 500 watts."

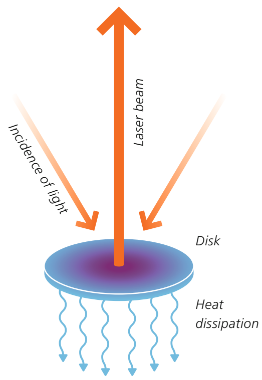
And now the disk laser is a well-established, robust and highly successful workhorse and you're talking about pulse energies in the kilojoule range. How do you intend to tackle the cooling problem with that kind of output power?

You're right that cooling has always been the key issue. It really does go hand-in-hand with any attempt to boost the laser power. A disk laser features less thermal deformation in real-life operation than a traditional laser by a factor of around 100. But there's more room for optimization even in that area. For example, there are publications from the U.S. on liquid nitrogen-cooled lasers. And we have already shown that temperatures between -30 and -100 degrees Celsius lead to significant improvements. But it's difficult to imagine those kinds of cooling systems in an industrial setting.

Björn Behrens

OK, but experts say that you don't need more than 6,000 watts for a disk laser in industrial use.
(laughs) Right. And in 1982 the experts said that industry wouldn't need more than 500 watts! Back then they were talking about the CO_2 laser that TRUMPF developed in collaboration with the German Aerospace Center. Our goal was an output of 1,000 watts. The TRUMPF experts pledged to support us even though they figured that a maximum power of 500 watts would easily be enough for industrial applications. And now look where we are. 6,000-watt disk lasers have almost become the norm for industrial use. Obviously, there are limits, because you have to deliver the laser power to the workpiece in a controlled way. But I feel sure that there will always be a demand for more power and that we'll be able to supply it.

"Boosting laser power has always come down to the issue of cooling."



Because the disk is thin with a large surface area, heat dissipates quickly—often even passively via a heat sink.

You recently left the German Aerospace Center to enjoy your retirement. When I see your enthusiasm for the disk laser, I find it hard to believe that you can ever let go!
You're right, it's not easy. My colleague Friedrich Dausinger and I founded a company in 2007. It's based in Stuttgart and now employs 15 people. We plan, develop and build disk lasers for companies and institutes that need high-power lasers for very specific applications, and we provide support to companies that are using this technology for the first time. And it's going very well.

It seems extraordinary that such a sophisticated and pioneering technology wasn't immediately seized upon by manufacturers everywhere. Why was that?
The disk laser was a total departure from how lasers had been built before. It requires a complete shift in thinking, and that's not exactly easy. Take TRUMPF for example, which has worked hard on developing this technology and invested a great deal. You need some serious capacity for that to pay off, because it really is a big investment.

But the disk laser has big potential for the future, too. That's why we are striving to make that know-how more widely available. It's true that I've retired, and I'm enjoying spending time with my family, but I still want to keep tabs on what's happening and help shape things in whatever way I can. ■

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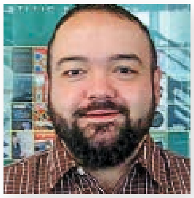
phone: +49 (0) 711 907060 – 550,
info@dausinger-giesen.de

PROF. DR. ADOLF GIESEN obtained his doctorate in physics from Bonn University. His doctoral thesis reveals that he had already developed a keen interest in lasers. From 1982 to 1986, he worked on high-power CO_2 lasers at the DLR Institute of Technical Physics in Stuttgart. From 1986 to 2007, he headed up the laser and laser optics department at the University of Stuttgart's Institute for Beam Tools (IFSW). It was during this period that he developed the basic concept for the disk laser. In 2007, he was appointed as the director of the DLR Institute of Technical Physics in Stuttgart. In that same year, he founded the company Dausinger und Giesen GmbH with his colleague Friedrich Dausinger.

Adolf Giesen won the Berthold Leibinger Innovation Prize in 2002. He received the Rank Prize in 2004 and the Charles Hard Townes Award in 2017.

