LASER COMMUNITY.

Of people and photons

I miss nothing

Laser machines know what they're doing thanks to sensors. Welcome to a new era of process control, quality assurance and system design.

#25

#25

NOVEMBER 2017

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Let's look at things in a new light

By adopting a fresh perspective on the world around us and changing the way we look at our work, structures, and familiar routines, we can create so much that is new. And that's why I'm taking this opportunity to ask all of us to start looking at things in a new light. We've already started doing exactly that at TRUMPF—by restructuring our Managing Board, for instance. So today I'm writing to you as the new CEO of Laser Technology, which makes me responsible for our Laser Community magazine. Meanwhile, my predecessor Peter Leibinger is devoting himself to his new role as Chief Technology Officer, responsible among other things for opening up new areas of business.

Looking at things in a new light is particularly important when you are faced with a seemingly intractable challenge. For example, French glassmaker Saint-Gobain asked us to come up with a way of applying an extremely uniform and completely invisible coating to large panes of glass. In laser material processing, it used to be enough to regard laser light, quite simplistically, as a beam. But we've since realized that we can achieve some remarkably elegant solutions by shifting the focus of our development activities to the wave properties of laser light. That also proved to be the turning point in this particular case: by studying the laser in this far more sophisticated and complex light, our engineers managed to create an entirely new form of optics for Saint-Gobain.

A new generation of optical sensor systems is allowing us to peer right into the heart of the manufacturing process, and to capture data in real time. Our systems are acquiring senses. They can see how and where a workpiece is positioned, feel the energy delivered by the laser, hear the progress of the work completed so far, and even apply a kind of sixth sense that allows them to predict when a component might fail. All this is helping us look at processes in an entirely new light as well as gradually modify and optimize how they work. Ultimately this is exactly what lies behind the concept of Industry 4.0: the idea of taking a fresh look at the way we manufacture things by illuminating them in the bright light of digital opportunities.

And since we've started looking at so many things in a new light, we decided it was time to give our magazine a fresh new look, too. We think that the new format, new paper and redesigned layout are a change for the better, but we would love to hear your opinion, too. Whatever the case, we hope you enjoy this issue!

DR._ING. CHRISTIAN SCHMITZ

Chief Executive Officer Laser Technology
Managing Director of TRUMPF GmbH + Co. KG
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Gernot Walter

Light for light

The transparent nature of window glass makes it tricky to photograph. So there was a very real chance that our photo shoot at glassmaker Saint-Gobain might end up being a complete flop. That's why we enlisted the services of Ralf Kreuels — he knows exactly how to deal with light. You can see the results of his work **on page 20.**

Super sensors

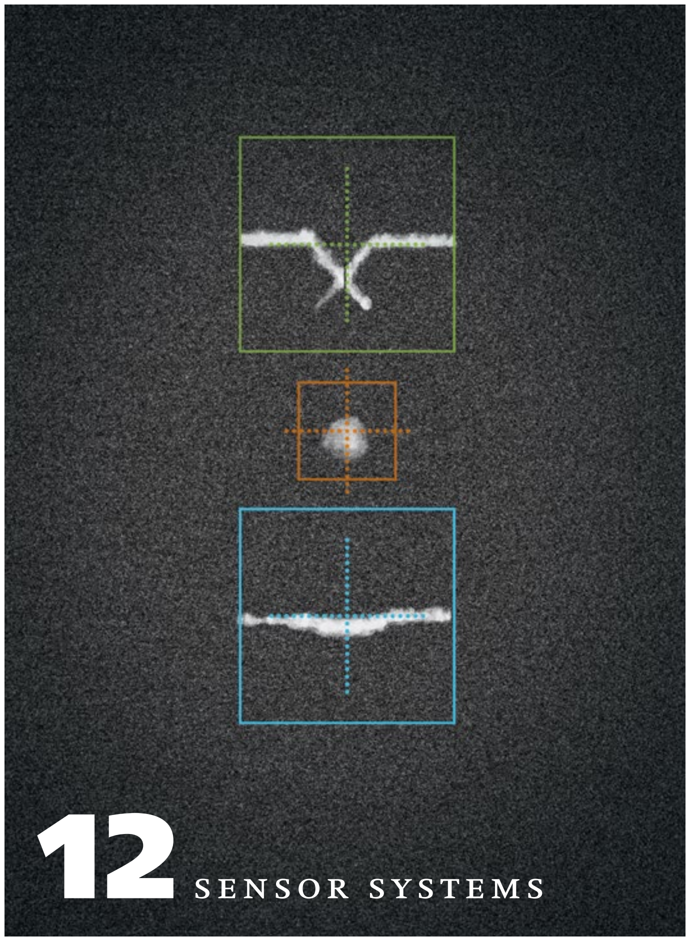
We've waited so long for the chance to welcome the most famous of all superheroes to our pop-culture column. But now the time has finally come, so let's hear it for Kal-El, Clark Kent ... Superman! Plus his almost-as-famous friend Lois Lane, who often takes big risks. Find out what this has to do with laser technology **on page 35!**

Hi Tom!

OK, we might have shed a tear when "our" laser-community.com website went offline. But only briefly, because its successor — the new TRUMPF online magazine — is even more marvelous and diverse. We call it Tom here in the office, and from now on it will be home to all our tales of laser technology. **trumpf.com/s/magazine**

Fotolia / ouh_desire, Gernot Walter, Ralf Kreuels

LASER



TRUMPF, National Research Council Canada

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COMMUNITY.

Ralf Kreuels, Fotolia / weseetheworld, Norbert Voskens

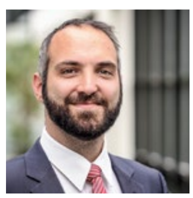
POWER

HONOR INTACT: THE LASER IS STILL FASTEST

There are two subjects that laser advocates used to shy away from when talking about coatings that protect parts against wear and corrosion: thin layers and speed. But EHLA has changed all that.

From cutting and welding to applying coatings, dyed-in-the-wool laser fans firmly believe that light is always a better choice than other tools. So it's frustrating when that turns out not to be the case. For example, when a customer requests a coating just 0.1 millimeters thick on a hydraulic cylinder with a surface area of half a square meter, and wants it executed multiple times—ideally by tomorrow. It used to be that laser disciples like us could do little in such cases but look sheepishly at our feet. We knew that technologies such as hard chrome plating or thermal spraying would be far faster. And, worse still, a laser couldn't even produce such a thin coating!

The Fraunhofer Institute for Laser Technology ILT was adamant that something had to be done, especially since laser metal deposition offers such outstanding crack-free and pore-free coatings with a metallurgical bond. That's why we came up with EHLA, our new technique for extremely high-speed laser metal deposition. The key lies in how the powder is delivered. Instead of blowing metal powder onto the part and using laser light to generate a melt pool where it lands, the EHLA process strikes the powder with laser light higher up, before it even reaches the melt pool. The light heats the powder almost to its melting point while it is still on its way to the part. That means the laser can travel along its programmed path far faster and the weld depth is far shallower. The laser produces much finer beads, applying the energy it delivers far more efficiently to the task of forming a coating layer. EHLA can achieve coating rates of 250 square centimeters per minute and produce coatings as thin as 10 micrometers. What's more, the EHLA processing head can easily be incorporated in existing machines. So laser aficionados can once again stand tall and face the world with a renewed sense of pride! ■



Thomas Schopphoven worked with Dr. Andres Gasser and Gerhard Maria Backes to defend the laser's honor. Their efforts were rewarded with the Joseph von Fraunhofer Prize.

Gernot Walter

GLORY

Schawlow Award-winner Paul Seiler has been engaged in the development of modern industrial lasers for over 50 years.

Angelika Grossmann

THREE FOR ETERNITY

Paul Seiler, the founding father of the industrial solid-state laser, recently received the Arthur L. Schawlow Award for his life's work. So why were his achievements so important?

Seiler is responsible for three key developments in industrial solid-state lasers: the original laser machine, the continuous wave solid-state laser, and the most ingenious accessory ever developed: the laser light cable.

In the early 1970s, Paul Seiler decided he had spent enough time drilling little holes in diamond drawing dies with a laser. He was determined to wrench the new and exciting field of laser technology out of its comfortable niche and drag it into the wider world of industrial manufacturing. Gathering together his wife and four children, he moved to the Black Forest and accepted a position at Haas. Welding was his goal—and laser light was the tool he had chosen to wield. In 1973, he and his team built the first system to incorporate a laser in an automated machine tool. The system was designed to weld watch springs, and whatever solid-state laser machines you use in your factory or lab today, they all have their origins in Seiler's spring welding machine.

The laser had finally breached the walls of industry, and it has been gaining ground in production facilities all over the world ever since. Seiler himself was appointed as the managing director of Haas Laser, which would ultimately become TRUMPF Laser in Schramberg.

In the early 1990s, Seiler notched up two major coups. In 1991, he successfully decoupled the beam source and optics. Like all the best ideas, it seems remarkably obvious in retrospect that we can simply transport laser light from where it is generated to where it is needed. Seiler presided over the development of the laser light cable and presented it at an exhibition in 1991 together with a corresponding solid-state laser system. In a sense, his company had shot itself in the foot, because now a single beam source could be used to deliver laser light to multiple optics—which meant you needed fewer beam sources for each application. However, once people realized that the laser light cable made laser processes easier to integrate and more economical to run—simpler and cheaper, in other words—they were lining up to take advantage of it.

Seiler dropped his next bombshell that very same year, showing how to operate a solid-state laser in continuous wave (CW) mode and in the multi-kilowatt range. Previously, powerful solid-state lasers had only been able to emit pulses, while CW had been the domain of the CO_2 laser. The combination of CW and the laser light cable opened up a whole range of new opportunities. ■

In October 2017, the Laser Institute of America recognized Seiler for his lifelong achievements in the field of industrial solid-state lasers by presenting him with the Schawlow Award at the ICALEO in Atlanta

"WE WANTED TO BE THE FIRST"

Yosuke Sasaki, with his team and partner, introduced laser welding technology for tailored welded blanks to Russia. This was not the only first in this area for the Japanese executive.

