Laser Community

THE LASER MAGAZINE FROM TRUMPF

#23

READY WHEN YOU ARE

Lasers are the perfect tool for Industry 4.0

#23

November 2016

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Using the asset-light approach of the sharing economy, Airbnb and Uber have figured out a simple, user-friendly way to link free capacity to an existing market. The theory is that similar scenarios exist in industry.

But Industry 4.0 is not one dimensional like the sharing economy. It is horizontal and vertical. The vertical aspect of Industry 4.0 is the seamless digital link from sensors at process level, via production equipment, shop floor and factory into the cloud. For the first time we are able to read, collect and analyze massive amounts of sensor-level data and consolidate and analyze it. This leads to better availability and utilization of production equipment and facilities. But, it ultimately is a linear progression of productivity gains as we have known them.

Customer focus is paramount

The horizontal aspect of Industry 4.0 could be disruptive and lead to skyrocketing productivity and growth. It is the seamless and continuous end-to-end digitalization of the entire industrial process chain. Simplified, it is the order-to-cash process with all aspects of production, including planning, administration and logistics through the use of digital twins.

This has the huge potential to open up new ways to connect customers to existing capacity and to put an Uber or Airbnb type intermediate between producers of goods or commodities and their customers. Value generation will take place at this link, not where the product is made. OEMs will be reduced to mere production houses. Thus far the theory.

How realistic this scenario is, depends on the all-important customer relationship. In other words, customer focus is paramount in the age of digitalization in industry.

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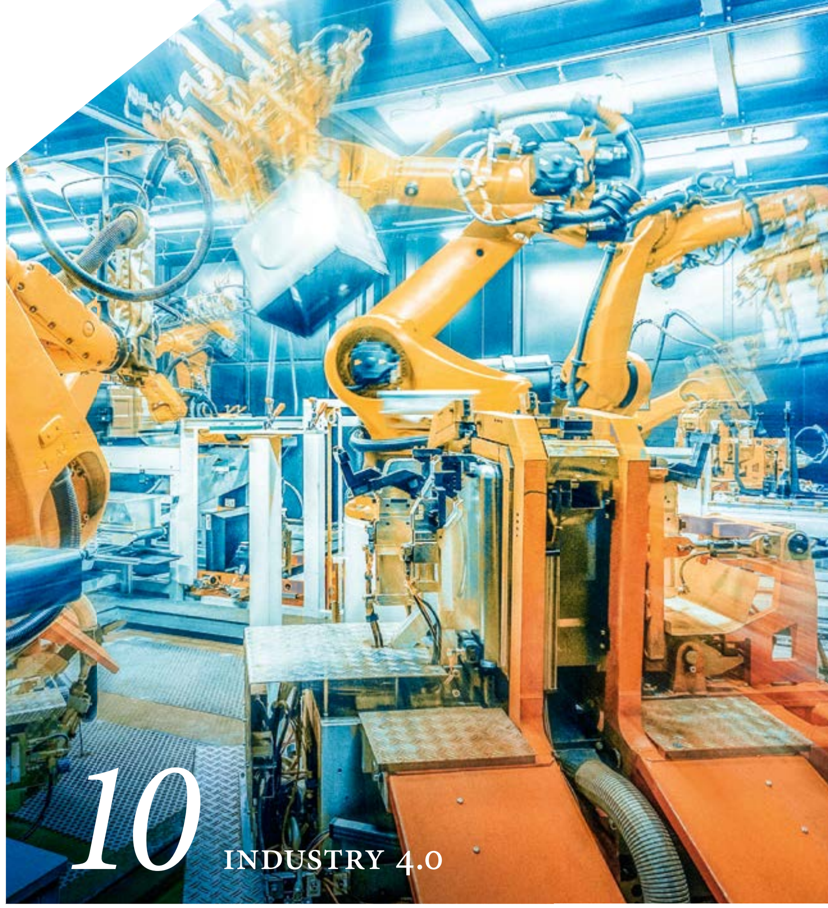

ISSUE

COMMUNITY

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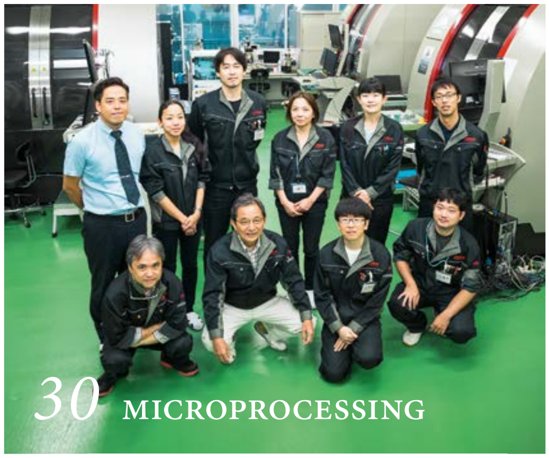

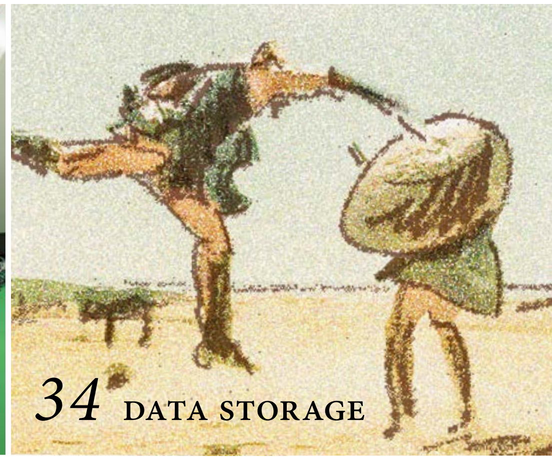

23/2016

Claus Langer, STFC, Gernot Walter, Benjamin Parks

POWER

LASER BRAZING HOT-DIP GALVANIZED SHEETS

Yvonne Gürtler, Industry Management Automotive at TRUMPF, led the brazing experiments.

Hot-dip galvanized sheet metal is in high demand, at least in the automotive industry. It offers multiple advantages over the electrogalvanized sheet steel currently used in car body manufacturing, including corrosion resistance, lower prices and easier availability worldwide. However, it also has one big disadvantage—it generally tends to produce more spatter, pores and uneven seams during laser machining. The problem is that automakers all over the world are increasingly relying on laser brazing to join panels that require visually appealing welds. This method uses a laser to join two parts together with filler wire. The wire is generally made from a copper-based alloy, since this material has excellent machining properties and produces a smooth and accurate weld seam. That's why joins on exterior body panels where seams are visible—such as the roof sides and trunk lid—have traditionally been brazed rather than welded. But what can you do if the material you are hoping to braze with a laser is unwilling to play along? That question has been investigated at some length by Yvonne Gürtler, Industry Management Automotive, and her project team at TRUMPF. They carried out their tests using a disk laser with six kilowatts of power and adaptive laser processing optics with built-in seam tracking.

The trick they came up with was to modify the shape of the laser beam. The team split the beam into three separate beams with different diameters and output power. The small focal points play an important role, preparing the sheets by removing the zinc coating and preheating the base material. That ensures everything runs smoothly in the subsequent brazing process, enabling the hot-dip galvanized sheet to be joined without spatter or pores—and at brazing speeds that can currently reach up to 4.5 meters a minute.

Laser brazing for beginners — find out everything you need to know at www.laser-community.com/en/6641

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Cross section: Good tensile strength and an attractive finish—TRUMPF has finally found a way to join hot-dip galvanized sheets using laser brazing.

Gernot Walter, Tobias Funk

GLORY

AIMING A LASER POINTER INTO SPACE

Telescopes can finally reach their full resolution potential thanks to laser-generated guide stars.

Reliable guide-star lasers are revolutionizing astronomy. The “Guide Star Alliance” development team led by Wilhelm Kaenders, Wallace Clement and Domenico Bonaccini Calia made it onto the podium at the Berthold Leibinger Innovation Prize.

Stars don’t actually twinkle — but the atmosphere makes it seem like they do. All the refractive anomalies, temperature gradients and turbulence in the air distort our view, preventing astronomers from getting a clear look at outer space through their telescopes. Even when the sky seems perfectly clear, this interference can make the light from a star appear much brighter, obscuring any smaller astronomical bodies in its vicinity. Dim objects that the telescope normally has no difficulty in resolving simply disappear, and the surface features of planets merge into a blocky gray mush.

There are two ways to counter the effects of these disturbances: either by heading into space, like the Hubble telescope; or by locating a guide star with a known brightness. This latter option allows a computer to eliminate the distortion — the twinkling — of the guide star and derive the information it needs to control a variable mirror, physically deforming it in real time to compensate for the atmospheric distortion. That removes the twinkle from the other stars in the telescope’s field of view, too.

But what if you want to observe a portion of the sky where there are no suitable guide stars? Then you can just create your own using a laser beam! The idea, which originated in the 1990s, is to align a laser parallel to the telescope’s axis. At a height of around 90 kilometers, the laser light stimulates sodium atoms to absorb and re-emit light, creating a clear, bright “star.” For this to work, the laser must have a wavelength of exactly 589.2 nanometers, and that can only be achieved using dye lasers. With the required output in the low two-digit watt range, dye lasers require levels of technology and maintenance that can only be described as intensive.

But now Wilhelm Kaenders, Wallace Clements, Domenico Bonaccini Calia and their colleagues in the Laser Guide Star Alliance have come up with a new laser guide star system for large telescopes. The laser delivers exactly the right power output yet requires no more effort than using a laser pointer — at least in terms of the overall scale of running a large astronomical observatory. The first system to be installed has been guiding the European Very Large Telescope array on Cerro Paranal in Chile since April 2016.

It marks the start of a new era of astronomy, providing the technology to allow terrestrial telescopes with large mirrors to finally reach their full resolution potential. Mankind will soon be able to gaze even deeper into space.

Find out more at: www.eso.org

Star cannon at the ready! Laser light stimulates sodium atoms in the atmosphere, enabling a wavefront sensor to analyze the atmospheric conditions.

"NOBODY CAN COPY THAT"

Intrinsic values: The qualities that make this key so secure aren't visible externally.

A Swiss start-up prints the most secure keys in the world: the Stealth Key. Alejandro Ojeda, co-founder of UrbanAlps, wonders why nobody else came up with the idea earlier.

Mr. Ojeda, has your home ever been burglarized?
No, luckily not.

Then what inspired you to design more secure keys?
On August 2013 I was reading an article in Forbes about two MIT students who had 3D printed high-security keys. They claimed that 3D printing was the end of the mechanical key. Today, your neighbor's kid can secretly 3D scan your key and copy it on a 3D printer. I immediately thought, "They are completely missing the potential of 3D printing!" Just re-invent the key using 3D printing. And so we did.

But how?
Using selective laser melting, you build parts layer by layer. This enables you to create complex internals easily and shape them any way you like, and that's exactly what we do: our key has holes and recesses like any other key. But not only outside—inside as well! It is hollow and has an opening at the front. Our locks are able to mechanically read these security features concealed inside the key. You can't see them from the outside, and no 3D scanner can read them, either. The idea is so simple that I'm surprised nobody else thought of it earlier.

So the keys can never be duplicated?
The general public cannot. Admittedly, professional thieves with very special tools and skills could theoretically make copies. But those people have always been capable of copying keys. The issue for most people is the amateur copier: previous tenants at your home, your ex-partner or a caretaker. If you have our key, you don't have to worry about them anymore. Our Stealth Key system brings back the sense of safety.

Your key must be extremely expensive…
Not really—the manufacturing costs of keys produced using additive manufacturing are already roughly the same as for conventional high-security keys. And, unlike drilling holes on sheets of metal, this process is very young and its costs are going down year by year. Today with a single powder-bed system, we can print 800 keys in ten hours. You only need one machine, no key blanks at all and you have hardly any material waste. Moreover, each key can be completely different at no cost, say with a company logo.