Björn Behrens



CRACK-TIP MICROMACHINING BY FEMTOSECOND LASER

Is ultrafast laser ablation a viable method for creating artificial cracks in metal laminates for fracture testing? Ricardo Martin Martinez (31) addresses this question in his master's thesis at the University of New Mexico. He uses an ultrafast pulsed laser to ablate microchannels in copper/niobium laminates in order to mimic crack tips. He then examines the materials for layer restructuring and modification.

His complete thesis is available here: http://hdl.handle.net/1928/32253

SEQUENCING ALGORITHM FOR FIVE-AXIS LASER DRILLING

The aerospace industry uses two methods for high-efficiency laser drilling: on-the-fly drilling and percussion drilling. In his doctoral dissertation at Canada's University of Waterloo, Ammar Alzaydi (31) presents a new sequencing algorithm that can be used to generate trajectories for five axes. His algorithm optimizes the sequence of the waypoints, or hole locations, and the time intervals between waypoints.

You can access his complete dissertation here: https://uwspace.uwaterloo.ca/handle/10012/11039

FURTHER READING

How else can light be used as a tool? The work of five young researchers provides a glimpse into new possibilities.

ABLATION-COOLED MATERIAL REMOVAL WITH BURSTS OF ULTRAFAST PULSES

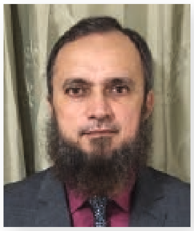
Femtosecond pulses ablate material with high precision. However, the low speed at which material can be removed limits the potential of femtosecond laser ablation. These limitations can be circumvented by exploiting ablation cooling, as Can Kerse (31), a student at Bilkent University in Turkey, describes in his doctoral dissertation. Laser pulses repeated at ultra-high repetition rates ablate material before the residual heat deposited by previous pulses diffuses away.

You can request his dissertation via email: cankerse@gmail.com.

NEW APPROACHES TO DESIGNING ULTRAFAST FIBER LASERS FOR ABLATION-COOLED MATERIAL REMOVAL

In her PhD's thesis at Turkey's Bilkent University, Saniye Sinem Yilmaz (28) explores using a fiber laser system to remove material by using the idea of ablation cooling. For exploiting the fully efficient ablation cooling, she first designs an oscillator that generates high-frequency bursts up to repetition rates of mega- to gigahertz. Next, she constructs a fiber amplifier system operating in burst mode for reaching the desirable pulse energy levels to material removal. These fiber laser systems based on their operating wavelengths can be applied to a variety of materials from metals to tissues.