Are there any benefits to being a pioneer?
To put it simply: yes and no. In our case, we at Severstal-SMC-Vsevolozhsk became the first, in 2014 to manufacture tailored welded blanks, or TWB, in Russia. This was a challenge on the one hand, because all automotive manufacturers in Russia were already working with imported TWB. On the other hand, it was an advantage, because of course we have something that these very suppliers cannot offer: we are still unique in Russia, close to our customers, and we know the country and its people.

Is that enough?
No, of course not! It's far from enough. As a newcomer to the Russian market, we needed two crucial things. One was reliable back-up suppliers, which we now have. And two, we had to offer more than our foreign competitors in terms of technology, productivity and quality. This is one important reason, for example, why we bought the disk laser systems from TRUMPF.

What was your motivation for the project?
There was no supplier for tailored blank welding anywhere in the entire Russian market—so something had to be done!

True, but how did it come about that you were the first there in 2014?
I was working in 2007 as a project manager directly for the Japanese Mitsui Group, a conglomerate with a great deal of experience in steel trading and production. We conducted a market survey in which all our industry contacts told us: there is no one in Russia who supplies TWB. Wow! And that in a country—one of the BRICS economies—with a major automotive manufacturing industry serving a huge market. Unbelievable, but it turned out to be true. It was a unique opportunity for us. We were determined to be the first to introduce this technology to Russia and, in doing so, create a market for it. We quickly found a way to achieve this: set up a service center for steel as a joint venture between Russian steel producer Severstal and Mitsui. TWB was to be included in its product range. And that's just what happened when we founded Severstal-SMC-Vsevolozhsk in St. Petersburg. Things were slightly delayed by the financial crisis that hit in 2008, but in 2014 I took over as Deputy General Director of Severstal-SMC-Vsevolozhsk. We were fully prepared and now supply TWB to Nissan, Ford, Hyundai and Volkswagen. Furthermore, we hope to add more customers soon.

Did everything go smoothly?
Without a doubt, the major challenge was training the people on site. We had an expert from Japan training the engineers here. People here are very excited and motivated for new technology, I believe.

Is this the first time you've gone abroad and introduced TWB to the market?
No, I worked on similar projects in Turkey as well. My job is to create jobs and tap markets with TWB. Entering new markets with innovative products is my kind of thing. And it always works very well with TWB.

What's it like being Japanese in St. Petersburg? Did you learn Russian?
Neither the city nor the language were new to me. It had been clear for a long time that Russia was an attractive emerging market. That's why, back in 2005, Mitsui sent me to St. Petersburg and Uzbekistan for two years to study Russian at the university and to complete on-the-job training. Now I'm back again, and I have to say I like it here. The city is beautiful and attracts tremendous numbers of tourists. There are great bars and restaurants. But if I could change one thing, it would be the weather: it's too cold for me. We recently had snow in the middle of summer!

TAILORED WELDED BLANKS are lightweight sheets of steel of various grades and thicknesses. Lasers are used to weld the components together to produce a steel blank, which is then re-formed by deep drawing to create the desired part.

Peek into the plant: trumpf.com/s/5gnm46

Roman Knertser

Yosuke Sasaki has been Deputy General Director of Severstal-SMC-Vsevolozhsk steel service center, based in St. Petersburg, for over three years.

AHEAD

“There were no tailored welded blanks anywhere in Russia—so something had to be done!”

Roman Knertser

SEVERSTAL-SMC-VSEVOLOZHSK is a joint venture between Severstal, Russia’s second-largest steel producer, and Mitsui, a Japanese conglomerate. The company produces mainly steel sheets for the automotive industry, including tailored welded blanks, and has an annual production capacity of approximately 150,000 metric tons.

Bead *by Bead*

How do weld beads interact when a laser lays them next to each other during laser cladding? Our contributor Syed Saqib began searching for answers to that question at the University of Windsor and ended up laying the foundation for a future process parameter database.

One of the biggest advantages of laser welding is that it is an almost entirely digital process. That means you can easily adjust it to the task at hand and get the results you need by simply selecting the right parameters.

This does, of course, assume that the user is familiar with the key parameters that affect the results and understands how they interact with each other—and we still have a long way to go before we reach that point in laser cladding! This welding process, which is also known as laser metal deposition, involves laying beads next to each other or stacking them in multiple layers. It is a process in which the various welds influence each other in a delicate and complex system of parameters and interdependencies.

The combination of multiple parameters and influencing factors as well as nonlinear coupling behavior makes it difficult to develop models that can deliver robust predictions. And that makes empirical data collection the only real recourse.

DATABASE OF PARAMETERS Together with other contributions, my work forms the basis of a long-term project that aims to use empirical data collection to provide a comprehensive overview of factors that have a non-negligible effect on the process and clad bead geometry. The task is to find out which process parameters can be varied to influence these factors. Ultimately, the idea is to transfer this knowledge into a database, a useful resource that will offer recommendations for various job scenarios, helping users select the optimum process parameters for positioning and aligning weld beads. The sensitivity of the process and the multitude of parameters call for a statistical approach, and our reason for choosing the statistical design and analysis of experiments method was to keep the number of actual experiments as low as possible. As a result, the data for the planned database will actually come from future research rather than our initial work. What lies ahead are multiple series of experiments that will pinpoint the key parameters and interactions from among a multitude of possibilities. These will be based on a previous series of experiments—the part of the project I have already completed—which laid the foundation for drawing up robust plans for subsequent empirical data collection.

This initial, basic series of tests was based on two main assumptions. First, we hypothesized that small variations in the manufacturing process parameters lead to variations in the bead shape parameters and that the relationships are nonlinear. Second, we assumed that the bead geometry of overlap and stacked layers will not be the direct multiples of a single deposited bead. We anticipated that this difference exists due to changing boundary conditions, since heat transfer occurs among the layers and the deposited bead's physical mass changes the deposition surface area.

Based on these assumptions, we welded and tested single beads, parallel overlapping beads, and stacks of overlapping beads in multiple layers. Even using the statistical design of experiment (DoE) method, this first series of experiments produced a huge quantity of data because we varied so many parameters at five different levels.

To determine how the various process parameters impact beads and dimensional quality, we applied the statistical analysis of variance (ANOVA) technique. We then examined the effect of changing the parameters using another statistical approach known as fractional factorial central composite design, or CCD.

RELEVANCE TO ADDITIVE MANUFACTURING The results of this work yielded various models of weld bead behavior under different conditions. Researchers can now build on these models to establish hypotheses and experimental plans for the next series of tests.

With laser cladding gaining increasing importance as an additive method of manufacturing three-dimensional bodies, we were particularly interested in the behavior of beads in stacked layers. So let's take a brief look at the observations we made in this context that are of particular interest for upcoming research work in our project.

One of the most eye-catching features in the macrographs is the "M" shape of the boundaries between the initial layers. Although the first layer is applied on a flat surface—and this initial layer itself also exhibits a largely flat surface before the next layer is

Ten-layer block produced using additive manufacturing. Changes in the orientation of the workpiece and the nozzle lead to significant differences in the vertical planes.

Macrograph view of a stack of beads: The pronounced "M" shape of the layer boundaries is particularly striking. This internal structure also has an impact on the outer surfaces of the stack.

Even with statistical DoE, the quantity of data is huge, because we are varying so many parameters at five different levels.

applied—the "M" is not a shape that becomes more pronounced layer by layer. In fact, the opposite is the case: the initial stacked layers reveal a clear "M" shape with spikes on either side, but this shape gradually flattens out and becomes less pronounced as subsequent layers are added.

In this context, we also investigated whether additional degrees of freedom in the machining process affected the results and altered the surfaces of the 3D body. To do this, we used a five-axis tool to produce a series of solid blocks (40 mm x 40 mm x 35 mm, see photo). The workpiece was tilted at different angles (10, 20, 30 and 40 degrees) while the deposition nozzle was not kept orthogonal to the substrate. The angled slope has a clear impact on bead application, as shown above. The choice of angle changes the shape of the bead, the internal structure of the layers and, ultimately, the surfaces of the block itself.

Developing an ideal bead shape for tasks of this nature with a process parameter model is, once again, very challenging—the nonlinear, dynamic environment of multilayer laser cladding makes it very difficult to make any meaningful predictions. What we need, once again, is an empirically based quantitative understanding of the extent to which process parameters such as laser power, laser scanning velocity, powder feed rate, and application geometry ultimately exert an influence on the hardness and microstructure of the deposited coating.