The industry must love the idea!
That's what we thought. But up to now, they were not as enthusiastic as we suspected. Our goal is to convince the industry to rethink their ways and to demonstrate the potential of 3D printing to them. We firmly believe that the future of high-security keys lies in additive manufacturing: it only has advantages. Many people think electronic keys are the way forward. Sure, there's something attractive about the idea of using your smartphone to open your front door, a safe-deposit box and maybe your car. For hotels and offices it is a fantastic solution. But then you come home with your bags of groceries in the pouring rain and you can't open the door because an update is missing or the battery is dead. Electronics bring convenience, mechanics security. We exist to help those who care about their security.

When will we be able to buy your locking systems?
They will be available next year, but for niche applications related to the banking sector. We're currently running endurance tests to ensure the mechanical longevity of the locks so that they will work reliably for 20 to 30 years. Everything's going very well.

Why not the front doors of homes first?
Penetrating the housing market is a real challenge and we will probably only expand to that phase together with established partners.

Contact: alejandro.ojeda@urbanalps.com

UrbanAlps

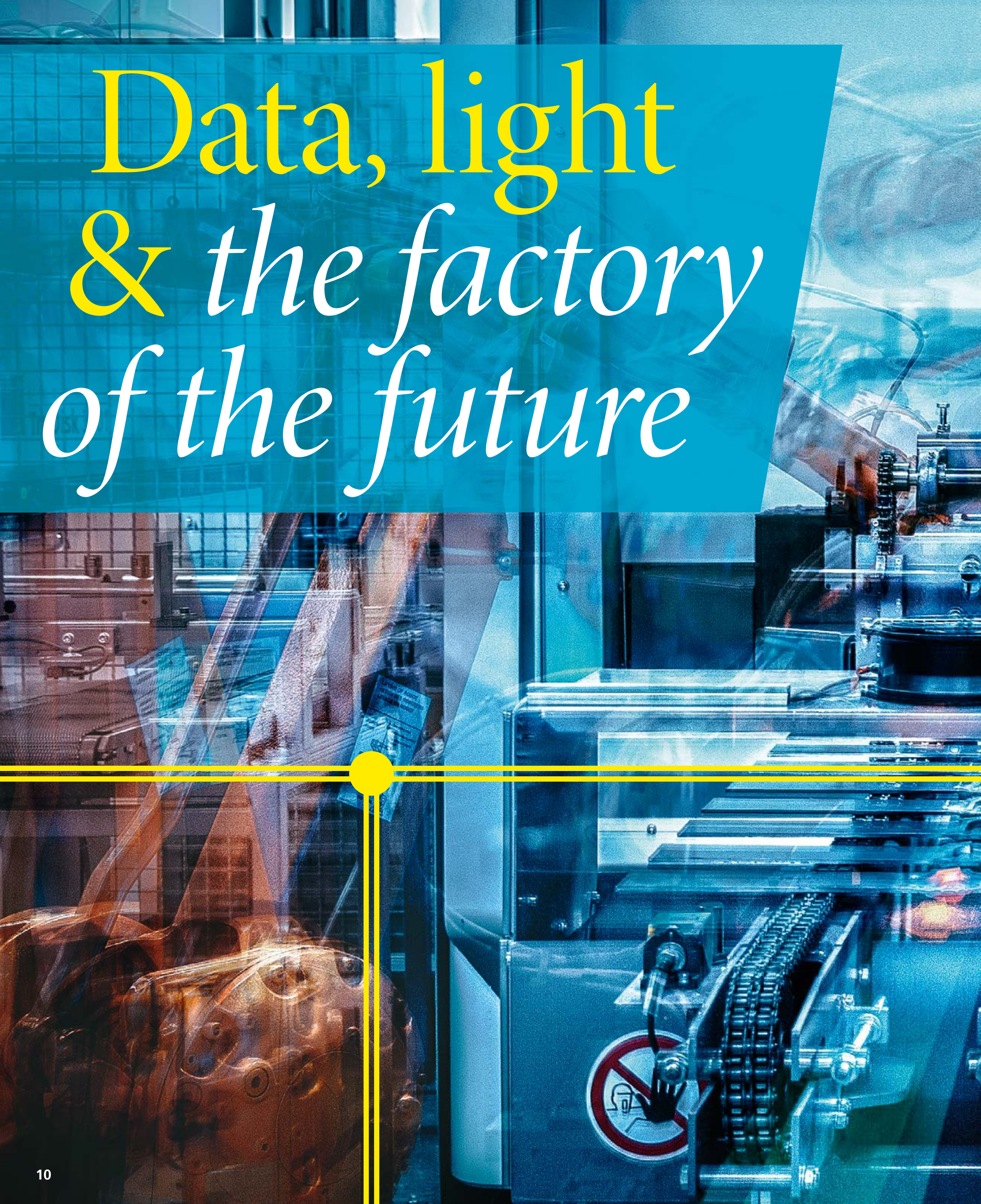
AHEAD

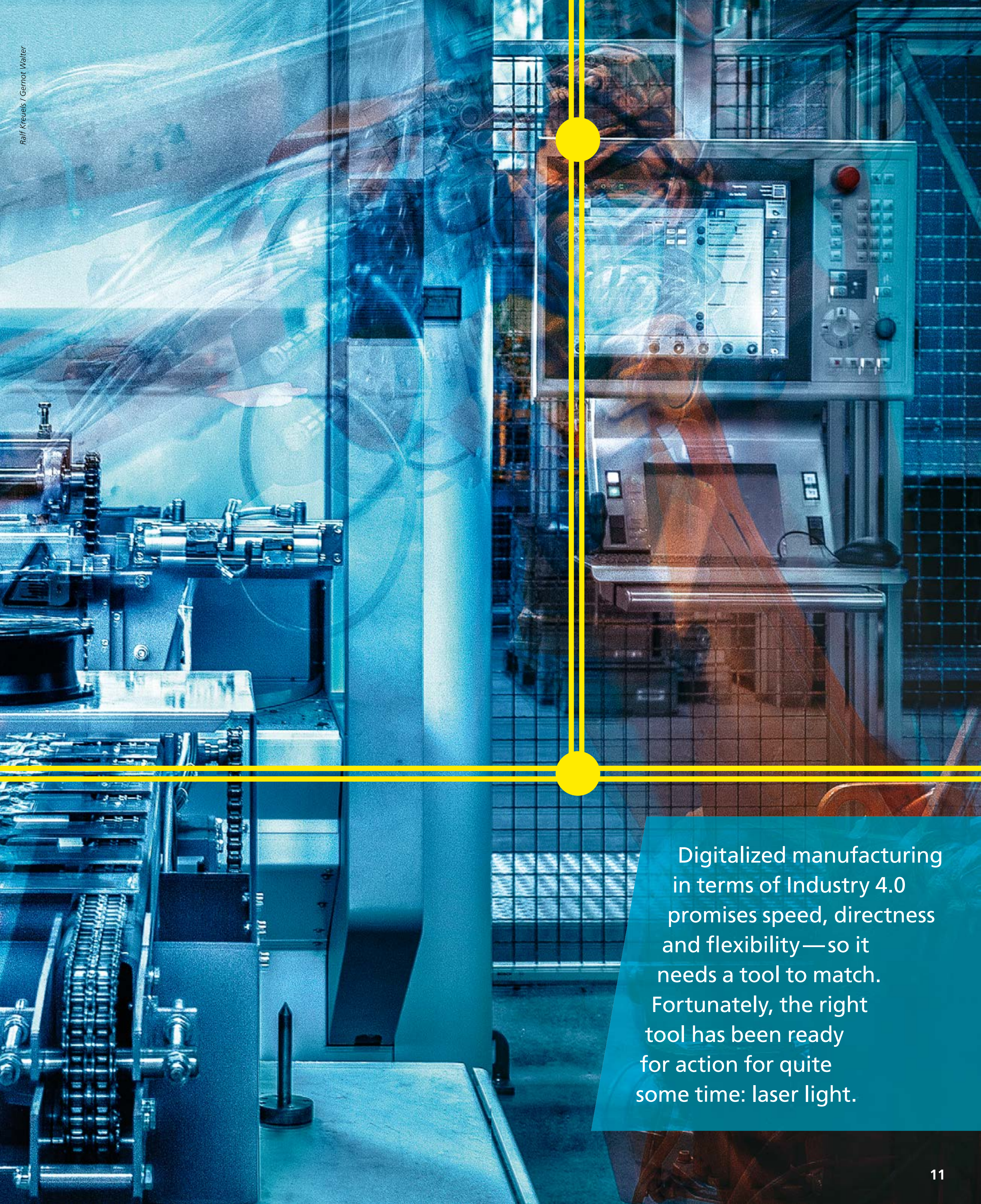
THE MAN: Alejandro Ojeda studied mechanical engineering in Las Palmas, Torino and Oxford. He worked in Zurich for four years as project leader, and completed his Ph.D. in laser processing at ETH Zurich in September 2016.

Alejandro Ojeda shows us the additively manufactured key by UrbanAlps. The 3D printing process enabled the young engineers to completely redesign the traditional key: their new key is hollow and conceals additional security features inside.

THE COMPANY: UrbanAlps AG was founded in July 2014 by Alejandro Ojeda and Felix Reinert, who subsequently developed keys with matching locks produced with 3D printing. They intend to launch their first products on the market in 2017. The two engineers had previously worked together at a company that produces gas turbines, where they focused intensively on additive manufacturing and laser-based processes.

Data, light & *the factory of the future*





Ralf Kreuels / Gernot Walter

Digitalized manufacturing in terms of Industry 4.0 promises speed, directness and flexibility — so it needs a tool to match. Fortunately, the right tool has been ready for action for quite some time: laser light.

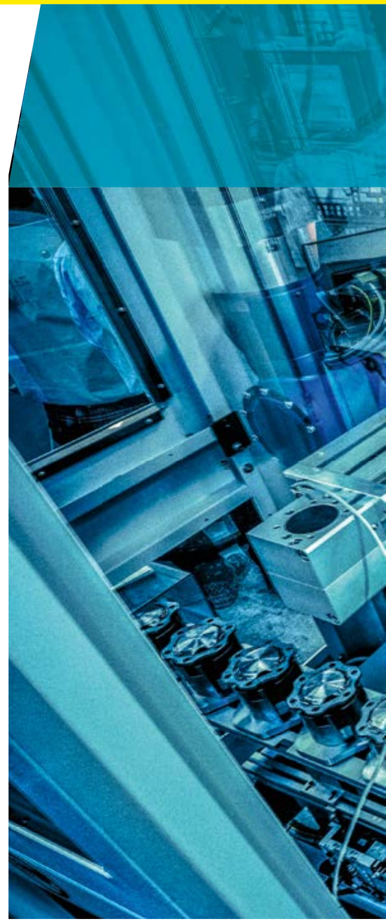
Ask people where the future of manufacturing lies and talk will quickly turn to concepts such as data analysis, programmed algorithms, smart ultra-flexible part flow, and connected machines. “One question is often left unanswered, however: what tools will we be using to actually machine the workpiece in all these highly connected, flexible operations?” says Andreas Gebhardt, Professor at the Aachen University of Applied Sciences and a pioneer in additive manufacturing and Industry 4.0. The problem is that data is intangible, yet at some point it has to be turned into products we can touch. “Digitalization is crying out for a tool that offers the same fast, flexible and physically unconstrained benefits that it does. And that’s a pretty good description of a laser.” After all, when it comes to laser machining, the only thing standing between data and form is a focused beam of light. Yet that light can do so much, from ablation and material deposition to drilling, cutting, joining, producing metallurgical changes and inducing intrinsic tension in glass, as well as roughening, smoothing and cleaning surfaces. Lasers are on for just about anything.