You can request her dissertation via email: sinem.yilmaz@fen.bilkent.edu.tr



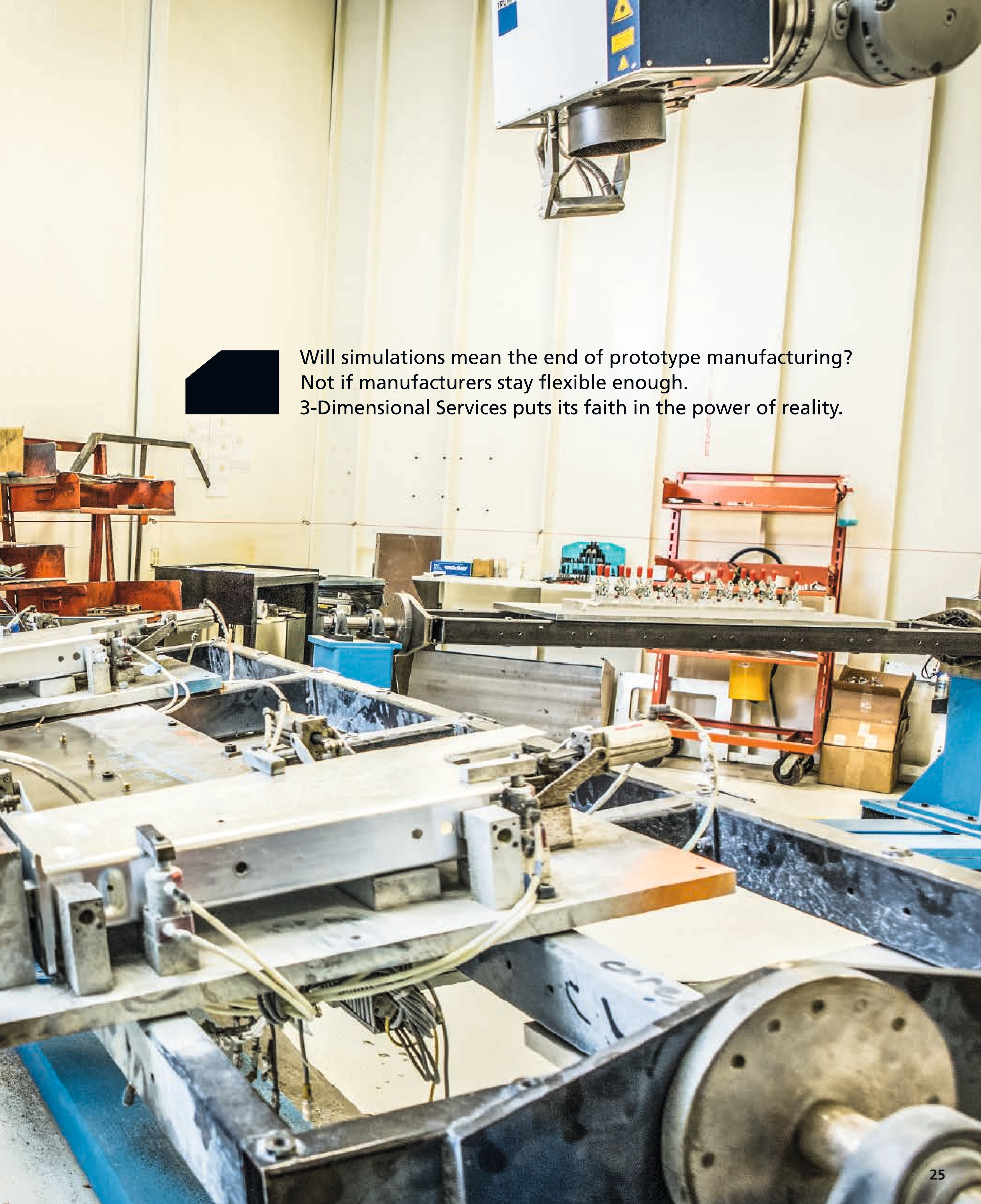
EXPERIMENTAL INVESTIGATION OF LASER CLADDING BEAD MORPHOLOGY FOR ADDITIVE MANUFACTURING

Laser cladding is integrated into industrial production lines to create high-quality surfaces. This process is influenced by multiple parameters and requires a deep understanding of process mechanisms. In his doctoral dissertation at Canada's University of Windsor, Syed Mohammad Saqib (50) experimentally investigates the effects that process parameters have on bead geometry during laser cladding.

You can access his dissertation here: http://scholar.uwindsor.ca/etd/5782/

NOTHING IS AS REAL AS REALITY

Tom McKenzie



Will simulations mean the end of prototype manufacturing?
Not if manufacturers stay flexible enough.
3-Dimensional Services puts its faith in the power of reality.

Communities close to Detroit remain the heartbeat of America's automotive industry. Sure, Michigan's largest city has seen better days. But nearby towns are home to many companies that are thriving. One such place is the industrial park in Rochester Hills, a prosperous city some 25 miles (40 kilometers) north of the industrial metropolis that is Detroit. Everything looks tidy: streets as straight as an arrow, manicured lawns and American flags flapping in the breeze at SMEs based here. This is also home to 3-Dimensional Services.

NOTHING AGAINST DATA, BUT ... To hear some industry experts tell it, this company will soon cease to exist. Such predictions lead Alan Peterson, one of the company's founders, to shake his head. "For years now, people have been telling me that the latest greatest computer program will make prototype manufacturing obsolete. But our company grows from year to year. We keep adding to our machinery. And our order books are full." In his experience, it doesn't matter how good simulations are. At the end of the day, customers want something real they can hold in their hand. "A computer can test only those parameters that a human specifies. But when you use a real object in a crash test, then something unforeseen can occur that nobody would ever think of," says Peterson. But this company president has nothing at all against the digital realm. On the contrary, prototype manufacturing at 3-Dimensional Services never would have gotten off the ground without data. In fact, Peterson pinned his hopes on lasers from the outset. "Prototype manufacturing entails machines handling new tasks all the time. That makes flexibility extremely important, which is where lasers come in," says Peterson. The reason is simple. In contrast to machine tools, there is no need for time-consuming and cost-intensive retooling with lasers. You just feed the laser data and it will do what you want.