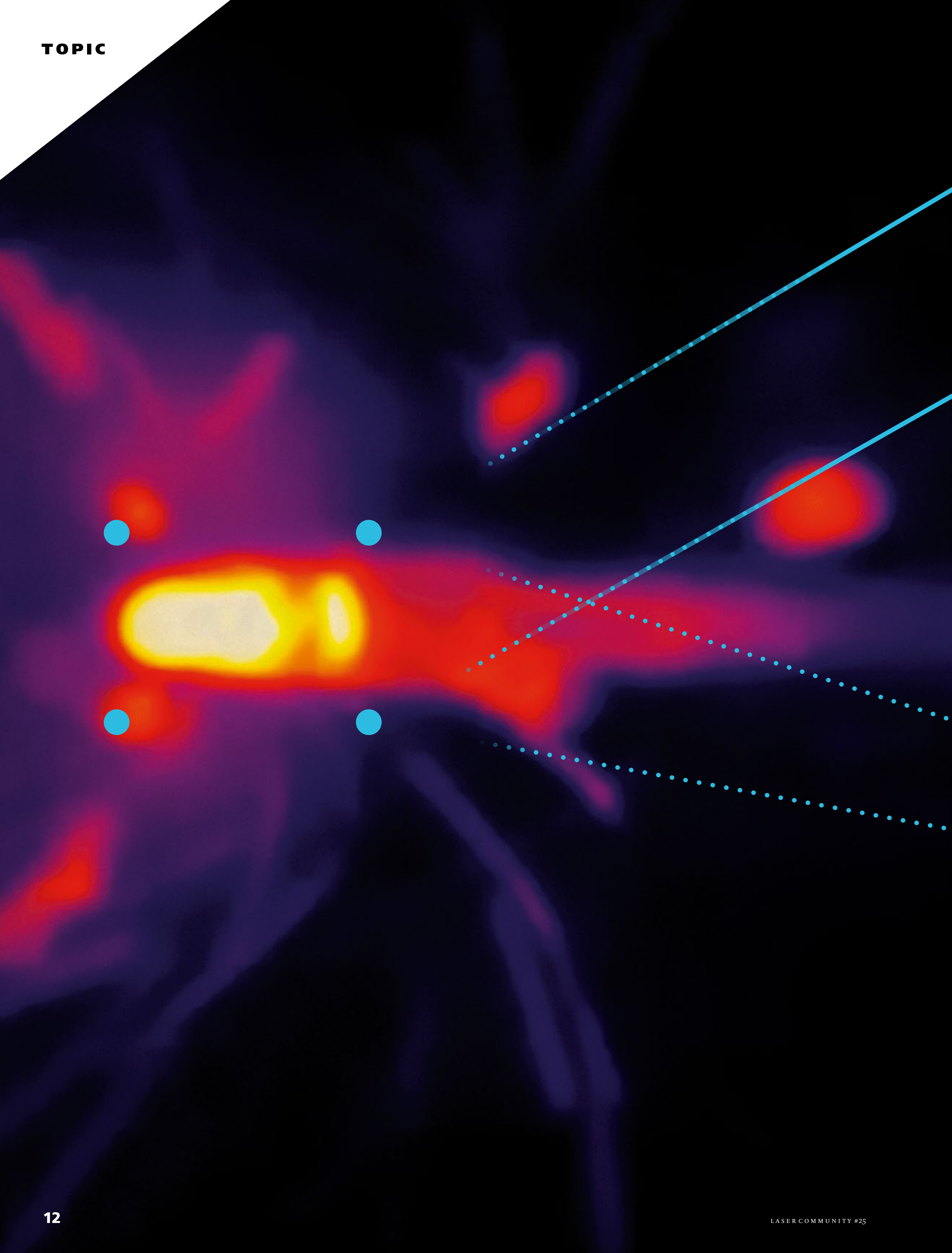
NEXT STEPS As discussed above, the long-term goal of the research work we have undertaken is to create a viable and flexible framework for planning bead paths and geometry using laser cladding in the context of additive manufacturing. An experimental study of bead morphology and the relationships between the various laser cladding process parameters in additive manufacturing is the first step down this path, and it lays the foundation for future research. The next steps will include investigating the relationship between changes in laser power and changes in the melt pool.

Another key task will be to follow up the observations presented in the second part of our work and carry out quantitative testing, development and comparisons of filling strategies for additively manufactured structures. This will bring us even closer to our ultimate goal of creating a process parameter database. ■

Read the complete research paper: http://scholar.uwindsor.ca/etd/5782/

As part of his PhD research into laser cladding at the University of Windsor in Canada, **Syed Saqib** investigated the impact of process parameters on single and overlapping stacked layers of 420 stainless steel powder. He is currently working as a postdoc conducting research into the hardness and geometry of stacks as well as the application of multiple layers in laser cladding processes. He also teaches classes in CAD/CAM at the University of Windsor.

Syed Saqib



CLOSE SCRUTINY

Monitor, adjust, document: The boom in process sensors is giving a whole new edge to laser material processing. Why are we using more and more sensors, and what impact is it having on the world of manufacturing?

TRUMPF

The future in a box: a camera monitors the process through the optics.

From the point of view of a machine, human beings are really quite remarkable things. They have no problem sketching a line on a piece of paper, working completely freehand. Humans can also hold an egg in their hand without crushing it, and then peel it for good measure. And they seem to have no trouble at all in sharpening a stick and using it to roast marshmallows over a fire without burning them! We humans can tackle these tasks because we have sensors that monitor and adjust our movements based on real-time feedback—in other words, our senses. So wouldn't it be great if machines had senses, too? Then we would finally be free from the hassle of having to program every coordinate path, teach every sequence of operations, and painstakingly slice open and inspect weld seams. We could simply trust our machines to do a great job. Wouldn't that be something? Well, in fact, it's already happening! Machines are already acquiring these kinds of senses in their own particular way. When laser marking first emerged, machine operators had to use an ultra-precise clamping fixture to get the markings in exactly the right place. After all, how could a marking laser be expected to find the right spot? All it could do was aim blindly at the point where two coordinates met and hit whatever happened to be there. But today's marking lasers are different: They have a camera eye that allows them to detect what's in front of them and align the optics to mark exactly the right spot. This development is already transforming the world of manufacturing—and there's plenty more to come.

LASERS FEEL BETTER There are essentially two types of sensors. Monitoring sensors supply data for quality assurance and documentation purposes, but do not actually intervene in a running process. One popular example is a sensor designed to monitor compliance with specified limit values. If the defined thresholds are exceeded, the machine sounds an alarm and the production manager can immediately check where the problem lies. Control sensors, on the other hand, measure a value and then intervene in the running process. Depending on the reading, a control sensor might modify the laser power, or adjust the feed rate or focal position. Generally speaking, control sensors are more complex than monitoring sensors.

Laser material-processing machines are particularly easy to equip with sensor technology. The optics are the perfect place to put a sensor, offering a simple connection to the mounting system and allowing the sensor to peer directly into the process. The incorporeal nature of a laser beam means it can only be controlled digitally, so it is very easy to incorporate it in a control loop that includes sensors (see box: top 5 sensor readings in laser material processing).

MAKE MORE MONEY WITH SENSORS Until just a few years ago, process sensors were the exception rather than the rule. But now they are regarded as an integral part of production in segments such as automotive and medical technology. And it's not hard to see why: sensors help companies make more money by introducing faster cycle times, better quality, seamless quality control, less scrap, and consistent traceability in the field.

In the realm of automotive-bodywork welding, sensor-based remote welding operates at over twice the speed of welding with filler wire. Cameras detect the position of the part during welding or marking. As a result, the part holder can be made to less demanding specifications, making it cheaper and easier to build. In welding processes, monitoring sensors provide reliable, seamless quality documentation along the entire length of the seam for each individual part. That gives a greater level of reliability than conducting destructive sample testing in the field, and it means this latter method can often be significantly scaled back or even

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“THE COMBINATION OF MELT TRAVEL AND TEMPERATURE MONITORING HAS RADICALLY INCREASED THE LIKELIHOOD OF DETECTING ERRORS.”

Hubert Hickl, project manager of connector-strip laser welding at Bosch

eliminated altogether. Monitoring sensors also deliver instant reports on any faulty welds, in turn allowing production staff to tackle the problem the moment the first part is affected rather than discovering at the end of the shift that hundreds of parts need to be scrapped. Meanwhile, control sensors endeavor to push scrap rates close to zero by making immediate adjustments whenever something goes wrong.

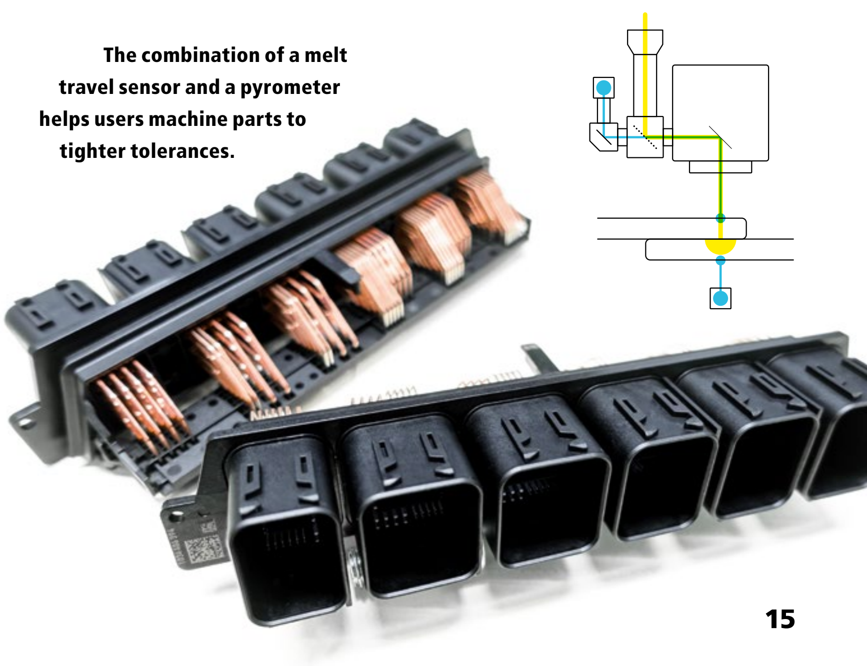
Steadily increasing demand for smaller and more precise components is also driving a trend toward greater use of sensor technology. The more complex the part, the more stringent the quality standards for tasks such as welding, and the greater the need for sensors capable of monitoring and controlling the process with a high level of precision. Of course this argument also holds true in reverse, with the power of sensors paving the way for new kinds of part geometries. In the case of remote welding of car-body parts, for example, the decision to shrink flanges became available only once the operator was confident that the seam-position control system would reliably locate the correct position for each and every fillet weld. This newfound confidence has been helping automakers reduce weight, use less material and speed up their production lines ever since.

A NEW LEVEL OF TOLERANCE Slowly but surely, these efforts to bring about machine perception are transforming the appearance and functionality of entire manufacturing systems. Previously, machines worked blind. Engineers had to guide them millimeter by millimeter, painstakingly anticipating every change in speed, component position, or contour. As expectations of component and machining precision have become more demanding, so too has the effort involved in mounting and positioning each part, sometimes reaching absurd heights. And machine frames have become heavier, bulkier and more complex as

Bosch: Two perspectives are better than one

01 SAMPLE APPLICATION

A multinational corporation and one of the biggest suppliers to the automotive industry, Bosch thrives on its reputation for making products that conform to the highest standards of quality. At its Waiblingen plant, the company produces components for electronic control units (ECUs). Bosch firmly believes in putting plenty of safeguards in place to ensure top-quality results, and its plastics laser transmission welding line for connector strips is no exception, combining temperature control with melt travel monitoring. “Our primary goal was to eliminate downstream quality checks while maintaining a high standard of documented quality assurance,” says Hubert Hickl, project manager for connector-strip laser welding at Bosch. In this process, a direct diode laser welds plastic modules securely to a modular frame. A pyrometer measures the heat radiated throughout the entire process and, at the same time, a scanner makes multiple passes along the weld contour. The system also includes a melt travel sensor that monitors the lowering of the component during laser transmission and switches off the welding program once the specified weld travel has been completed. The results of the measurements are collated and automatically documented. “The cut-off switch is precise enough to enable us to meet very tight positional tolerances—crucial for the downstream assembly processes. The combination of melt travel and temperature monitoring has radically increased the likelihood of detecting errors.”