“And the benefits don’t stop there,” says Gebhardt. “One of the biggest advantages of lasers is that they can process whatever material you like, from metals and glass to plastics and even skin. They give you complete freedom.”

FOUR ACTIONS IN A REVOLUTION Laser systems were up and running in factories long before anyone was talking about connected manufacturing or Industry 4.0. “Laser technology was digital right from the word go because it can only be controlled numerically—you could almost say that data-based manufacturing is in its DNA,” says Gebhardt. Many of today’s production planners are discovering that they already have experience with one highly mature industrial tool that is the perfect choice to meet the new requirements they are facing. “When laser experts hear about Industry 4.0, they simply take it in their stride.” For everyone else, it feels like a revolution. And there are four key actions to this revolution that are playing out simultaneously:

1. Manufacturing chains with lasers are on their way in, manufacturing chains with mechanical tools are on their way out.
2. The workpieces themselves are turning into data carriers with the power to communicate.
3. Parts can change shape with each different set of data.
4. Parts are being made completely from data sets.

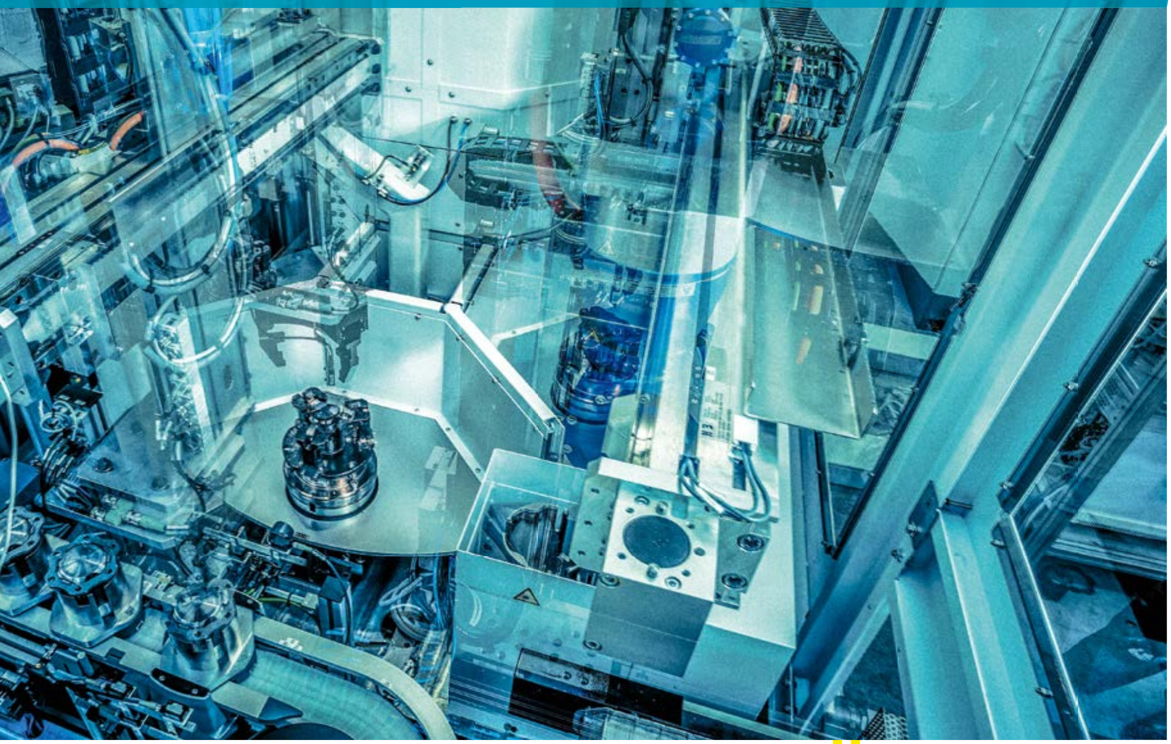
ACTION 1: FIGHTING FOR GREATER VARIETY Marketing departments always want to offer potential customers products that match their needs and surprise them with special editions. Meanwhile you can almost hear the production planners grinding their teeth as they field one request after another for new varieties and small batch sizes. And that’s especially true in factories that still depend heavily on mechanical processes such as milling, punching, sawing and drilling. The costs of toolmaking go through the roof—and tool set-up times stretch out to absurd lengths. Increasingly, set-up actually takes longer than the production process itself. This was exactly the situation faced by Zwilling, a German knife manufacturer based in Solingen. After the drop forging process, the company would use a punching machine to remove the final blade geometry from the blank. But Zwilling doesn’t just have three or four blade geometries in its portfolio—it has hundreds. And the numbers just keep going up, including a highly exclusive special series chef’s knife made from steel taken from Germany’s highest railway bridge to celebrate the company’s 285th anniversary. Ulrich Nieweg, who heads up Zwilling’s prefabrication department, recalls how tough things were getting: “We were building a new punching tool tool every time we had a new product or a change in geometry. It was tremendously costly and time-consuming, and so was the constant tool repositioning.” To tackle this problem, they opted for a laser cell that is loaded and unloaded by two robots—a flexible and programmable solution. Worries about toolmaking and set-up times are now a thing of the past: “Nowadays we simply send across a new data set and that’s that.” So is the laser cheaper than the punching machine? That question misses the point entirely. Companies like Zwilling that choose to rethink their production processes and manufacturing chain understand that laser light offers a level of freedom that mechanical processes simply can’t match. That’s because, by definition, their mechanical nature means they need something exerting an influence on something else.



This shift in thinking is now taking hold in all sorts of places. The Swiss mechanical engineering company THE Machines uses one and the same set of laser optics and one and the same beam source to process coils of different sizes made from different materials, first making a precise cut and then welding them together. The automatic switch from “cutting” to “joining” happens in the blink of an eye. Meanwhile the shears and TIG welders have quietly disappeared—and nobody wants them back.

The big automakers have spent decades eliminating one mechanical production step after another downstream from the forming press and replacing them with laser stations. One example is car doors: the designs currently used by automakers allow them to cut the highest possible number

Smart manufacturing means machines finding out for themselves what they need to do. For that to work, the production line needs tools that are highly flexible and easy to control.



Detlef Göckeritz / Gernot Walter

of different models from the pressed metal panels. After all, it makes no difference to a downstream laser whether an angle in car door A needs to be flatter or whether the diameter of a hole in car door B is larger. The laser simply receives its instructions in the form of data packets and immediately puts them into practice. All that smart scanner optics need is the data from a 3D simulation software program and they are ready to apply the welds to the workpiece—no teaching required. Even the word "set-up" no longer applies, because it's the machine itself that makes the necessary adjustments for each part.

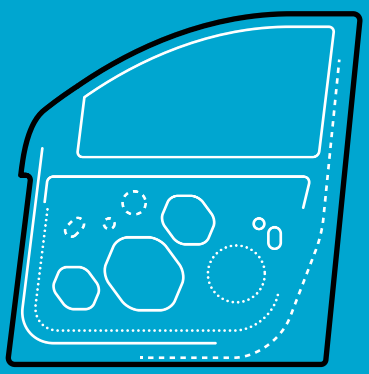
ACTION 2: IT CAN TALK! Things get even more connected when the parts themselves can communicate with the tool to say how they should be handled. Argo-Hytos, a German manufacturer of hydraulic and filter systems, is one place where the laser head asks each part "What can I do for you today?" Joachim Fischer, who heads up manufacturing process technology at the company, explains how this works: "We produce lots of short-run batches based on a strategy of zero set-up time." One example is the laser transmission welding of plastic filters and tanks. The scanner optics in the laser cell are mounted on a robot head and fed by a diode laser. The optics move freely around the workpiece, forming the welds in the correct places. Every part that enters the laser cell has a bar code.

The code tells the machine what to do, so it can fetch the relevant parameters from the database and get to work. Argo-Hytos works with many different kinds of plastic. "In many cases even the supplier of the semi-finished product doesn't have accurate information on its laser transparency." That's where the pyrometer integrated in the optics comes in handy, monitoring the temperature in the melt and providing data to the laser robot in real time. The robot and beam source adjust the power output as they work, producing optimum welding results. "It boosts the efficiency of our manufacturing process and produces even the smallest batches at a level of quality you would normally associate with large-scale production," says Fischer.

As well as being the perfect recipients of the messages transmitted by parts, laser systems can also teach workpieces to communicate in the first place. The machine tool manufacturer Chiron, based in southern Germany, has incorporated a marking laser in its laser cells that provides each finished part with a data matrix code. "Normally the production data includes information such as the time the part was manufactured, the processing station, the supplier number and the order number. But obviously you can also add additional codes to the marking," explains Thomas Marquardt, head of automation at Chiron. For example, these codes could tell a transport system where the part needs to go, and explain to a control system at the next processing station what program it needs to load. This transforms the workpiece into a carrier of its own blueprint—and it marks the beginnings of a genuine smart factory.

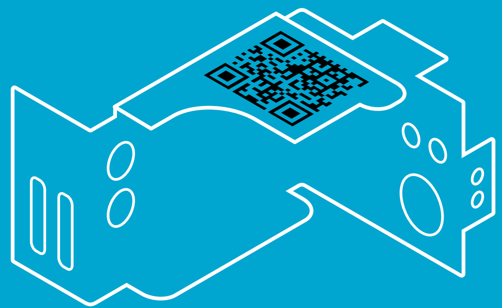
ACTION 3: DATA IS CHANGING PARTS Modern data-driven production, which offers a way to construct geometries, is entering the next phase. "Additive manufacturing is turning the process for manufacturing many components on its head," says Andreas Gebhardt from the Aachen University of Applied Sciences. That's exactly what Elfim, a high-tech contract manufacturer in southern Italy, is doing—

Product variety and small batch sizes



Manufacturing chains are gradually bidding farewell to mechanical tools. Laser light offers a faster, simpler and more flexible way to produce things on demand.

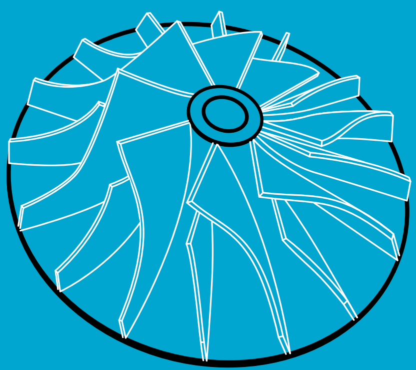
Parts carry their own data



Marking lasers write data onto parts. Laser machines read the data on each part to find out how to process it and execute the instructions immediately.

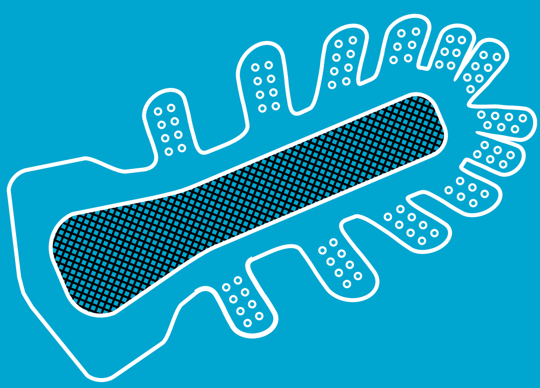
THE LASER IS A KEY PART OF THE DIGITAL REVOLUTION IN FACTORIES. IT PROVIDES FOUR KEY SOLUTIONS.

Digital construction



Laser metal deposition systems construct complex geometries on base parts. Additive manufacturing turns the production process on its head.

Turning data into components



Powder bed fusion turns an idea straight into an object like this bionic spine implant. Offering new levels of design freedom, it is the pure embodiment of data-based manufacturing.