PROTOTYPES & HIGH-VOLUME PRODUCTION

3-Dimensional Services has specialized in prototype manufacturing since the company was founded in 1992. It now employs 485 people. Customers are in the automotive, maritime, aerospace and household-appliance industries. On any given day, 3-Dimensional Services relies on forming, welding, milling, stamping and cutting for plastics, steels and umpteen alloys.

Peterson explains how they go about their work: "Customers generally give us design data, which we use to make 50 prototypes. Once the manufacturers have conducted initial testing, 3-Dimensional Services usually supplies another 300 to 400 units for market research. The next step is pre-series production of several thousand units. We accompany our customers throughout the development process—all the way to high-volume production." But sometimes batch sizes amount to hundreds of thousands of units. "That generally happens if there's a product recall, which might mean that a manufacturer needs replacement parts ASAP!" Customers almost always expect work to be fast and inexpensive: "Quality is no longer a topic of conversation with customers. Perfection is simply a given." That is just one reason 3-Dimensional Services has put its money on lasers since day one. When it comes to speed and precision, there is no match for laser tools. So the company's production facility uses 30 laser systems—including laser-cutting cells and laser-welding cells made by TRUMPF.

FLYING LASERS A glance inside the welding cell makes it clear how 3-Dimensional Services taps the advantages of lasers. A robotic arm precisely and continuously moves an aluminum workpiece to produce a welding seam. Naturally, it's not the robotic arm but rather a flanged laser scanner that creates the welding seam. The arm and the scanner move in perfect sync. This technique is referred to as remote laser welding, or "welding on the fly" because the scanner "flies" over the workpiece. "Aluminum conducts heat very well. The advantage with laser welding is that it heats the workpiece only for a short time—which means we can make seams that were impossible until recently."

Scanners at 3-Dimensional Services fly over workpieces in laser cutting as well. "We used to rely on hybrid machines, where the workpiece would move but the laser was stationary. But that makes production slower and less precise." That's why 3-Dimensional uses a TRUMPF laser-processing cell with a dual-station partition. The machine operator can thus set up while the laser is processing a workpiece. "That's another way we save time," says Peterson. He is flexible when it comes to laser sources. "A solid-state laser is unbelievably fast at cutting and the cutting quality is hard to beat. But sometimes a CO_2 laser is the better option. Especially when we're cutting a workpiece again at the same spot soon afterwards. A solid-state laser would heat the workpiece up too much." Peterson is especially confident about one thing: "Thanks to state-of-the-art technologies such as lasers, there's plenty of life left in prototype manufacturing. I'm sure of that!" ■