The combination of a melt travel sensor and a pyrometer helps users machine parts to tighter tolerances.

Robert Bosch GmbH, Gernot Walter

02 SAMPLE APPLICATION

LR Systems: *Real-time control of de-painting process*

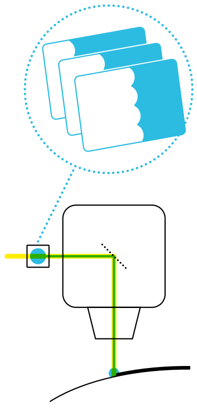
200 times a second: That's how frequently the laser beam strikes the surface of the aircraft in LR Systems' paint-stripping system. At the same time, a camera captures a high-resolution spectroscopic image of the results no less than 400 times a second. A software program analyses these images, determines whether the surface below the paint has been reached, and adjusts the position and speed of the robot arm and the power of the CO_2 laser accordingly—all at the same rate of 400 times a second.

All aircraft have to be stripped at regular intervals and provided with a fresh coat of paint. "Our ultimate goal is that the laser at the end of our robot arm should be able to de-paint an entire aircraft," says Peter Boeijink, CEO of robotic solutions provider LR Systems in the Netherlands. "And it should be able to do that faster and better than any human, and without user intervention. We're set to launch the system in 2018."

They have certainly had to overcome plenty of challenges to reach this point, not least working out how the robot could detect when it had removed the paint and reached the underlying paint layer—or even the composite surface beneath. A classification algorithm evaluates the images based on ten different criteria and forwards the signals directly to the robot- and laser-control units. "We have to transfer huge quantities of data incredibly fast, so a digital fieldbus signal would be much too slow for our purposes. That's why we switched to an analog input for the feedback controller."

LR Systems even decided to incorporate self-learning control software: "The algorithm learns from its mistakes and gradually starts to understand our criteria, apply them autonomously, and improve them. In other words, it gets better and smarter with every aircraft."

Each pulse is followed by the capture of an extremely high-resolution image. That shows the control unit where it should fire the next pulse.



LR Systems, Gernot Walter

"THE ALGORITHM LEARNS. IT GETS BETTER AND SMARTER EVERY TIME."

Peter Boeijink, CEO LR Systems

→

operators strive to meet the required tolerances in the micrometer range. Yet the moment a machine establishes contact with its environment, it becomes capable of formulating its own response to each part. Frames can be made narrower and smaller and reduced to the bare essentials, and positioning devices can be made more flexible. Ultimately a new level of tolerance emerges throughout the process, though the results are just as accurate as ever. Laser welding is the perfect example: place a part just about anywhere in the cabin, and the laser will get the job done.

DELVING INTO THE DATA MINE Factory managers have long recognized the importance of data as an integral part of Industry 4.0—and more is always welcome. This data stems from various sources, with one of the most reliable being the sensors that monitor production processes. At the same time, however, small and medium-sized enterprises are facing something of a dilemma as to what they should actually do with all the data they collect. In response, a pioneering wave of suppliers is already busy developing intelligent services designed to analyze process data. The ultimate goal is to use big-data methods to spot imminent problems in a manufacturing process or to develop an algorithm that—when fed with enough data—can autonomously suggest how to improve a process and even execute the necessary actions itself. Condition monitoring for individual machines is already well established; the next step is status monitoring for an entire factory, followed by sensor-based production control.

In the meantime, experts are busy working on new sensors and sensor combinations. They are currently pinning their hopes on interferometric sensors, a highly promising development that is currently very much in vogue. This type of sensor uses the interference of light waves to measure a broad range of parameters ranging from weld depth to seam detection. Although interferometers are still an expensive substitute for cameras when it comes to position sensing, their prices are steadily falling, and it won't be long before the

The five most important sensor readings in laser material processing:

01 — PATTERN RECOGNITION

The camera can easily detect even the smallest hairpins on electronic components, identifying the specific points that need to be welded, and forwards this information to the focusing optics. In the case of laser marking, the image processing system verifies that the marking is in the proper position and checks that the text or code is correct and legible.

02 — TEMPERATURE

A pyrometer measures temperature changes during the active process. During the laser transmission welding of plastics, this can be carried out at the seam welding point: as soon as the specified target temperature is reached, the system adjusts the laser power to ensure the temperature remains stable.

03 — MELT TRAVEL

An inductive melt-travel sensor records the time and displacement of a part while the process is running. In laser transmission welding, the sensor measures the lowering of the upper plastic part. The laser stops once the specified amount of travel has been achieved. This method also makes it possible to compensate for component tolerances.

04 — WELD DEPTH

A low coherence interferometer measures distances with a degree of accuracy better than a tenth of a micrometer. In laser welding, it can be used to monitor the depth of penetration. That enables the quality control team to ensure that the weld depth is exactly right—in other words not too deep, and not too shallow.

05 — WELD JOINT

With the aid of line lasers projected onto the weld joint, a high-speed camera detects the seam position during the welding process and adjusts the scanner before the process starts. The seam-position control system is an ultra-fast, non-contact solution that operates in real time. Examples of its use include fillet welds in automotive-body manufacturing, butt joints in gearbox welding, and continuous pipe welding. It makes the welding process faster while producing significantly less scrap.

LR Systems

"IF THE PROCESS GOES WRONG, WE DISCOVER THAT WITH THE VERY FIRST PART."

Peter Schömig, Team Manager Corporate Production, Welding and Brazing Processes at ZF Friedrichshafen

devices become smaller and cheaper. No one doubts the benefits they offer. Perhaps at the top of the list is their ability to produce three-dimensional images. This is particularly useful when measuring volumes, especially in applications such as laser ablation and laser metal deposition.

THE DREAM OF DOING NOTHING The promise of autonomous manufacturing is drawing ever nearer. Small companies, in particular, have long been clamoring for simplified production processes where machine operators can simply place any machinable part anywhere they like in a machine. Using its database of CAD drawings, the machine would then identify the part, decide how it should be machined, and execute the necessary welding operations. In principle, there would be nothing else the operator would have to do. Or course there is still some way to go before this becomes reality—the evolution of autonomous driving would perhaps be an apt comparison—but we are clearly heading in the right direction. One example of a sensor capability that really does seem to be just around the corner is material recognition, a technology that will make processes such as laser marking even simpler. The future certainly looks bright!

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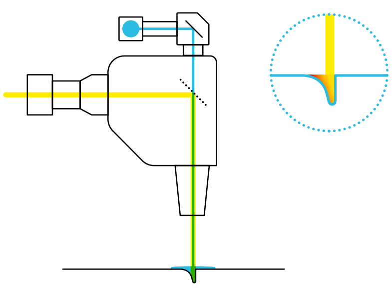
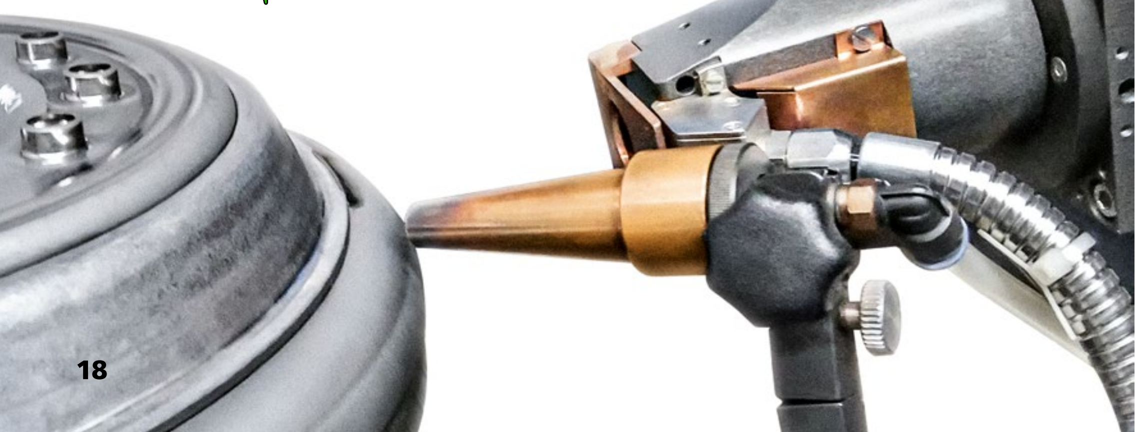
ZF Friedrichshafen: deep penetration welding under scrutiny

03 SAMPLE APPLICATION

Peter Schömig, Team Manager Corporate Production, Welding and Brazing Processes at ZF, has a clear goal: "We want to significantly reduce the amount of destructive testing we use. We need to find other ways of guaranteeing high-quality parts." Automotive supplier ZF has been trying out a new laser-welding process for powertrain components that takes advantage of interferometric monitoring—and Schömig is confident it is suitable for high-volume production. An optical coherence tomography (OCT) system attached to the laser optics monitors the capillary during deep penetration welding and measures the weld depth in real time, providing a direct quality-control solution along the entire length of the weld seam. "The quality standards for the powertrain are extremely high, because the entire engine torque is transmitted through the welded parts. That's why it's such a big plus for us to be able to detect and document the penetration depth at every point of each individual part. It allows us to significantly reduce the costly and laborious use of metallographic sections." If the sensor detects that the required depth of penetration has not been reached or has been exceeded, then the system sounds an alarm. "So if the process goes wrong, we discover that right with the very first part rather than at the end of the shift. That means we can take action straight away to avoid producing parts that end up having to be scrapped." Schömig nevertheless emphasizes that the current incarnation of the OCT system is essentially just a good interim solution: "In the long run, we hope to incorporate a control sensor that not only reliably detects the weld depth, but also takes action to ensure that everything goes exactly as it should."



An optical coherence tomography system measures weld depth in the running process in order to spot faulty seams.