Gernot Walter

starting with an unspectacular milled base, they use laser metal deposition to construct complex blades for various impellers. “We used to start with a metal block and then mill away more than 70 percent of the material to end up with the right impeller geometry. Completely crazy, really,” says Michele D’Alonso, the company’s co-founder. “Now we just add the necessary material instead of cutting away the unnecessary.” Not only is this process faster and more resource friendly, but the final impellers are also better. “With laser material deposition, we can construct other, more exact blade geometries. As a result, one of our gas impellers has 50 percent more capacity!”

Although Elfim is manufacturing its impeller blades using different methods, the blades essentially look the same as before. “Yet designers all over the world are discovering that additive manufacturing offers the ability to completely rethink parts,” Gebhardt argues. Automakers are currently working hard to modify the design of many components and reduce vehicle weight. Currently, each individual manufacturer uses the same economical, mass-produced cast parts for all its vehicle models, including chassis and body parts, engine components, and brake discs. That means the load-bearing capacity of the parts is dictated by the heaviest model. In other words, little city runabouts typically contain parts that are heavier and more stable than they need to be. Experts are hoping to turn that around in the future by designing parts based on the lightest load they will have to withstand. That makes them lighter and cheaper. For heavier models, these parts are then partially reinforced with weld beads, creating a fusion of customization and lightweight design. In the future, auto designers are also hoping to use this method to improve crash-relevant parts made from high-strength steels: clever application of weld beads can allow them to absorb so much force in the event of an accident that the actual base part can be made thinner and lighter. Car body panels essentially have predetermined points beyond which a panel should not travel in a crash. Combined with the predetermined bending points incorporated using laser annealing, the engineers can determine precisely how the parts should crumple in the event of a crash. Targeted reinforcement of parts using laser metal deposition is on the verge of moving into full-scale production.

STEP 4: IDEA → LIGHT → OBJECT Additive manufacturing using powder bed fusion takes this process to its logical extreme. Loaded with metal powder, the machine simply waits for instructions and then produces whatever is required. The designers’ ideas are immediately brought to life. “3D printing is the pure embodiment of data-based manufacturing,” says Gebhardt. With such tremendous freedom to choose geometries, designers can create new and improved parts. That’s exactly what happened at Grindaix, a German manufacturer of coolant supply systems that was determined to improve its coolant nozzles using 3D printing. These nozzles are used to distribute lubricoolant on the part during ID cylindrical grinding. Now they are designed on the basis of bionic principles—and the benefits of this new approach are remarkable. “We can create nozzles with curved channels designed for optimum flow,” says Dirk Friedrich, owner and CEO of Grindaix. “They deliver the right doses of coolant to exactly the right place on the part with lower pressure losses. Our customers benefit because they can run their grinding process faster and even achieve higher quality.” (see page 26).

“We’re currently seeing a transition from the mass production of mass-produced parts to the mass production of individualized parts,” emphasizes Gebhardt. This change has not gone unnoticed by contract manufacturers, and some of them are seizing the opportunities it offers. The company C.F.K. Kriftel GmbH, based near Frankfurt, has been using 3D printing since 2004. It all started with rapid prototyping, but it has progressed in leaps and bounds. “We get lots of jobs that involve printing finished parts in our laser metal fusion machine,” says managing director Christoph Over. C.F.K. Kriftel’s products include spinal implants with a fine lattice structure that promotes tissue growth. “We can produce between 120 and 180 implants simultaneously in 20 variants with just one load of metal powder. That’s certainly one step closer to mass production.” Other customers contact Over because they want to finally produce components as one piece. “We often see specialist nozzles and connection plates for industrial automation consisting of multiple individual component parts that all have to be manufactured in different ways and then joined together. We can simply print the complete part as a single piece. And in many cases we can even make it better or more compact.” Customers are increasingly discovering the design freedom 3D printing offers, and contract manufacturers with the right machinery are springing up on every corner. At the same time, more and more engineers have the expertise required to design parts specifically for 3D printing. The Laser Zentrum Hannover, for example, began offering courses to 3D printing professionals this year. “Design know-how will be the key to 3D printing—and we’re only at the beginning of that road,” says Over. He also cites two other key tasks for the future: “We need to conduct more research into the core process and understand how lasers and metal powders actually interact. And it will be even more important to automate machines and integrate them into the manufacturing chain.”

> ***Digital manufacturing is in the genes of laser technology.***

THE TOOL OF THE DATA SOCIETY Gebhardt has a strong hunch as to which tools will be needed in these manufacturing chains: “Nobody knows exactly what additional requirements will emerge in the field of connected manufacturing, but my personal feeling is that laser systems are a great way to prepare for whatever lies ahead. There are simply so many cases where if anything can do it, it’s a laser!”

When the laser first saw the light of day in the 1960s, some people said it was a tool looking for an application. Now it appears it may have finally found its purpose as the tool of the data society. ■

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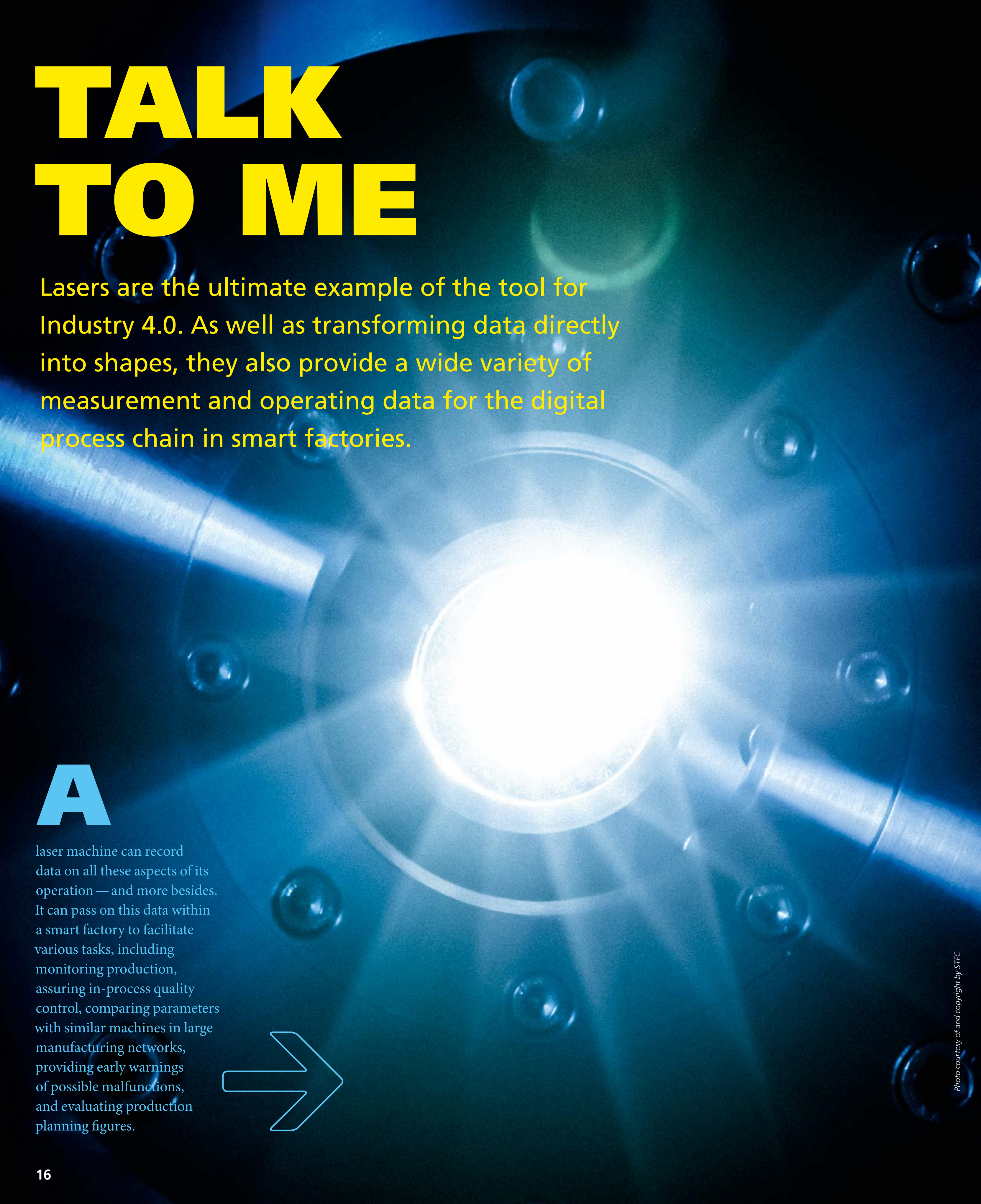


Photo courtesy of and copyright by STFC

TALK TO ME

Lasers are the ultimate example of the tool for Industry 4.0. As well as transforming data directly into shapes, they also provide a wide variety of measurement and operating data for the digital process chain in smart factories.

A laser machine can record data on all these aspects of its operation — and more besides. It can pass on this data within a smart factory to facilitate various tasks, including monitoring production, assuring in-process quality control, comparing parameters with similar machines in large manufacturing networks, providing early warnings of possible malfunctions, and evaluating production planning figures.

Energy check:
on, with fault message
pulse energy: 20 µJ
Energy tolerance: 0.3 µJ
Nom. laser program no.: 3
Act. Laser program no: 3
Energy saving mode active: 3
Nominal scanner program no.: 14
Act. scanner program no.: 14
Nominal light path: 1
Act. light path: 1
Measuring channel: 1
Nominal number of pulses: 347
Max. percent to deviation energy: 0,009
Min. percent to deviation energy: 0,0085
Program line no: 14
Report pending: nein
Disruption pending: nein
Pulse count: 124
Act. pulse duration: 5 ms
First pulse energy: 10.1 J
Act. pulse energy: 10.1 J
Act. average pulse energy: 10.05 J
Avg. created pulse energy: 492
Act. max. pulse energy: 10,2 J
Act. min. pulse energy: 200 Hz
Act. pulse frequence: 200 Hz
Amplification: – 1,5
Nom. pulse frequence: Rep.
Nom. pulse shape: Rechteck
Nom. avg. pulse shape output: 1,000 W
Nom. pulse shape duration: 5 ms
Nom. square pulse duration: 3 ms
Work center number: 7
Input voltage: 400 V
Power frequency: 60 Hz
Current: 20 A
Nom. laser output: 2,500 W
Actual value laser output: 2,502 W
Cooling water feed temp.: 19.3 °C
Cooling water filling level: 0.95
External cooling water pressure: 4.5 bar
Cooling water temperature: 25.1 °C
No. of operating hours: 37,452
Self-test: O.K.
Software version: 2.15

QUALITY ASSURANCE

Assigning component IDs from laser and process data enables automated backup & seamless tracking of quality data. Bad parts are identified in real time when they deviate from defined process parameters – these parts are then tracked via their IDs and culled. Analyzing the deviation reports helps to systematically recognize errors and optimize process parameters.

TRANSPARENCY

Using easy-to-understand dashboards, operators can determine the status of every machine in the entire pool with just a glance. Events and changes in condition are automatically sent to the correct recipient. Status-based maintenance information, for instance, are sent only to the maintenance personnel, while manual programming procedures are visible to application managers.