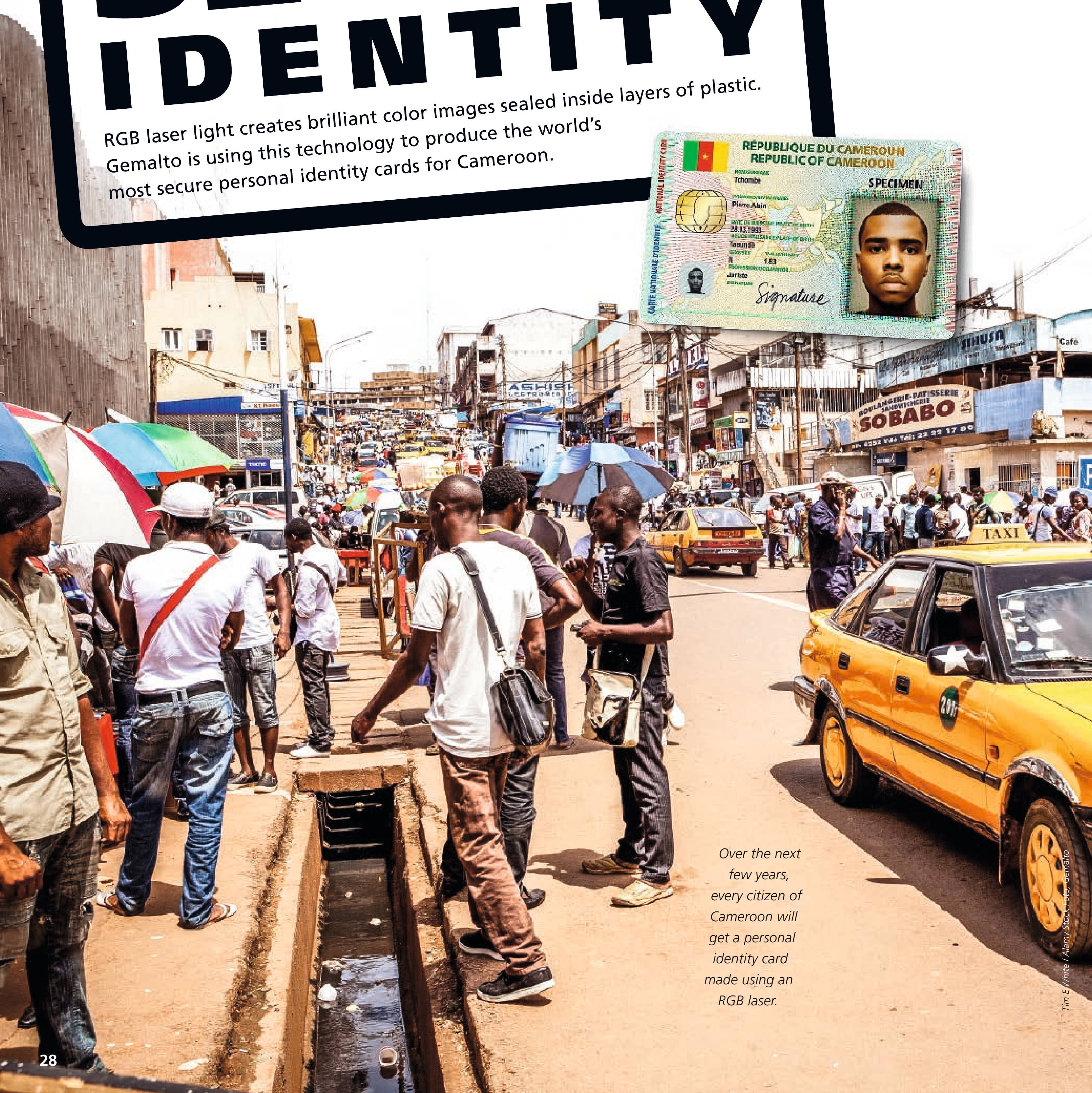
Contact: 3-Dimensional Services, Alan R. Peterson,
phone: +1 (248) 852 – 1333, apeterson@dimensional.com

The prototypes are clamped in place and the welding optics are guided over them. For company co-founder Alan Peterson (bottom), "welding on the fly" is a key part of keeping prototype manufacturing fast, flexible and affordable for his customers.

Tom McKenzie

SECURE IDENTITY

RGB laser light creates brilliant color images sealed inside layers of plastic. Gemalto is using this technology to produce the world's most secure personal identity cards for Cameroon.



Over the next few years, every citizen of Cameroon will get a personal identity card made using an RGB laser.