ZF Friedrichshafen AG

LASER BEAM WELDING OF STEEL AND TITANIUM USING A LOCAL VACUUM DEVICE

A steady increase in the output power of laser sources is opening up new avenues for welding thick metal sheets, though it also has some negative repercussions. These include the metal vapor plume that forms in the keyhole due to the extremely high temperatures. The plume moves in the direction of the laser beam axis, decreasing the usable power of the laser beam source. In his doctoral dissertation submitted to TU Berlin, André Schneider (39) solves this problem using a local vacuum device. You can read his dissertation here:

https://www.depositonce.tu-berlin.de/handle/11303/6231

LASER PLASMA ACCELERATION WITH ULTRATHIN FOILS

In her doctoral dissertation for TU Berlin, Julia Bränzel (37) has succeeded in accelerating heavy ions to kinetic energies of up to one mega-electron volt per atomic mass unit using ultrathin gold foils and ultrahigh laser contrast. This marks an important step forward in the development of new and improved compact particle accelerators, which are an essential tool for structural analysis in physics, biology and medicine. Highly charged heavy ions are attracting particular interest in cancer research. The full dissertation is available here:

https://www.depositonce.tu-berlin.de/handle/11303/6149

So what does the future hold for light as a tool? Work by four young researchers gives some idea of what possibilities lie ahead.

LATEST → RESEARCH

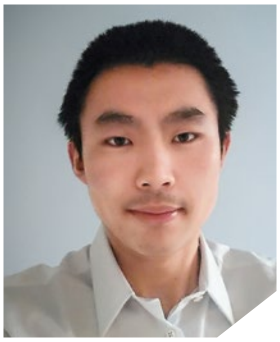
LASER BEAM WELDING OF HIGH-ALLOYED ALUMINUM-ZINC ALLOYS

When it comes to fusion welding, it is well known that Al-Zn alloys can be difficult or even impossible to weld. In her doctoral dissertation submitted to Hamburg University of Technology, Josephin Enz (33) describes a two-pronged approach to solving this problem: the use of an appropriate filler material during welding, plus the deployment of a high-power fiber laser with a large beam diameter and high beam quality. Al-Zn alloys are light and very strong. Find out more at:

https://tubdok.tub.tuhh.de/handle/11420/1408

INDUSTRIAL ROBOT MOTION CONTROL IN LASER WELDING

Path accuracy is a critical issue when it comes to laser welding with industrial robots. In his thesis submitted to University West in Sweden, Jiaming Gao (25) investigates the extent to which the ABB EGM path correction module can be used for robot motion control in real time. He has developed a test method to determine the suitability of the control module for laser welding and assess its limitations. You can read the full thesis here:



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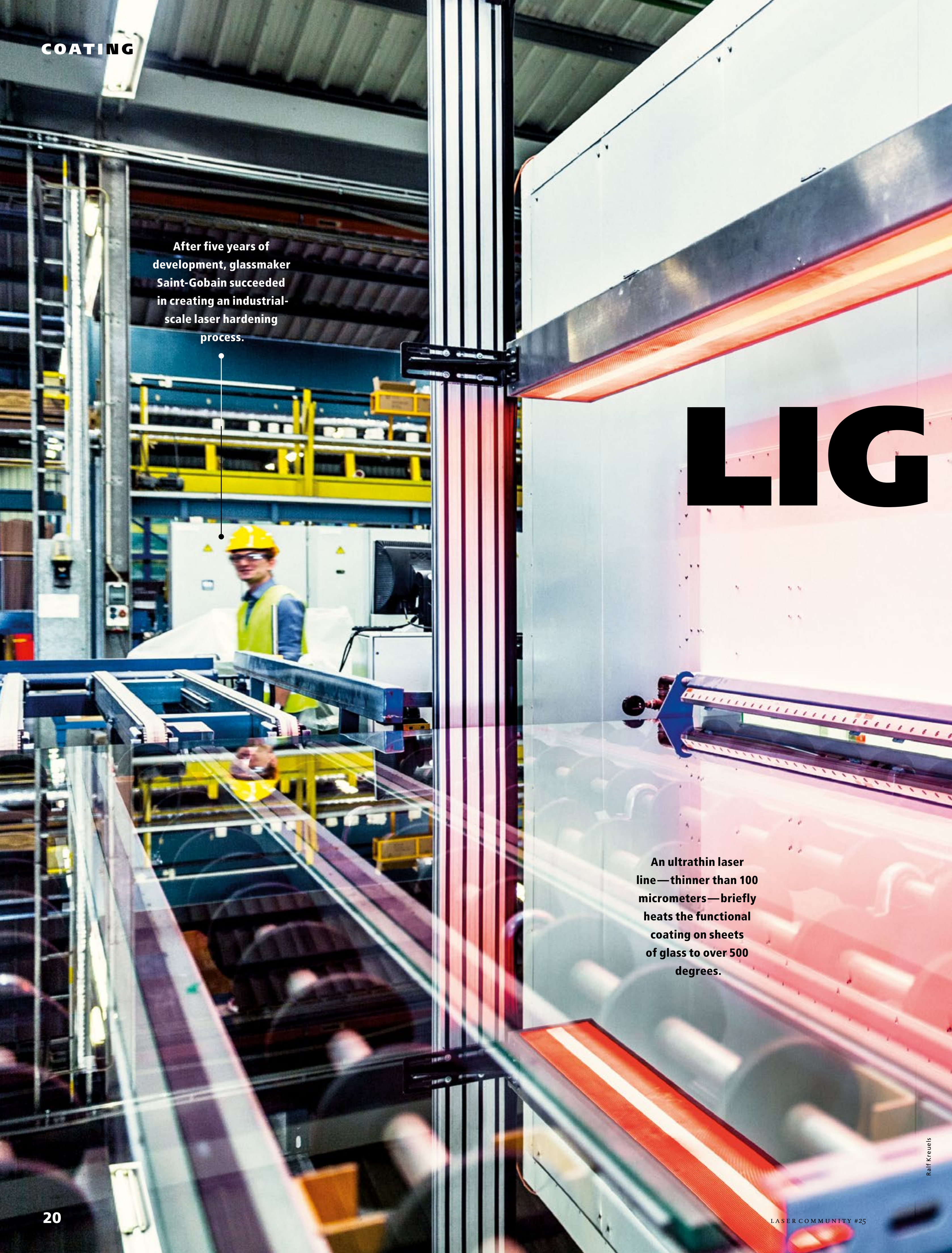


After five years of development, glassmaker Saint-Gobain succeeded in creating an industrial-scale laser hardening process.

LIG

An ultrathin laser line—thinner than 100 micrometers—briefly heats the functional coating on sheets of glass to over 500 degrees.

Ralf Kreuels

A new kind of window glass from Saint-Gobain lets in lots of light and strongly reduces heat losses. All it took was an impossible laser optic.

THE NEW HT SOURCE

There it is: an impressive 45 meters long and eight meters wide. A kind of bridge spans it over a width of 3.30 meters. The bridge carries eight boxes manufactured with high precision, each equipped with a laser optic. A fiber-optic cable connects each of these with powerful TruDisk lasers. Together the twelve high-performance lasers generate 144 kilowatts of power. Their combined beam strength would not melt steel. It only heats up a thin silver coating just a few nanometers thick, changing its amorphous state to a crystalline one. A small alteration, to be sure—but one that has tremendous results.

This very large system is located in Cologne, Germany, on the premises of French glass manufacturer Saint-Gobain. One remarkable feature is what is known as the rapid thermal processing unit: it is used for the

heat treatment of functional coatings, such as silver, on jumbo-size glass. Produced by Saint-Gobain, the glass measures 3.2 meters in width, 6 meters in length, and weighs some 750 kilograms. During the heat treatment process, a conveyor section moves the glass panels under the bridge at speeds reaching 25 meters a minute. The high speed is vital because the ultra-thin laser line—less than 100 micrometers—heats up the coating very briefly at a high degree of intensity to more than 500 degrees. At this temperature the silver crystallizes. But as the coating absorbs a majority of the laser energy, the glass substrate remains unaffected. The term for this is rapid thermal processing; it was TRUMPF experts who developed the extraordinary optic that made it possible on an industrial scale. But let's start at the beginning.

SOUNDS SIMPLE, BUT ... Laws dictate that window glass must use what is known as low-emissivity, or low-e, glass. This is glass coated with an ultra-thin sputtered metal coating, such as silver encapsulated inside a precise sequence of layers to impart all required functions. The functional layer reflects infrared rays in both directions, inwards and outwards; in other words, it reduces the glass's emissivity while allowing heat to remain inside the house and ensuring considerable transmission of visible light.

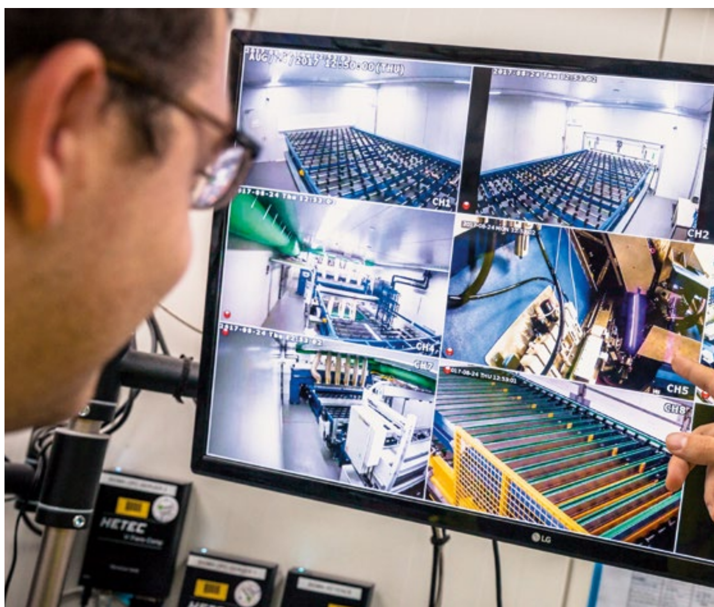
As long as ten years ago, Saint-Gobain launched a project aimed at developing a glass that fulfilled the statutory energy-efficiency requirements of triple glazing but was as transparent as double glazing. The experts were sure this could be done by changing one element: if the silver coating on glass could be changed from an amorphous state to a crystalline one, its conductivity would increase by around 20 percent—as would its insulating effect. Sounds easy, but it's not.