EARLY WARNING

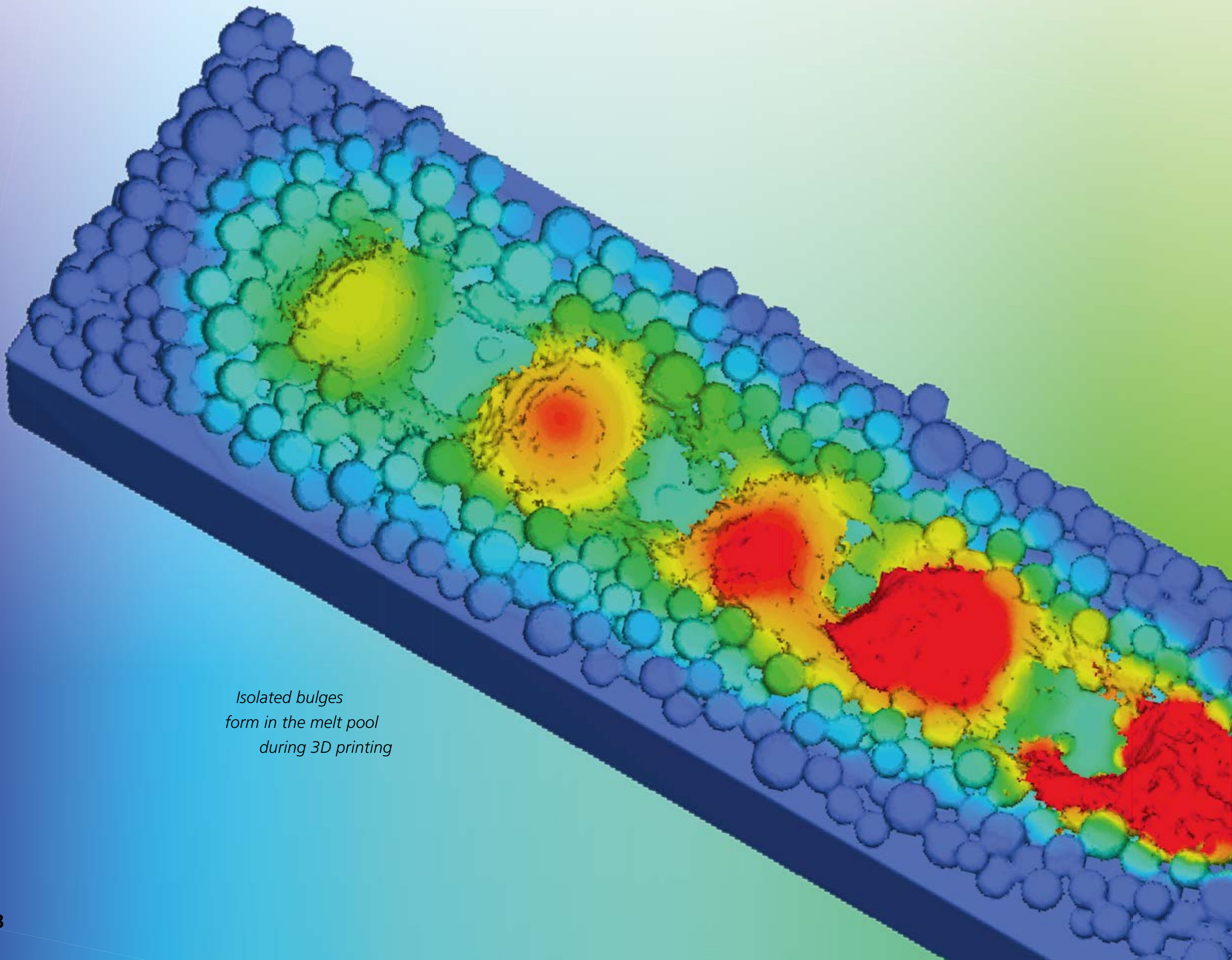
In addition to visualizing the current status, algorithms can be used to analyze condition data. Recognizing trends and patterns helps to identify faults early and to inform the person responsible before a failure occurs. Using the calculated prediction times, maintenance can harmonize repair measures with the production plan.

Scanner PCB softw. vers.: 4.38
Safety loop PCB softw. vers.: 1.05
Wavelength: 1.030 nm
No. of outgoing lines: 3
Type: LLK-D
Length: 20 m
Max. length: 50 m
Diameter: 0.2 mm
Wave length: 900 – 1.070 nm
Specification: Suitable for robots
Soiling of protective glass: 3 %
Cooling water feed speed: 65 l/h
Cooling water connection: Functional
Cooling water conductivity: 30 µS
Pump speed: 55 Hz
Wavelength: 900 – 1,070 nm
Cooling water feed temp.: 28.4 °C
Scanner temperature: 35 °C
Illumination: On
Offset x: + 5 µm
Offset y: + 2 µm
Offset z: – 20 µm
z position: + 5 mm
Max. correction value x: 50 µm
Corr. value y alert threshold: 40 µm
Temperature: 40 °C
Max. laser power corr.: +/– 100 W
Final parameter: 3,956 W
Component O.K.: O.K.
Evacuation system: on
Illumination: on
Nom. feed rate: 20 m/min
Delay: 2 ms
Rotation correction: – 2°
Focal length of lens: 450 mm
Defocus: – 5 mm
Lens: Typ 2
Serial number: 4,855
Light path: 2
Focus position z: 0 mm
Store cam. image p. component: yes
Component ID: 36
Seam width: 600 µm
Type: 15D.12
Distance: 4,5 mm
Material: 14.301
Process successful: yes
Temperature: 467 °C
Position: 91 °
Orientation: Horizontal
Offset in x: 1 mm

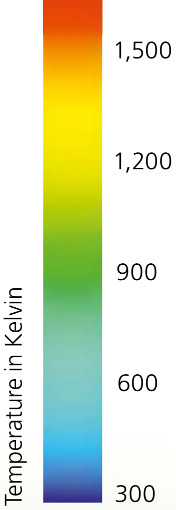
Dr. Yousub Lee

FOCUS ON PARTICLES

How do laser metal deposition and laser metal fusion actually work? Two simulations help clarify the physical processes involved. The goal? To improve reproducibility and surface quality in both methods.



Isolated bulges form in the melt pool during 3D printing

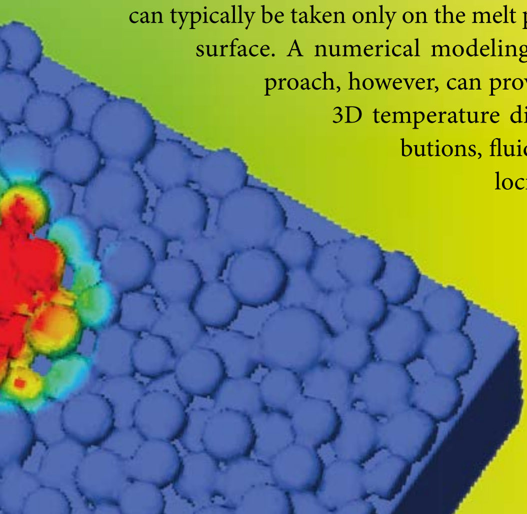


Particularly when using costly metallic materials, laser additive manufacturing (LAM) is an ideal manufacturing process, as it creates complex 3D parts in near-net shape directly from computer-aided design (CAD) data. In contrast, conventional methods require as-built parts to be finished with machining tools. Despite this unique benefit, broad application of LAM has been impeded because additively manufactured parts still have defects such as porosity and balling, which again can require finishing. Also, the difficulty of predicting dimensional tolerances and the inhomogeneous material properties of final parts hinder extensive industrial usage of LAM. Overcoming these issues requires a quantitative understanding of the relationship between process parameters, heat transfer, molten metal flow, melt pool shape and solidification microstructure. However, experimental observation of physical phenomena is very difficult, since LAM melt pools are inherently localized and transient. In addition, in situ measurements of thermal and fluid variables using optical and infrared cameras can typically be taken only on the melt pool surface. A numerical modeling approach, however, can provide 3D temperature distributions, fluid velocities, melt pool shape and solidification conditions (temperature gradient G and solidification rate R) at any time and location. Unfortunately, many previous numerical simulations that focused on laser or fusion welding processes did not account for the characteristic features of the LAM process in detail.

Thanks to the simulations we finally understand all the relevant process parameters.

IN THE MELT POOL Laser metal deposition (LMD) and Laser Metal Fusion (LMF) are both processes that use powder particles and a laser beam to form a deposit layer. The interaction of the laser, powder and substrate must be incorporated into LAM simulations. In LMD systems, the powder particles interact with the laser beam during their flight into the melt pool. The interaction attenuates the power of the laser beam through reflection, absorption and radiation. In addition, the catchment efficiency (= area ratio of melt pool to powder jet) should be accommodated in LMD simulation, since powder particles striking the melt pool are used only to form the deposit layer. In LMF systems, the absorbance of the laser beam depends on the configuration of the particles in the powder bed. The melt pool shape, as well as the temperature gradient and fluid flow, are significantly affected by local particle arrangement. Therefore, the effect of powder bed configuration on thermal conditions, surface quality and microstructure should be examined in LMF simulations. The goal of our simulations was to provide a quantitative understanding of the relationship between the process parameters, thermal conditions, fluid flow, melt pool shape and the resultant microstructure. LMD simulations were performed to show the influence of fluid convection on melt pool shape, solidification microstructure and deposit dimension. Meso-scale models for LMF were created to show the effect of powder particles and process parameters (i.e. laser power and scanning speed) on melt pool characteristics, particularly temperature profile, melt pool fluid flow, melt pool surface profile and related surface defects. Then, the solidification conditions obtained from the simulation were used to quantitatively assess the solidification microstructure.

COOLING IN LMD For LMD with powder injection, we used a transient 3D transport simulation that took into account the effect of heat transfer, fluid flow, powder particle addition and laser/powder/substrate interaction to investigate the effect of fluid convection on melt pool formation in single-track and single-layer IN718 deposits. →



Yousub Lee

1 *LMF: The laser beam strikes the top layer of the powder bed. As it moves to the right ...*

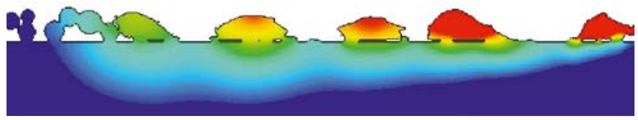
LMD mixes hot melts and cold melts — and that makes exciting things happen.

The model showed that the most deeply penetrated melt pool was formed at the intermediate region adjacent to the rear melt pool but behind the laser focus spot. This increased melt pool depth occurs due to the impingement of two opposing surface fluid flows induced by the transition of the surface tension gradient from positive to negative along the x-axis. The predicted melt pool shapes were comparable to experimental measurement in width, height and penetration depth at three different laser powers: 350W, 450W and 550W. The temperature gradient G and solidification rate R were obtained along the melt pool fusion boundary in the model to assess the effect of fluid convection on the solidification microstructure. The cooling rate (G x R) was calculated and the size of the primary dendrite arm spacing (PDAS) was predicted along the fusion boundary using the theoretical models of Kurz-Fisher and Trivedi. The prediction showed that the cooling rate values in the intermediate region decrease not only from greater to lesser depth, but also from the center to the lateral edge of the melt pool boundary. In other words, the general pattern showed that the cooling rate increases with increasing lateral width and depth. The simulation results indicate that the mixing of the two opposing flows in the intermediate region leads to the mixing of hot melt (moving backward from the front of the melt pool) and cold melt (moving forward from the melt pool rear). Consequently, the cooling rate decreases in the region, which corresponds well to the predicted size of the PDAS. Similarly, the predicted size of the PDAS increases near the melt pool lateral edge in the region. The predicted values of PDAS matched well with the measured mean values of 9.9 µm.