Tim E White / Alamy Stock Foto; Gemalto

With a soft click the flap opens and a stack of plastic cards drops into the output tray. The operator retrieves the identity cards from the Color Laser Marking personalization system. It's at the Délégation Générale à la Sûreté Nationale authority (DGSN) in Yaoundé, Cameroon's capital. The employee examines one of the cards, satisfied with the result. The reverse side features in warm colors a hilly landscape near to the village of Rhumsiki located in the Région de l'Extrême-Nord of Cameroon. The front bears the photo of the card's future owner—the colors are vibrant, perfectly reflecting the original, and the image is razor-sharp. Some 7,000 kilometres away, Joseph Leibenguth is sitting in his office in the French town of Meudon. He is Gemalto's Secure Documents Director and explains enthusiastically that this technology is truly ground-breaking: "Previously, we had only been able to embed black and white images in the polycarbonate cards in such high resolution. We wanted to do the same with color images while still offering the same level of security—but without having to make any major changes to the production process." Gemalto is a global provider of digital security systems and "Color in PC" is the group's latest personalization solution for Identity Documents. Cameroon is the first country in to world to draw on the new technology. "Personal identity documents have to be completely tamperproof," Leibenguth stresses. For this reason, the security technologies behind them are becoming increasingly intelligent. Integrated electronic chips containing biometric data such as the holder's fingerprint are now standard. "By using lasers to embed the high-resolution color images into the cards, we can provide even higher levels of protection against forgery and misuse. The images can't be manipulated and it's easy to establish whether or not the person in possession of the document is really the same person as in the photo."

"Images embedded by the laser provide higher levels of protection against forgery and misuse."

Joseph Leibenguth
Secure Documents Director at Gemalto

LAYERS OF INTELLIGENCE The structure of the plastic cards also provides, quite literally, added layers of security: "The final document is composed of five to seven polycarbonate layers," Leibenguth explains. "The core layer is white and between 300 and 400 micrometers thick. It houses the data chip and the antenna that enables contactless reading of the chip's contents." The blank cards are manufactured at one of Gemalto's global production sites. Since end users' personal data may be stored or engraved on the cards only in their respective countries of residence, responsibility for the personalization stage lies with government printers and national authorities—or service providers like Gemalto acting locally on their behalf.

THREE LASERS, TERRIFIC IMAGE QUALITY With its new laser engraving technology, Gemalto embeds color images in a special layer of the card. "The process involves working with a polycarbonate layer that contains photosensitive black ink composed of cyan, magenta and yellow pigments, also known as CMY," says Leibenguth. CMY serve as the "primary" colors in color printing, given that they can be mixed in different ways to make any other color. When combined, the CMY pigments make black. Red, green and blue (RGB) lasers are used to selectively bleach the individual pigments using their three different wavelengths. This is what creates the nuanced colors visible to the observer once the process is complete. The red, green and blue lasers bleach the cyan, magenta and yellow particles respectively. The result is a high-quality color image securely sealed in the polycarbonate body. "There's no need to add ink during the personalization stage, as the black layer already contains all the pigments required to reproduce the color photo. It doesn't require any additional consumables. That's what makes our process so great," emphasizes Leibenguth.

IT'S ALL ABOUT THE PULSE To make all this possible, however, Gemalto first needed an RGB laser capable of achieving exceptionally high pulse stability, an extremely important prerequisite. This was a task for the research and development experts at TRUMPF's Laser Application Center (LAC) in Grüsch, Switzerland. In a joint effort with Gemalto, they developed the pulsed solid-state lasers, which have beam diameters of 40 to 50 micrometers and are capable of delivering nanosecond pulses. For two of the three lasers, the developers had to halve the wavelength, and thus double the frequency. "Our focus was always on achieving a high pulse stability," explains Andreas Conzelmann, General Manager at TRUMPF Laser Marking Systems AG in Grüsch. "Any variation of peak power of the pulses would immediately distort the colors." A power regulator ensures the required power and pulse stability. "The laser always functions at its ideal working level. The design we developed specifically for this application allows us to adjust the laser's power extremely precisely from pulse to pulse—and a hundred thousand times a second," explains Conzelmann.

MULTITASKING AT TOP SPEED They got the technology working, but for it to be employed in Gemalto's personalization systems, it was also required to achieve a very fast color bleaching processing time to deliver an extremely high throughput. The best strategy for placing laser points on the photo needed to be found—as well as simultaneously on multiple identity cards. TRUMPF achieved this with its software. First, two infrared lasers work in parallel to mark information such as name, date of birth and signature in black on the front and reverse sides. Then the RGB lasers get to work. As soon as the red laser has finished bleaching the cyan pigment in one card the green laser takes over, while the red laser moves on to process the next identity card. "When the machine is running at full speed, five lasers are working simultaneously," says Conzelmann. This is the case in Yaoundé, where the system is producing more than 1.2 million identity cards per year. Not only are they absolutely secure, they also look good. ■

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Making a big bang with lasers

PHOTONS MAKE YOU RICH AND SEXY—I'LL BET YOU ANYTHING!