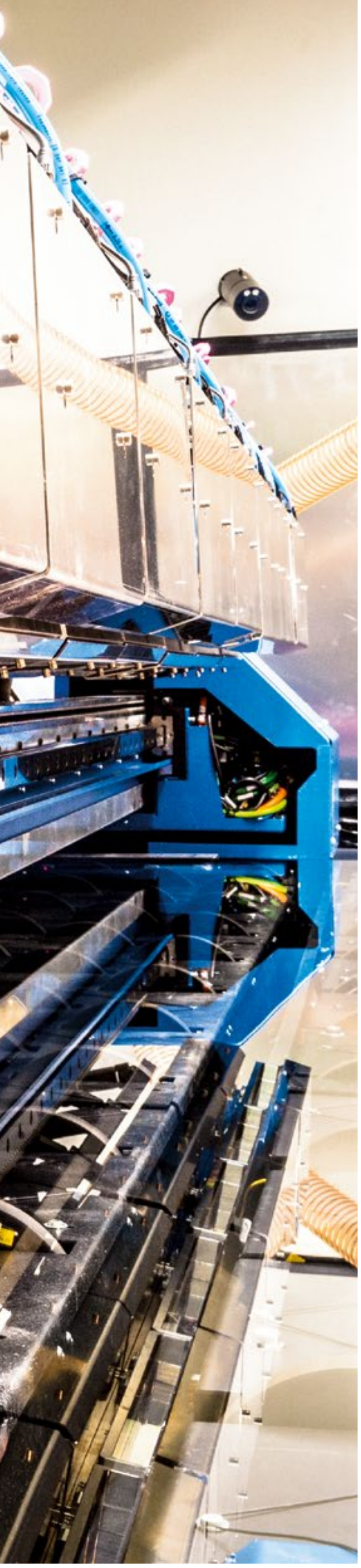
Coatings are in an amorphous state when they are applied in cold environments. They must be crystallized during a subsequent thermal process. While this is being done, the temperature of the glass substrate must remain under 150 degrees so that the glass can be easily processed further. Lorenzo Canova, RTP project leader at Saint-Gobain Glass Germany, says: "We were sure that a short, high burst of heat that heats only the coating and not the glass substrate can be accomplished only using a laser with high efficiency." The glass specialists developed a laboratory facility with a complex laser unit as its centerpiece. Using rapid thermal processing, they created a procedure that enabled them to verify their chosen approach. So far, so good. But making this system suitable for industrial use proved to be a technical impossibility.

"We got in touch with Manz, a high-tech machine manufacturer in Reutlingen," Canova explains. The experts there eventually brought TRUMPF on board—and a four-year development partnership got under way. Saint-Gobain was clear about what it needed its partners to provide: the solution had to be robust, suitable for industrial use, cost-effective and compatible with typical glass sizes.

The bridge houses eight laser optics. They are connected to twelve TruDisk high-power lasers via laser light cables. Together, the twelve lasers generate 144 kilowatts of power.

Heating the glass coating very briefly to a high temperature is an essential part of the hardening process. The glass experts at Saint-Gobain spent five years working on their rapid thermal processing method.





"THANKS TO THE NEW PROCESS, WE ARE IN A POSITION TO CREATE BRAND-NEW PRODUCTS."

Lorenzo Canova,
project manager for rapid thermal processing at Saint-Gobain

LIVE DATA COLLECTION The Manz employees involved in the project started by working on the development of a new conveyor path and added it to an existing unit in Cologne. "We had never designed such a jumbo-sized and highly accurate glass conveyor. The biggest challenge was achieving consistently high synchronization, which is crucial to the laser process," explains Axel Zemler, senior mechanical-design engineer at Manz. During a six-month live test run, the specialists in Reutlingen together with Saint-Gobain teams collected and evaluated data for the construction of the new system. This data was also crucial for the developers at TRUMPF. Michael Lang, from microtechnology industry management at TRUMPF, says: "It was our job to deliver the lasers and optics, because it was clear that several would be needed. It's simply a technical impossibility to create such a long line with one single optic. No machine in the world could make lenses and reflectors with these dimensions." Using the data collected in Manz as well as Saint-Gobain's process and product expertise, the laser experts set to work.

Although the core team of five employees could rely on the combined laser expertise of their colleagues from Schramberg and Ditzingen, there were two problems that pushed them to their limits. As Lang describes it, "We needed to guarantee a laser beam that was extremely homogeneous; that is, within a range of plus/minus five percent. If heat is applied unevenly, the coating is very unforgiving and immediately goes streaky." But not just that: homogeneity also had to be guaranteed in the areas where the laser beams from two adjacent optics meet each other.

To ensure an unusually high level of individual beam uniformity, the team developed a new kind of optic in which the laser beam is especially formed until it has achieved the necessary uniformity. Lang explains, "An optic like this didn't exist before. It's built around core TRUMPF know-how." The optic features an impressively low line width and a high depth of field, and it can be used with the most powerful lasers available on the market. For homogeneous transitions between the individual beams, the TRUMPF experts resorted to a procedure that has been mastered by just a few in the industry: wave optics simulation. He continues: "We took our expertise to the next level in this project. That was the only way we were able to understand the interference effects at the ends of the line segments—by means of precise mathematical calculation—and to check that the homogeneous beam path could be reproduced across the full width of the glass."

SAFELY SHIELDED The laser process was tested on a model system at Saint-Gobain's development center in Thourotte in northern France, and only then—to some extent in parallel—transferred to the industrial pilot machine. The extremely high power levels of the laser line meant the mechanical engineers at Manz had to equip the inline system with certain extras. Along with the high-precision conveyor section, they supplied the bridge with the boxes housing the optics. The process called for maximum manufacturing precision. "The laser light shield we had to install around the laser line was a first for us," Zemler explains. Beam traps, as they are known, are located both underneath and above the conveyor section. He adds, "Depending on the coating type, the laser beam either goes through the glass and must be captured and cooled down below it, or is reflected back from the surface. In that case, you need the protection on top." Moreover, all parts of the laser line need to be cooled, and all cables and water lines must be shielded from scattered radiation.

"Besides the pure development work, it was challenging to install and ramp up the new machine without affecting production, where some glasses are coated using laser hardening and others are not," Canova recalls. But their efforts and the five years in total, during which more than ten specialists from the glass manufacturer's various development departments were involved in the project, have paid off. At the Glasstech 2016 trade fair in Dusseldorf, Saint-Gobain introduced SGG ECLAZ: a new generation of thermally insulating glass for double and triple glazing, which offers not only high light-transmittance values but also 20 percent higher energy efficiency compared to similar glass. A satisfied Lorenzo Canova adds: "Thanks to the new process, we are in a position to create brand-new products." ■

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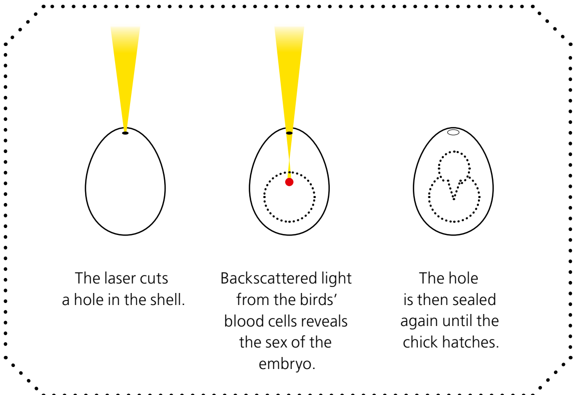
Ralf Kreuels

DEAR LASER

01

Down with chick shredding:

The market needs more hens than roosters, not just for egg production but also for the type of meat people prefer to grill. Since it is impossible to determine the sex of chicks in the egg, farmers simply hatch all the eggs and then remove and kill countless male chicks. But now the laser has achieved the impossible by introducing a method of determining the sex of chicks just three days after incubation.



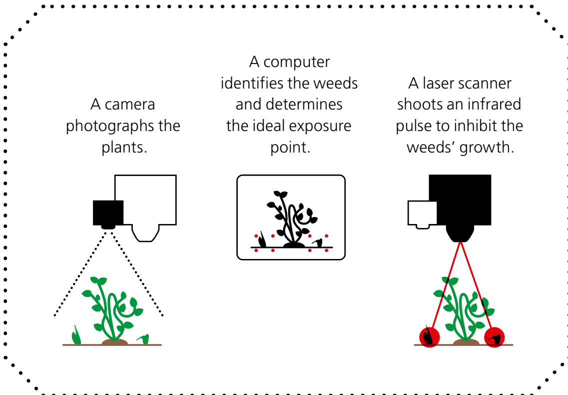
Now egg farmers can keep the eggs that will hatch hens and dispose of the ones that would have hatched male chicks—long before the male embryos are able to feel pain.

STATUS: PROTOTYPE PLANNED

02

Phasing out chemical extermination:

The world clearly needs food, but large-scale farming is almost impossible without herbicides. The problem is that the poison kills not only unwanted weeds, but also much more besides—and, over the long term, herbicides pose risks to people who eat crops or wear clothes made from crop-based products. Laser light could potentially replace these hazardous chemicals—and might even save the weeds themselves from destruction.



Tested in a lab setup, the system even works on the back of a rumbling, jolting tractor—but it is still a long way from matching the sheer size of the areas that chemical herbicides can cover.

STATUS: PROOF OF CONCEPT

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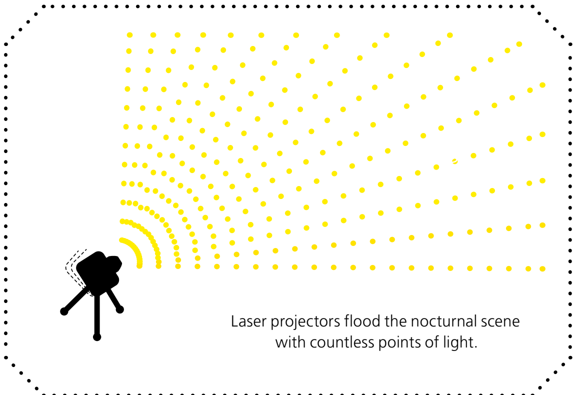
Farmers have to defend themselves against all sorts of accusations, from calf culling and chick shredding to species eradication. Lasers can help improve things.