MUSHROOM-SHAPED BULGE The 3D model explained above was extended to an LMD process with multiple layers on a single track to investigate the influence of fluid convection on melt pool formation and deposit build dimension. Unlike single deposition on a flat substrate, the laser beam and powder particles are projected onto a convex free surface as the layers are stacked. Due to Marangoni shear stress and particle addition, fluid circulation occurs in a melt pool with a convex surface. The simulation showed that the shape of the bottom of the melt pool continually shifts from flat to convex as the build height increases. The analysis at the bottom of the melt pool showed that the convex shape of the melt pool bottom is partially attributable to the convex free surface of the prior layer. Moreover, the investigation of dimensionless numbers (Peclet, Prandtl and Marangoni) and fluid flow patterns showed that Marangoni-driven fluid penetration into the previous layer becomes deeper at the outer edge, thus further intensifying the convex shape of the melt pool bottom. Based on the analysis above, an additional study was carried out with three distinct fluid flow patterns induced by different types of surface tension gradients (positive, negative and mixed), to show their effect on final build geometry. A similar mushroom-shaped bulge was observed at the start of deposit build with material that had a positive or negative surface tension gradient. However, when the material had a mixed surface tension gradient, the lateral width of the bulge was reduced by approximately 56% compared to the bulge width of material having a negative gradient. The fluid flow pattern analysis showed that the collision of two opposing flows induced by the mixed gradient is effective in minimizing bulging of the deposit sidewall. Thus, manipulating the surface tension gradient can be an alternative for improving dimensional accuracy and surface finish quality of the deposit sidewall.

2 … the temperature distribution in the melt pool causes the powder to form little islands.

3 These bulges, known as balling, create a "hilly" surface. Parameters supplied by the simulation can help solve this problem.



The denser and finer the particles in LMF, the lower the frequency of balling defects.

FLUID CONVECTION IN THE POWDER BED In LMD, the injection of individual particles can be approximated by a lumped mass flux into the melt pool, since the laser beam diameter is about 2 mm, which melts hundreds of powder particles. In contrast to LMD, the ratio of laser beam diameter (100 µm) to particle diameter (20 µm – 40 µm) for LMF is small. Only a limited number of powder particles can be melted at any given time. Therefore, higher resolution of individual powder particles is required for better simulation accuracy.

A computational framework for LMF was developed in meso-scale resolution. First, a powder bed arrangement was calculated using a discrete element method (DEM) model. DEM accounts for each individual particle as an individual mesh, so the model is able to consider the physical interactions between the particles and the wall. Then, the calculated powder packing information (i.e. locations and radii of individual particles) is exported into a 3D transient heat transfer and fluid flow model as an initial geometry. The 3D transport melt pool model captures the interactions between the laser beam and the powder particles, particularly free surface evolution, surface tension and evaporation. Therefore, the effect of particle size distribution (PSD), powder packing density, key processing parameters on bead geometry, the occurrence of balling and the solidification microstructure were quantitatively investigated with the 3D model.

SOLIDIFICATION MORPHOLOGY IN LMF The simulation results showed that particle distribution containing a higher fraction of fine particles produced a smoother melt pool contour. It was also found that a higher scanning speed and lower laser power increase the likelihood of balling. The formation of balling defects initiated from a void at the center of the melt pool. As the void grows, Rayleigh instability causes the melt pool to break into separate islands. Higher packing density is expected to reduce void formation due to augmented mass filling of any new void. In other words, the likelihood of balling occurring can be mitigated by increasing powder packing density. Furthermore, the solidification conditions (G and R) obtained from the simulation were used to assess the solidification microstructure. The predicted morphology was predominantly columnar and PDAS was estimated to be in the range of 1.32 – 1.87 µm. The calculated solidification microstructure was consistent with experimentally observed morphology and size.

BASIS FOR OPTIMIZATION The 3D transient transport simulations used above are limited to simple pass or tracks due to the high computational cost. Nevertheless, the models effectively captured essential characteristics of LMD and LMF based on the computation of heat transfer, fluid flow, free surface of the melt pool and solidification microstructure for the LAM process. Based on our work, we anticipate that the quantitative physical insight from these simulations will enable spatial programming of process parameters to attenuate or accentuate localized microstructures and inhomogeneous material properties during fabrication of LAM parts. ■

Yousub Lee

Yousub Lee** is currently a postdoctoral researcher at Oak Ridge National Laboratory in Tennessee, USA. He received his Ph.D. degree in welding engineering at The Ohio State university under Prof. Dave Farson and Wei Zhang. His Ph.D. projects were funded by Rolls Royce through the National Science Foundation-Industry and University Cooperative Research Center and U.S. Office of Naval Research.* ***Email: leey@ornl.gov

All one piece: Redesigned by Bionic Production, this nozzle offers gentle curves and optimized flow straight from the 3D printer.

The 3D design developed by Grindaix already features significant changes, but the flow is still slowed by unnecessary kinks.

FORM FOLOWS

The old nozzle was manufactured in four steps: milling, screwing, drilling, and bonding. These conventional manufacturing techniques produce a relatively angular nozzle.

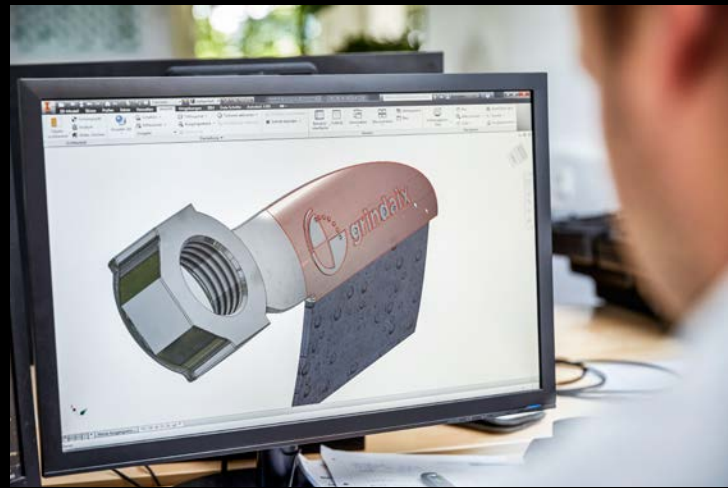
3D PRINTING STARTS IN YOUR HEAD: Designers need to rethink their approach to unlock the huge opportunities offered by this relatively new manufacturing technology. The experts in coolant systems at Grindaix did exactly that.

FUNCTION

The biggest challenge of internal diameter (ID) cylindrical grinding is the limited space between the part and the tool. It's not easy to accommodate a conventionally produced coolant nozzle that meets all the requirements—and in the case of very small holes it's often impossible. That's why, in practice, manufacturers tend to carefully inject the lubricoolant required for grinding from the outside. That makes the ID cylindrical grinding process very slow, and it poses a risk that not enough lubricoolant will reach the machining site. This results in higher cycle times and correspondingly reduced productivity as well as high scrap rates due to parts suffering thermal damage. Dirk Friedrich, owner and CEO of the company Grindaix, was far from satisfied with this solution.

Headquartered in Kerpen, Germany, Grindaix GmbH specializes in optimizing and remodeling coolant supply systems for machine tools and develops optimum solutions for minimizing grinding burn and coolant wastage. The experts at Grindaix are always open to new manufacturing technologies

Matthias Schmidt-Lehr, head of sales at Bionic Production, (right) and his colleague Eric Wycisk know all the ins and outs of 3D printing: designers need to start by forgetting everything they've learned before and opening their minds to the new technology.



that might help them achieve these goals. "We've been focusing on 3D printing for a long time. When we took a look at the market, we saw very few tailor-made, highly efficient, customized nozzles for specific applications in ID cylindrical grinding. So we reckoned that this new manufacturing technology would be a good choice for making those kinds of nozzles," says Friedrich.

NOTHING IS IMPOSSIBLE Anything is possible in the world of 3D printing. In theory that's true—but before a part can be made, extensive engineering expertise is required to ensure that what the 3D printer builds up layer by layer will actually fulfill its purpose. Injecting this kind of specialist knowledge to create a 3D printing-compatible design is far from easy, as the Grindaix engineers discovered. "We're used to designing things in the traditional way, in other words with a constant focus on the manufacturing process. I'm not saying 3D design is alchemy, but it does require a shift in thinking," Friedrich emphasizes.

So Grindaix decided to enlist the help of the Hamburg-based company Bionic Production GmbH. Founded by former employees of the Laser Zentrum Nord, Bionic Production aims to ramp up 3D printing processes to an industrial scale. As well as manufacturing parts, Bionic Production also offers services including consulting, training, component optimization, and process and material development. "The team of experts at Bionic Production revised and optimized our initial design to make it suitable for 3D printing. They showed us what we needed to focus on. We learned so much from them that we're now able to design 3D parts on our own," Friedrich explains. Matthias Schmidt-Lehr, head of sales at Bionic Production, knows all the ins and outs of 3D printing. "Designers need to

Dirk Friedrich: "The new nozzle features an optimized coolant flow that reduces pressure losses by up to 20 percent. The curved channels and optimized jet trajectory take the lubricoolant to the precise place it is needed."

The internal surfaces of the nozzle are polished using an abrasive fluid. A further step is also required to ensure proper tightness of the connecting thread. Dirk Friedrich argues this finishing work is a price worth paying for the high flexibility of the 3D printing method.

Claus Langer, Erik Krüger

start by forgetting everything they've learned before and opening their minds to this new technology. Only in exceptional cases do you need straight lines and rectangular structures. 3D printing gives you the opportunity to create free-form surfaces, many of which would be difficult or impossible to produce using conventional CAD tools."

Equally important is the ability to recognize the limitations of the 3D printing process and sidestep them where possible. "In 3D printing we hold the part in position on the 3D printer platform using supports, which have to be removed once the process is finished. But in many cases you can avoid using supports completely by designing the part in a certain way," says Schmidt-Lehr.

To design a part for 3D printing, the first step is to model all the essential aspects, in this case the defined lubricoolant entry and exit points and the space required to avoid collisions with moving machine parts. The designer then adds only as much material as is absolutely necessary for the part to fulfill its purpose. "Machine cost per hour is still a key cost driver in 3D printing. The smaller a part's volume, the shorter the process time required to construct it. By leaving out any material that is unnecessary we make the part lighter, and that's often a major advantage in its own right. But even if it doesn't matter how heavy the part is, reducing the volume still makes it cheaper to produce," says Schmidt-Lehr.

Unlike conventional methods, the designer can focus purely on optimizing how the part works. In the case of Grindaix coolant nozzles, curved channels lead to a lower drop in pressure thanks to reduced flow losses. That reduces the amount of pumping power required, so the end customer benefits either from the ability to use a smaller pump or from a higher coolant exit velocity.

THINKING AHEAD IS KEY Using the specifications provided by Grindaix and a TRUMPF TruPrint 1000, Bionic Production created the perfect model of the new nozzle in a step-by-step process. "Software allows you to perfectly simulate many aspects of the design, such as the direction of the coolant jet. But the benefit of 3D printing is that it makes it so much easier to create prototypes, try them out, and then modify them as necessary," says Schmidt-Lehr. That enabled the team to implement every possible optimization within a reasonable timeframe and budget. The improvements are clear: as well as fitting in the smallest of spaces, the new nozzle can also be individually tailored to each customer application. Dirk Friedrich from Grindaix is delighted: "We make a huge number of different product variants. The 3D manufacturing technique enables us to supply the perfect nozzle to virtually every single one of our customers."

The new nozzle is efficient in many different respects. The flow of coolant has been optimized, reducing pressure losses by up to 20 percent. That means you need a lower pressure—and less energy—to achieve the specified coolant exit velocity. The curved channels and optimized jet trajectory take the lubricoolant to the precise place it is needed, delivering no more and no less than is required to carry out the process in an optimum manner without causing thermal damage to the part. This reliable and automated solution for delivering lubricoolant eliminates factors that may have previously caused hold-ups in the manufacturing process.

BENEFITS OUTWEIGH DOWNSIDES Despite his enthusiasm for 3D printing, Friedrich essentially sees this particular manufacturing method as just the icing on the cake. What really gives the nozzle its unique selling point is the clean engineering process that guarantees an accurate geometric design.