Laser Community's editor-in-chief Athanassios Kaliudis writes a regular column on the laser as an object of popular culture.

The incessant hum of the ventilation system blends with the sizzling of the soldering iron as it touches the damp sponge, releasing toxic fumes. A tangle of cables fills the space between the measuring instruments and the test rig, a daily hazard to be negotiated with the utmost care. We're in a research laboratory—and it has about as much sex appeal as a magazine column boring its readers with a clumsy attempt at scene setting!

Leonard Hofstadter's lab experiences are in a whole different league. He is one of the leads in the U.S. sitcom "The Big Bang Theory," in which he plays a gifted physicist. In one episode, his girlfriend Penny, a waitress, pays him a visit in the lab, and Leonard shows her a floating hologram that can be controlled with gestures—a hologram based on laser technology. Penny, who normally dismisses Leonard's scientific explanations as "boooooring," is suitably impressed, and shortly afterwards we see Leonard sitting in the cafeteria, completely disheveled. The obvious conclusion is that lasers make you sexier! And not just to waitresses—I'll bet you ten to one that any halfway decent venture capitalist would have found Leonard equally irresistible after his hologram demonstration.

Throw out the words venture capital and disruptive technologies, and most people immediately think of software and apps. But there's another field with huge disruptive potential that is just waiting to be tapped into by would-be start-up founders with smart ideas: photonics. From laser-based optical microphones and industrial robots equipped with sensor systems right through to light-based fluorescence microscopy and intelligent lighting concepts for the smart cities of the future, photonics is a gold mine for entrepreneurs.

As far as I know, no start-up has yet emerged from the idea behind the gesture-controlled holograms Leonard showed Penny, even though it has such amazing potential. But a few episodes later, Leonard's colleagues really do found a start-up to commercialize a groundbreaking gyroscope that uses quantum effects to pinpoint a location in space with unfailing precision. Even NASA ends up calling the gang of physicists to find out more about their invention. Obviously the gyroscope isn't a laser application, but once again I would bet ten to one that it couldn't exist without laser technology. So the prospects look good for some chilling out in the cafeteria once the demonstration is over! ■

Do you agree that ingenious ideas make people more attractive?
Let me know by email: athanassios.kaliudis@de.trumpf.com

Gernot Walter

Where's the laser?

IN THE URINE: If you want to bet on what will eventually finish off humanity, an incurable bacterial infection would probably be a good guess. That's why the United Nations launched a battle against drug-resistant superbugs in 2016. These are bacteria that can no longer be treated by any antibiotics. They have built up resistance through people using too many antibiotics to treat patients and fatten livestock, often in entirely uncontrolled ways. But now researchers at the University of St Andrews in Scotland have developed a laser-based diagnostic technique that can identify the bacteria present in an infection in a matter of seconds—all from just one drop of urine. The sample is placed in a hollow plastic ball featuring a spherical mirror and is then targeted with a laser beam. The beam is scattered in a million directions inside the sphere, ultimately providing a precise image of the bacteria. That means a doctor can prescribe exactly the right antibiotics—and perhaps help stop humanity being devastated by an incurable infection. Maybe it's better to bet on being hit by an asteroid after all …

Gernot Walter

0.2c

Cosmic jackpot: An earthlike planet just four light years away! “We have to get there somehow or other!” decided the famed physicist Stephen Hawking and his team. His idea is to fire thousands of tiny spacecraft with giant solar sails into space. A 100-gigawatt laser array would blast the sails with light and accelerate the craft to 20 percent of the speed of light (0.2c). The hope is that at least one probe would reach the Proxima Centauri star system and send back the first panoramic photograph of an exoplanet just 44 years after launch. www.breakthroughinitiatives.org

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