03

Save the fireflies:

China has a tradition of firefly festivals, an experience that involves lighting up a magical nighttime scene with tens of thousands of dancing points of light. But the fate of the fireflies themselves is not so pretty: collected solely for the event, they are released in areas that offer little chance of survival, and they then die in vast numbers. So why use the poor little things in the first place?



Laser projectors flood the nocturnal scene with countless points of light.

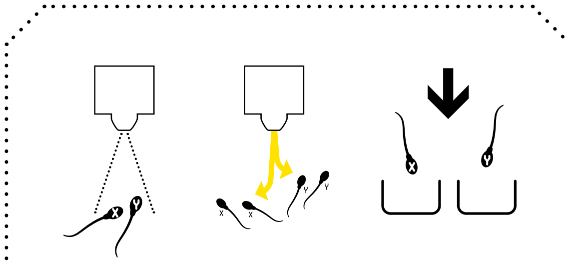
This summer, the first firefly-themed park in China announced that its annual event would take place as normal—but without the use of fireflies.

STATUS: IN THE FIELD

04

A clever way to avoid culling:

Cattle breeders face a similar problem to poultry farmers—too many males—and are still struggling to find an ethical solution. Although artificial insemination can be used successfully to determine a calf's genetic make-up, there is no way of specifying whether an X or Y chromosome comes out on top. But now a solution is in sight.



Fluorescent light is used to determine which sperm are which.

A laser pulse pushes the X and Y sperm down different sides of a channel.

The channel splits into two branches and the sperm are separated.

Cattle breeders end up with sperm that has been almost perfectly sorted, and the chance of them getting the calf they want is overwhelmingly high.

STATUS: ON THE MARKET

Hunters of hidden treasure

DATA IS LIKE GOLD IN INDUSTRY 4.0—AND EVIDENCE SUGGESTS THAT SHARING IT CAN MAKE IT EVEN MORE VALUABLE. DAIMLER SHOWS HOW IT'S DONE

Some of the greatest potential for improving productivity in Industry 4.0 lies in new forms of collaboration between customers and system providers. Daimler is the perfect example. By working together with TRUMPF, it has managed to increase the availability of its laser welding lines by reducing downtime while simultaneously optimizing its internal operating processes. The automaker embarked on a project in collaboration with TRUMPF to unearth the hidden treasure in its data.

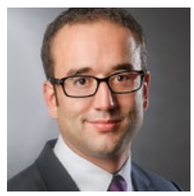
Laser welding is a key feature of the Mercedes-Benz plant in Sindelfingen, Germany: Groups of robots equipped with intelligent I-PFO scanner optics weld the doors and tailgate to E-Class vehicles, powered by a network of TruDisk lasers. The data obtained from the lasers, processing optics and process sensors is funneled into a kind of data highway at the automaker's factory. Some of this data is uploaded to the AXOOM Cloud via the Internet. Daimler knows exactly which data sets are forwarded from the laser systems, and all the data is encrypted before being transmitted via secure channels.

Algorithms and TRUMPF experts then set to work plugging the data into trend analyses. The goal is to prevent malfunctions and identify ways of improving efficiency.

The results have been positive. For example, the team in Sindelfingen noticed that the measured values for laser beam reflection were changing over time. It wasn't immediately possible to determine what had caused this change, but it was obvious that something wasn't quite right. A TRUMPF service technician got in touch with the appropriate system specialist at Mercedes-Benz, who was able to trace the problem to a focusing angle that had been misaligned by the self-teaching algorithm. It was immediately corrected, heading off any problems before they even emerged.

To supplement this expert knowledge, Daimler has also chosen to introduce TRUMPF's Smart View Services. These enable Daimler employees to detect and resolve many minor anomalies on their own, thanks to the user-friendly live overviews provided in the central customer portal. Anyone with access to a PC or smartphone can check the status of the plant at any time, and from anywhere in the world. As a result, the availability of the laser welding machines has increased significantly. ■

In 2017, TRUMPF received the Daimler Supplier Award for its outstanding collaboration.



Marco Holzer is responsible for Product-Management Services and Condition-Based Services at TRUMPF.

TRUMPF

"Delving into the fundamentals of nature is almost akin to a religious experience"

Albert Stolow uses ultrafast laser technology to make "movies" showing how electrons rearrange themselves around atoms and how molecules are formed. His research is paving the way for a whole new field of laser material processing—and seeing this progress gives him a profound sense of serenity.

"

> *"I can assure you that the only way we'll be able to machine the materials of the future will be with ultrashort pulse lasers."*

You say you take a dynamic view of nature. What do you mean by that?
We are living in unusual times. We tend to forget that just 100 or so years ago, we had no idea about the fundamental structure of molecules, steels or pharmaceutical drugs. Quantum mechanics, X-ray diffraction and spectroscopy completely transformed our view of nature and we began to understand the fundamental relations between structure and function. The DNA molecule is a prime example: it wasn't until we discovered its double helix structure that we understood how it functions. There are many other examples and these structure-function relationships carried us to where we are today in science and technology. But it is a static picture and therefore incomplete. Nature isn't static, it is also dynamic.

What do you mean by that?
We must differentiate between a structure and a process. If the required function involves something dynamic, something changing, then a purely static, structural perspective will not suffice. Imagine designing an aircraft, for example. This cannot be done without understanding what happens when it's in motion. The same holds true on a molecular level. To understand fundamental material or molecular processes, we first have to accept that they are dynamic. This is especially true for processes involving the interaction of light with matter. Photosynthesis, the basis of life on Earth, involves ultrafast transformations occurring on a femtosecond time scale (10^{-15} of a second), a tremendously dynamic process.

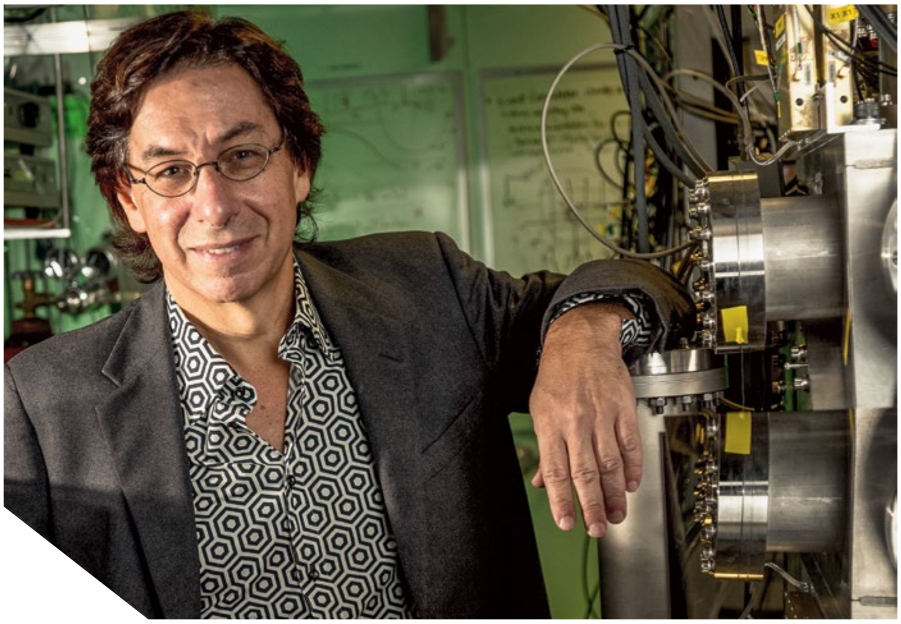
Right, but what does that have to do with shape or geometry?
Let me give you another example: the rod cells of your retina contain a molecule called retinal, which acts as a kind of antenna for light. In simple terms, when a photon strikes a retinal, it changes shape from bent to straight. This causes a mechanical stress on the rod cell membrane, leading to a change in electrical conductivity. The result is a tiny current, a nerve signal, that tells your brain: I see something. Vision relies on this ultrafast change in molecular geometry. If it were too slow, the system would just relax and there would be no current and, therefore, no vision. Since we cannot tell how fast something goes just from its structure, in the 21st century we will need to develop a new paradigm, a dynamics-function perspective of nature.

Would I be right in thinking that we'll be using laser pulses to do that?
Absolutely. Only laser pulses are fast enough to observe atomic and molecular processes on their natural time scales. In addition, matter is ultimately held together by electric forces. And light is of course an electromagnetic field. Lasers also allow us to apply strong electric forces to matter in highly precise and controlled manners. This is why we use ultrafast laser technology.

How can you do that?
Everything we do is related to the interactions of light with matter. There are basically three key aspects of ultrashort laser pulses: time, phase and intensity. The most obvious one is time: ultrashort pulses allow researchers to observe the fastest processes in nature. We developed a technique of time-resolved photoemission spectroscopy here in Ottawa. Put simply, we use a femtosecond laser pulse to excite a material or molecule into a non-equilibrium state. We then use a second laser pulse, delayed with respect to the first, to suddenly kick out an electron. We can learn a lot about how electrons, vibrations, heat, etc. flow on ultrafast time scales by observing these emitted electron distributions as a function of time. The second aspect is phase: we developed a new type of quantum control called dynamic Stark control, using specially phase-shaped, strong ultrafast laser pulses—a method that controls material processes without any net absorption of light. It works by taking advantage of the effect of the laser's electric field—the Stark effect. This is a whole new way of using lasers to control material responses. We're still at an early stage, but I think it has a lot of potential. And finally, we have intensity. With modern, high-power lasers, we can create electric fields that are stronger than those which hold matter together, a new regime of light-matter interaction. We're basically using light as a tool to make carefully controlled changes to matter on a molecular level. Finally, we use low-energy ultrashort pulses in microscopy, allowing us to do real-time imaging of cells, tissues, materials, etc. in a chemical-specific yet completely label-free (i.e. no added stains or dyes) manner. This gives you a rough idea of the different ways in which we use and apply ultrafast laser technology.