"There's a correlation between the pressure of the lubricoolant in the coolant line upstream from the Grindaix nozzle and the velocity with which it exits the nozzle. We calculate the exact figures for each custom-made nozzle shape. And there's also a correlation between the velocity at which the water or oil exits the nozzle and the grinding speed," says Friedrich. "If you know the grinding speed, then you can achieve adaptive control of the pressure with the aid of the Grindaix nozzle flow rate diagram. That means we can tell our customers exactly what pressure they should use upstream from the nozzle to achieve a specific coolant exit velocity in the grinding process. We never used to be able to achieve such tremendous precision in nozzle applications for ID cylindrical grinding."

But no matter how pleased Friedrich is with the new nozzle, he never tries to conceal the the process drawbacks from his customers. "Sintered parts have a rougher surface than those made from conventional metals. On the outside, at least in our case, this is an issue in how the part looks, and we can correct it through polishing. And to eliminate the roughness on the inside surfaces, which would once again lead to flow losses, we pump an abrasive fluid through the coolant nozzle at high pressure."

The roughness of the connecting thread also has to be corrected in a separate process to achieve a tight seal. On the plus side, the original nozzle was produced in a total of four production steps, while the new one only requires two steps, so that cancels out these apparent drawbacks. All in all, Friedrich argues that the high flexibility of the process significantly outweighs the disadvantages. "This nozzle would be impossible to produce without 3D printing. If you're aware of the limitations, then you can compensate for them." Matthias Schmidt-Lehr from Bionic Production agrees: "In many cases you don't actually need smooth surfaces, they are just a side effect of the drilling or milling process. But in cases where smooth surfaces are vital to how a component functions, then you inevitably need to do some reworking if you take the 3D printing route."

He finishes off by clearing up another myth: "Many companies seem to think that you can make any component using 3D printing and that it will end up cheaper. But in fact this method is really only suitable for a small number of parts. When you do get the right match, however, the benefits can be huge."

50 NOZZLES AT ONCE The new Grindaix nozzle is still a development project at the moment, though some customers are already using the nozzles and Friedrich is optimistic about their future sales potential. "We've already progressed well beyond the prototype stage. Together with TRUMPF and Bionic Production, we've been developing concepts that will allow us to print 50 different nozzles at once in the future using a printing process on large-scale printers. That will obviously have a positive impact on manufacturing costs." He is clearly impressed by the flexibility offered by 3D printing. "With all the know-how we've accumulated in this joint project, we would certainly consider producing 3D printed parts ourselves in the future." ■

Contact: Dirk Friedrich, phone: +49 (0) 2273 95373 – 0, d.friedrich@grindaix.de

"This nozzle would be impossible to produce without 3D printing."

Only suitable for prototypes? Absolutely not! Grindaix, Bionic Production and TRUMPF have been working on a joint project to develop concepts that make it possible to print multiple different nozzles in a single operation on large-scale printers.

Erik Krüger

GRAPHENE OXIDE SATURABLE ABSORBER FOR Q-SWITCHED FIBER LASER

The chemical advantages offered by saturable absorbers for Q-switched fiber lasers make them easier and cheaper to produce with graphene oxide than with graphene and carbon nanotubes. In his doctoral research at the University of Malaya in Kuala Lumpur, Malaysia, Ahmad Zarif Zulkifli (32) used two different methods to create saturable absorbers with graphene oxide, demonstrating the advantageous properties of the alternative material.

Ask for the thesis: zarifz41@gmail.com

MICRO LASER METAL WIRE DEPOSITION FOR ADDITIVE MANUFACTURING

The use of wire in the production of micro parts in additive manufacturing is fast reaching its limits. As part of her master's research at the Politecnico di Milano, Martina Riccio (24) converted a TRUMPF PowerWeld into a fully automatic system for micro laser metal wire deposition. She then used the converted system to produce thin-walled components made of stainless steel, achieving a wall thickness of 700 micrometers and a material utilization of nearly 99 percent. *Ask for the thesis: martina.riccio91@gmail.com*

FURTHER READING

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

ZINC OXIDE NANOSTRUCTURES BY LASER ABLATION

Until now, vertically aligned zinc oxide core-shell nanorods have been created by means of a multi-step growth process, often requiring metal catalyst particles or layers. In his doctoral research at Dublin City University, Dr. Saikumar Inguva (29) set about simplifying this process by developing a two-stage growth process that can generate crystalline zinc oxide cores and amorphous zinc oxide shells by means of laser ablation, without the need for a metal catalyst and without the need for a separate growth step for the shell region. These nanostructured architectures have applications in energy storage, solar cells and nanolasers. *The full thesis is at: doras.dcu.ie/21004*

RESIDUAL STRESSES IN SELECTIVE LASER MELTING

Selective laser melting produces thermally induced residual stresses that may cause component deformations or cracks. In his thesis, submitted as part of his doctoral work at the University of Leuven, Bey Vrancken (27) studied the effects of various process parameters on residual stresses, as well as the interactions resulting from the use of nine different materials. His work has led to the development of a set of guidelines for reducing residual stresses during the selective laser melting process.

The full thesis is at: lirias.kuleuven.be/handle/123456789/542751

IMPROVING EFFICIENCY IN STRUCTURAL STEEL WELDING

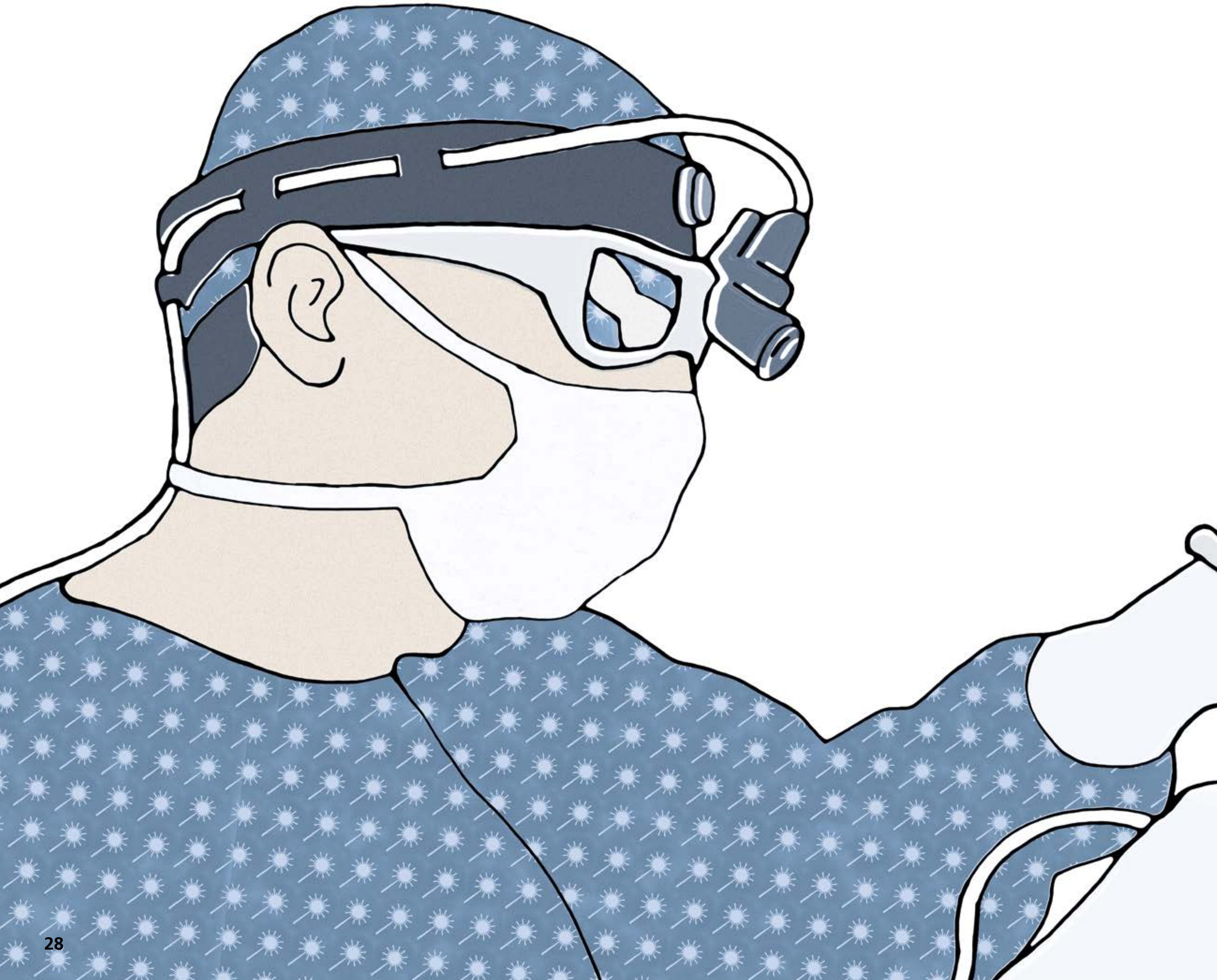
In his doctoral research at the Lappeenranta University of Technology in Finland, Mikhail Sokolov (29) investigated ways to improve the efficiency of thick sheet laser welding of structural steel. His research included looking at the effects of edge surface roughness as well as the effects of the air gap between the joining plates on the welding process.

The full thesis is at: doria.fi/handle/10024/113525

Private

MINIMALLY INVASIVE APPROACH

For a long time, laser therapy was too risky to use inside the body. If the fiber failed during the procedure, it would cause serious injury. Now, a little box in the beam path is offering a ray of hope for these applications.



Lasers already perform many useful functions in the field of medicine, acting as optical scalpels for surgeons and providing tools for correcting defective vision and treating skin conditions. Dentists use them, too, for example to pinpoint and remove tooth decay and clean periodontal pockets. In all these cases, the laser light is decoupled outside the body, so the only safety precaution required is some form of protection against burns and eye damage. “But it’s always been too risky to use a laser once you get under the skin,” says Stefan Hambücker. Part of the fiber that guides the light waves in minimally invasive procedures runs inside the patient’s body—and that’s exactly what makes it so dangerous. If the fiber were to fail due to breakage or overheating, the burning fiber or ‘fiber fuse’ could lead to an embolism. In the worst case scenario, the patient could die. “That’s why it was always too tricky to perform those kinds of procedures in the past—but now we’ve found the solution!” says Hambücker.

Precise sensor

Hambücker is a managing partner at Ingeneric GmbH, a company located in Aachen, Germany, which produces ultra-high-precision micro-optical systems. “There’s no way of eliminating the structural risk of fiber fuse or failure. So we decided to look for a kind of early warning system that would deactivate the laser within a matter of milliseconds if it detected any sign of imminent failure.” The clearest warning of fiber fuse or failure actually comes from the laser light itself. There is always a certain amount of back reflection within a fiber, but when a fiber starts to fail, the emission spectrum of the light changes. This change is minimal, but measurable, so the engineers decided to develop a highly sensitive and spectrally selective sensor as the centerpiece of their solution. The result was a small black box with two connection ports that, at first glance, does not look particularly remarkable. “The sensor is positioned between what is known as the proximal fiber—in other words the supply fiber to the body—and the distal fiber, the connection to the light source.” It measures both the incident light from the beam source and the outgoing light in the proximal fiber, and continuously transmits the results to the control software. This software also works continuously to check these measurements against the back reflections. If it detects a deviation, it switches the laser off within three milliseconds.

Telltale back reflection

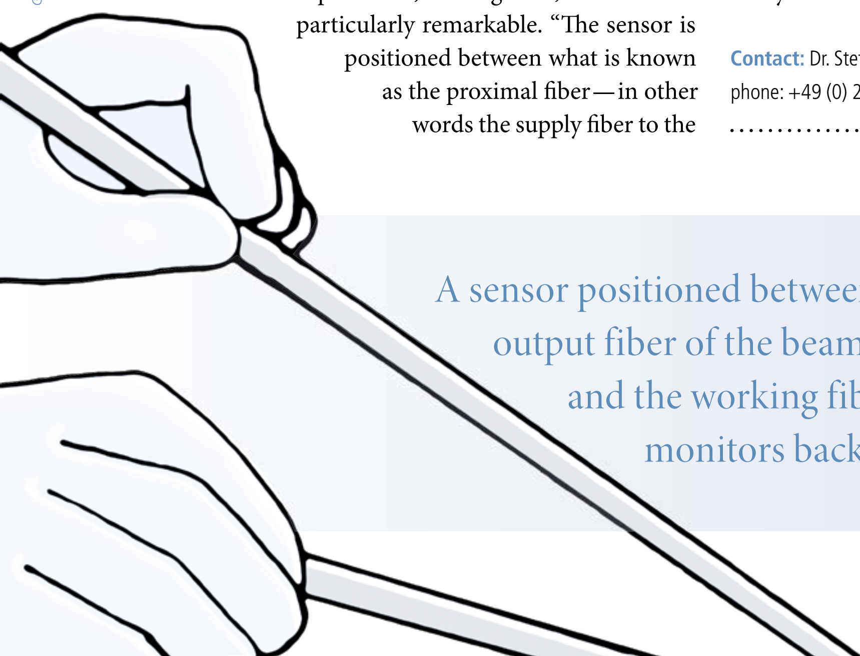
The most common time for a fiber to fail is when it is switched on and a tiny, existing area of damage suddenly gives way as the laser light passes through the fiber, Hambücker explains. “That’s why we added an additional safeguard in the form of a green pilot beam, which the control system sends through the fiber first. This beam is too weak to cause fiber failure, but strong enough to generate a telltale back reflection if an area is damaged or if the fiber is not properly connected and to prevent activation of the working laser.”

In principle this kind of safeguard could be incorporated into any medical laser system. To ensure perfectly reliable control of the process, however, Ingeneric has also developed the complete laser system for these kinds of applications, based on the principle that the greater the developers’ understanding and control of the beam source and light path—including its respective parameters—the more accurately they can calibrate the safety system. One example of a suitable beam source is a thermoelectrically cooled high-power diode laser. To ensure the laser beam doesn’t damage the catheter fiber, the power is increased slowly until it reaches its working level. Combined with the sensor, the system is also suitable for use in other medical applications. It can cater to a range of wavelengths, so there is no risk even when using polymer-clad fibers. As Hambücker puts it so succinctly: “The door to minimally invasive laser therapy is finally open!” ■

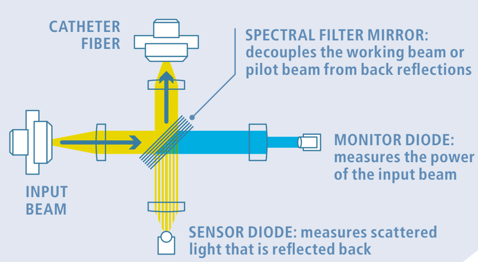
Contact: Dr. Stefan Hambücker,
phone: +49 (0) 241 963 – 1341, hambuecker@ingeneric.com

***Dr. Stefan Hambücker** is a managing partner at Ingeneric, a leading manufacturer of micro-optical systems and aspherical lenses. TRUMPF has been the parent company of Ingeneric since 2014.*

The spectrally selective sensor inside this little box opens the door to minimally invasive laser therapy.



A sensor positioned between the output fiber of the beam source and the working fiber monitors back reflections.



LPS Works conducts research for industrial firms and universities.

Small but in the know

Tokyo-based LPS Works develops new microprocessing methods for unusual materials. And as if that wasn't enough, the 18-strong knowledge cell can also take the next step of providing customers with the right machine for industrial mass production.

Benjamin Parks

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Small cars drive through the narrow lanes of the industrial park in Ōta — the southernmost of Tokyo's districts. This is where the process developer and integrator LPS Works is based, and from its office window you have a clear view across a narrow estuary to Tokyo's Haneda Airport, the world's fourth largest airport. A constant stream of aircraft land and take off on this man-made island, a bustling scene that is echoed inside the LPS Works building as well. A total of 18 engineers are busy in the company's laboratories, carrying out complex technical work on ceramics and new kinds of steel.

From research to mass production LPS Works is an investment of the successful machine part manufacturer Fujita Works. Masahito Terui, superintendent of sales, explains the concept behind their business: "Our company was founded in 2009 as a microprocessing knowledge cell. Nowadays many industries need materials to be processed on an ever-smaller scale with ever-increasing levels of precision. The semiconductor industry is just one example. Our job is to develop and accumulate the know-how they require to achieve that." LPS Works' customers cover a broad spectrum, ranging from universities and national research institutes to big and small companies based in diverse sectors of industry. They have a common need to incorporate tiny features or perform high-precision cutting and drilling work on a micrometer scale, and they are on a common quest to find someone who can develop a suitable technical process. "Since the beginning, we've mainly worked with ultrashort pulsed lasers. Much of the work we do is so complex that we have to develop or integrate the beam guidance system, optics and all the rest of the machine. So it makes perfect sense for our customers to purchase the machine from us after we've developed the whole process. This step-by-step process of carrying out the research, producing prototypes and selling the machine has now become the knowledge cell's most successful business model. Obviously that affects how the engineers approach each job: "Right from the start we're envisaging how it will work on an industrial scale, so it's no good just finding a solution for the actual processing. Whatever we develop has to work fast, and you need to know exactly how it will be integrated into the customer's production environment."

Cutting-edge steel One example is an automaker that contacted LPS Works in 2013 hoping to find a way of structuring a new kind of ultra-high-strength C steel, known as a carbonized UHSS (Ultra High-Strength Steel). The company had already made unsuccessful attempts using milling machines and UV lasers, so the Tokyo-based engineers decided to develop a USP laser process. Today the machine is up and running on the production line, where it is used to structure a fine die surface of ultra-hard auto parts.

Another industry that relies on LPS Works when the going gets tough is the semiconductor industry. "For example, we developed a technique for drilling ultra-small holes with a diameter of just 30 micrometers in ceramic plates. The application called for the distance between the holes to be just 100 micrometer, which was extremely challenging." LPS Works built a special trepanning optics system that angles the beam generated by the ultrashort laser pulses and rotates it around a wobble point. This corrects the taper angle, enabling the engineers to give the tiny holes an edge angle of exactly 90 degrees. But that was only part of the story, says Terui: "The hardest part was reaching the tremendously high speed the customer needed along with the enormous precision: only a few seconds per hole." These rapid movements generate frictional heat at the axes, and the material expands more and more. "In reality of course it expands very little, but on the scale we're talking about it's enough to create significant inaccuracy. So we had to find a way of keeping the temperature constant everywhere throughout the entire process," says Terui, and then pauses. "Unfortunately I can't reveal how we did it, but it really is tremendously exciting!" he says, laughing. ■

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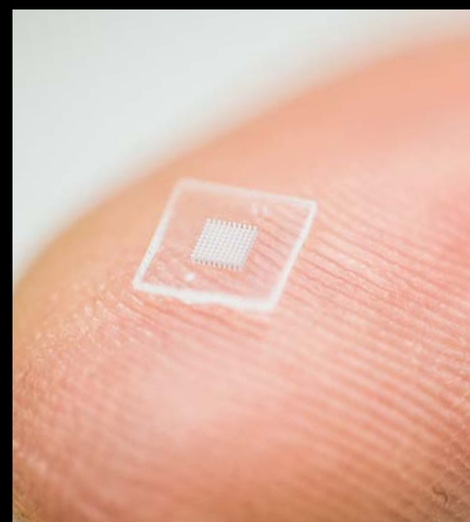
The team of engineers discuss the next application for ultrashort pulsed lasers.



Masahito Terui sees the company as a developer and knowledge gatherer.

"You can't just come up with some random machining solution. It should also always be suitable for mass production."

Masahito Terui

Left: Barely visible to the human eye, tiny surface structures and holes are the core business of LPS Works.

This seemingly unremarkable door (top) is the entrance to one of Japan's best and most successful material processing laboratories (bottom).

Benjamin Parks

Forever Troy

HOW LASERS ARE MAKING US VIRTUALLY IMMORTAL

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

Eternal life is a dream that people have long shared. Even Achilles and Hector—the heroes of Homer's Iliad and the Trojan War—envied the gods' immortality. The reason we know that is because someone took the trouble to transfer those texts and information to the various new media that emerged over the centuries: first papyrus, then parchment, then paper. Nowadays, of course, we have digital copies of the Iliad on CD, DVD and hard drives, so this knowledge is safely stored. But for how long? "Nothing Lasts Forever" sang the English rock band Echo & the Bunnymen in 1997. This phrase often refers to the transience of life, but it applies equally well to the dilemma facing data and texts: the data storage media we use nowadays are not particularly robust and have a short lifespan. They really don't last forever. And if one day the Earth ceases to exist, there will be no memories of the world we used to inhabit. Everything we have created, from epic poems to rock music and magazine columns, will be forgotten, no more than stardust flying through the universe. Unless Superman can come to the rescue of course! Perhaps you can picture Superman standing in his Fortress of Solitude, holding the solution to our immortality complex in his hands: a transparent crystal. Stored in this crystal is the entire knowledge of the civilization that was lost when his home planet of Krypton was destroyed. A crystal was the perfect choice to suggest purity, incalculable value, mysticism and an aura of eternity. So it's hardly surprising that crystals appear in so many sci-fi and non-fiction books. What may come as a surprise is that crystals really are the data storage medium of the future! Ultrashort pulsed lasers are now capable of writing huge quantities of densely packed optical data onto small crystal discs. It is estimated that these glass discs, which can withstand extreme temperatures, can store data for 13.8 billion (!) years without degrading.

So Achilles can breathe a sigh of relief: it seems we will still be able to captivate our ancestors with tales of his victory over Hector, the Trojan prince, for many centuries after the destruction of our Earth, assuming we have found a different planet to live on by then. And ultimately even Echo & the Bunnymen might have to admit that something does last forever after all. All thanks to lasers. ■

The White Album, Lord of the Rings or Breaking Bad—which data would you want to save for all eternity? Let me know by email: athanassios.kaliudis@de.trumpf.com

Making the data cristal work: www.laser-community.com/en/6473

Gernot Walter

Where's the laser?

In data privacy systems: It seems the days of transferring information securely over the Internet may be numbered. Professional data snoopers are currently working on quantum computers that will enable them to crack any code they capture in the blink of an eye. Even the popular RSA cryptosystem based on prime numbers would be defenseless. Everything would be exposed, from bank accounts and medical records to trade secrets. Cryptography experts all over the world are preparing to face that moment. They are pinning their hopes on quanta or, more accurately speaking, on photons. Their idea is to use a laser beam to ensure that the RSA encryption key cannot be captured in the first place. The fact is that nobody can tap into an optical signal without interfering with the transmission. If the system detected an eavesdropper, it could break off the transmission and switch to a new key. The first research satellite designed to facilitate this form of communication over long distances was launched in August 2016.

iStockphoto/scubaluna

Glug!

A robot-guided beam from a disk laser cuts through five-centimeter-thick steel underwater. At a rate of 60 centimeters a minute, it works 20 times faster than the best commercial diver. The technique was developed by the Laser Zentrum Hannover, primarily to perform work on steel sheet pile walls, bridges and offshore wind farms. Equipped with a laser, the robot divers are also designed for use in dismantling decommissioned nuclear power plants — because cooling ponds contaminated with radioactivity are no place for human divers.