But are you really just observing? Aren't you actually interfering in the processes you want to observe with your photons?
Right, obviously we can never see what goes on without the light. As we know, quantum mechanics is a theory of measurement and the first lesson is that observation always changes the process:

PROFESSOR ALBERT STOLOW is the Canada Research Chair in Molecular Photonics at the University of Ottawa and a member of the National Research Council of Canada's Molecular Photonics group. He is a Fellow of both the Optical Society of America and the American Physical Society. Together with his research group, he uses ultrafast lasers to observe the fastest processes in nature: the motion of atoms and electrons and the response of matter to laser fields. Stolow has won several awards, including the 2017 Earle K. Plyler Prize from the American Physical Society and the Canadian Queen Elizabeth II Diamond Jubilee Medal.


National Research Council Canada

there is no glass wall between us and the universe! However, this physics is very well understood and all of the key advances in science and technology over the past century are based on it. We also must use quantum theory and electromagnetic theory to understand our experiments.

What kind of lasers do you use?

Ultrafast laser physics is currently undergoing something of a technological revolution prompted by new powerful Yb:YAG disk lasers. Unlike conventional Ti:sapphire lasers, Yb:YAG disk lasers produce femtosecond pulses that are freely scalable in terms of their repetition rate and energy. We're currently working with the world leader, TRUMPF Scientific Lasers, to build a unique high-power laser system here in Ottawa. One of the main outcomes will be a tabletop ultrafast X-ray source. This new system will enable us to conduct basic and applied research into laser material processing.

What contribution does your research make to the world?

Well, in the short term, we are developing new types of nonlinear microscopy which we hope anyone will be able to buy and use for their imaging research. In the medium term, a new understanding of ultrafast light-matter interactions will lead to new forms of laser material processing. Just think of all the new materials that are being created with unusual mechanical, electrical and thermal properties and often heterogeneous structures such as composites and laminates. How will people drill, cut or finish such materials? I believe that the only way we'll be able to process these materials of the future will be with ultrashort pulse lasers. And, looking even further ahead, we believe that our research will contribute to the understanding of how molecular systems can transport charge so efficiently and coherently: this relates to the future of solar energy conversion and molecular-scale electronics.

Where do you get your motivation for what you do?

All humans have looked up at the starry sky and asked: Why are we here? Deep inside us we have a powerful need to find meaning. Obviously, we might never find the answers. Nevertheless, we have entered into a long dialogue with nature. Contributing to this dialogue is what motivates many researchers, myself included!

How does it feel to move so close to the very fundamentals of nature?

I will happily admit that it can be hard to understand nature. We simply need to believe that there is a logical order, a rationality, even if we don't yet understand it. And when, on rare occasions, you do manage to put a few pieces of the puzzle together, it feels like a revelation: for some it is almost akin to a religious experience. I get a profound sense of serenity in those moments.

Does that happen often?

No, unfortunately not. Most of the time I'm just confused!

"Nature is dynamic. Our job in the 21st century will be to discover the relations between dynamics and function."

PROBABLY THE LONGEST LASER MACHINE IN THE WORLD

Pieter den Oudsten specializes in extra-large sheets.

M. den Oudsten Buigwerken, a Dutch company, wanted the world's largest laser cutting machine. There is only one company that dared build it.

Pieter den Oudsten stands in his new factory, admiring his Spanish eye-catcher. At four-and-a-half meters wide and 66 meters long, it is the largest laser cutting machine in the world. Headquartered in Rhenen, Netherlands, M. den Oudsten Buigwerken is a specialist for leser cutting and XXL bending. The company's laser machine cuts giant sheets and plates for truck bodies, ship hulls and buildings. The workpieces are as large as 3 by 12 meters—and as thick as 30 millimeters. These sheets and plates lie at the ready on the 66-meter cutting table, which is recessed in the floor. A laser booth 20 meters in length travels to each of five working positions one after the other. While the machine is cutting a sheet, the operator can load and unload other sheets.

You read that right: it takes just one person to operate this gigantic machine. Because the table is at ground level, inserting sheets is easy. "Instead of having to climb onto a table, the operator can simply load and unload the sheets using a ceiling crane," says den Oudsten. Once a sheet is in position, barriers at the sides tip up; then a booth moves over the sheet, covering it completely. Roller gates on both sides of the booth descend—and cutting can begin. Two cutting heads dance across the sheet, cutting the specified shapes. Both of these optical systems are mounted on a single portal that moves over the sheet in the direction of cutting. As soon as a sheet has been cut, the roller gates ascend and the booth moves on to the next sheet. "This approach allows us to cut five or even ten sheets in one go, depending on sheet size."

FOUR FIBERS FOR TWO HEADS This gigantic cutting machine was nearly not built at all. "It wasn't at all easy to find a manufacturer that would even consider building such a humongous machine. Only Tecoi stepped forward," says den Oudsten. Tecoi, a company based in León in northern Spain, likewise specializes in medium and oversized solutions. The oversized machines the

Check out our photos and videos of the machine at: trumpf.com/s/y1tk8v

5
MINUTES
is how long it takes the booth to shift from one working position to the next.

2
CUTTING HEADS
equipped with 0.5 and 1 mm fibers can cut individually or in parallel.

66
METERS
A table this long is perfect for even the largest sheets, and it also creates space for loading and unloading while the machine is cutting.

"At first you have mass, dynamics and precision all pushing in different directions."

Jorge Luís Rodríguez, CEO Tecoi

company manufactures are at least 6 meters long, which is unique in this market.

Mr. Jorge Luís Rodríguez, CEO at Tecoi, still clearly recalls the order from the Netherlands. The booth and the portal turned out to be challenging in making a cutting machine for Buigwerken. "It was essential that we strike a good compromise between height and weight on the one hand and, on the other hand, the booth's dynamics—or acceleration and deceleration behavior. Weight was crucial, especially when it came to the portal, because the dynamic movement must adjust precisely to the speed of cutting."

Tecoi certainly knows how to take laser cutting to the next level: by placing two different fibers in a single cutting head. "This allows us to combine two beams that cut in different ways. The first fiber is ideal for thin materials—between just 0.8 and 1 millimeter. The other fiber cuts materials as thick as 30 millimeters. Regardless of the task at hand, you don't need to change the cutting head." The Spanish company calls its innovation the double-fiber process (DFP) system. What's more, Tecoi uses two of these cutting heads per portal. They work in parallel for even faster cutting. The laser-beam source is a TruDisk 6002 made by TRUMPF.

BIG AND FAST Den Oudsten at Buigwerken in the Netherlands is a happy man. "This disk-laser system handles complicated sheet-cutting jobs twice as fast as a CO_2 laser. That makes us faster and more flexible than the competition. We can deliver in less than five days, which is lightning-quick in our industry!" Buigwerken wanted an XXL cutting machine that can produce as many as 4 large sheets per hour. After all, the more cutting tasks there are per sheet, the better the two-headed monster can leverage its superior speed. ■

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Norbert Voskens, Tecoi

Super sensitive

HOW SUPERMAN'S SUPER-SENSES ALLOWED ENGINEERS' IMAGINATIONS TO TAKE FLIGHT — AND WHY LOIS LANE CAN HANDLE MORE THAN ANY LASER PROCESSING HEAD.

Picture this iconic scene: Investigative reporter Lois Lane has once again taken too big a risk and fallen out of an airplane / spaceship / helicopter / skyscraper. The situation seems hopeless, and her fate is surely sealed. Lessons on Newton at school taught us that this kind of fall means hitting the ground at about 200 kilometers an hour, meaning certain death, at least for a normal person. But Lane is not normal—she is Superman's true love. And, fortunately, Superman can not only fly, but is also equipped with Kryptonian super-senses!

He can hear Lane scream from a hundred miles away, locate her position, and see her falling, even through walls. At the same time, his superhuman brain processes all the data perfectly despite everything unfolding at such extraordinary speed. The result is a heady mix of romance and sci-fi: Superman catches her in the air, carefully equalizing their relative speeds to ensure she doesn't come to a nasty end when she collides with his super-strong arms. That's the kind of sensor technology that inhabits many engineers' wildest dreams, especially those who are currently investing so much effort in adding a healthy dose of superpowers to the realm of material processing. One thing they need is a tool that is super-flexible and capable of adjusting itself in a matter of microseconds. You've guessed it: the laser! And the second thing is a sensor system that allows machines to "see" and "feel" at breathtaking speed. These sensors can detect the position of the workpiece and the energy delivered by the laser as well as the pulse duration, light path and job progress—and they can even predict when a component might fail. At the same time, they can react faster than Lois can say "Clark." That yields processes featuring ultra-efficient loops with high tolerances at the preparation stage and absolute precision at the machining stage.

Obviously you still need hardware that can handle all this without collapsing—taking in its stride, for example, a laser processing head accelerating or braking at 9 G. Of course, that wouldn't be a problem for Lois Lane. She can brake at 100 G without coming to any harm, just before Superman gently brings her back to Earth—and we celebrate yet another happy ending. ■

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

→ *Can you think of any other iconic scenes that can be explained only by superpowered sensor systems? Let me know by email: athanassios.kaliudis@de.trumpf.com*

Gernot Walter

WHERE'S THE LASER?

Being hip: The population of the industrialized world is getting older, and so too are people's hips, knees and limbs. The spirit may be willing, but the joints are weak, so doctors are increasingly adding more implants to give peoples' bodies the support they need. In fall 2017, new guidelines were introduced for medical devices, requiring them to have a UDI code that ensures each implant can be clearly tracked and identified throughout its lifecycle. Ultra-short light pulses create the codes by applying a rough nanostructure to the device. This small-scale light trap produces a mark with a high-contrast, deep black hue which is both robust and corrosion-proof. Fast forward 4,000 years, and alien archaeologists will no doubt be digging up artificial hips by the dozens—and they will still be able to read the UDI codes!

Fotolia / stockpackshot

200

KILOWATTS
OF LASER POWER ...

... to carve a path through the perpetual ice. That's the plan hatched by a Russian team of researchers at Astrofisika, a subsidiary of the state industrial corporation Rostec. The scientists want to equip icebreakers with high-powered lasers capable of carving through the sea ice as the ship moves forward. This technique can double a ship's ice-breaking capabilities, opening up new year-round trade routes through the Arctic. But where do you get the energy for that kind of laser out at sea? Fortunately, the ship's own nuclear reactor has plenty of power to spare. Soon the researchers will be setting sail with a 30-kilowatt laser on board to perform their first real-world tests.

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