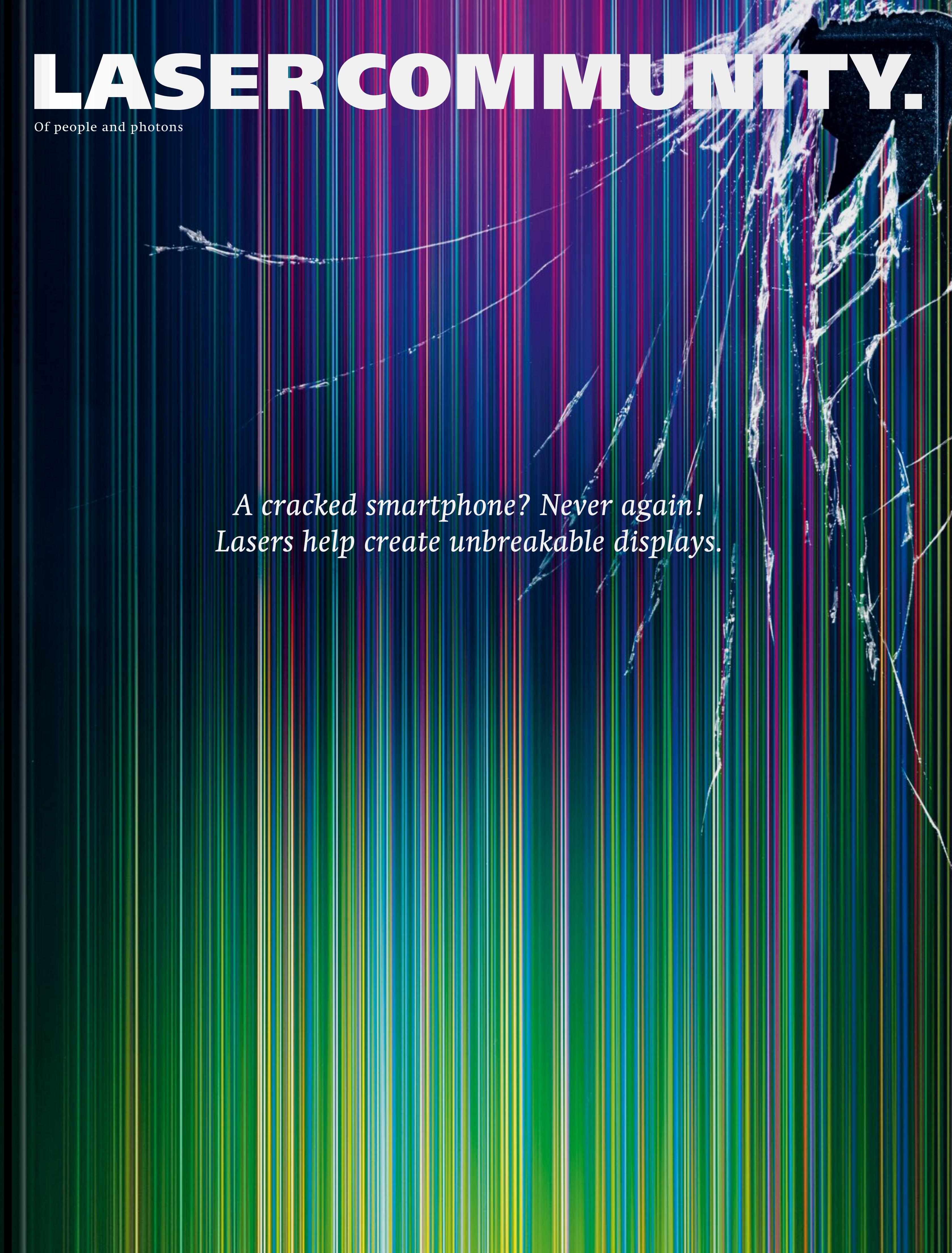
LASER COMMUNITY.

Of people and photons



A cracked smartphone? Never again!
Lasers help create unbreakable displays.

LASER COMMUNITY. *#34*

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Gernot Walter

Sometimes they just turn up, but often they announce their coming!

As a student of particle physics at the University of Siegen in the late 1980s, my fellow students and I still used the federal mail to swap diagrams, formulas and calculations with the relevant institutions! On one occasion, I even copied a diagram from the monitor onto paper, because I had to show it quickly to my professor. Don't forget: there was no internet! But then Tim Berners-Lee came along. It was his development of the http protocol in 1989 that laid the foundations for the World Wide Web. All at once, we were able to send measurement data electronically and even chat with faraway colleagues. Was it a revolution? No, it was a disruption! And today? A world without the internet is inconceivable. Today, everything is a mere click away—thank goodness! What makes this disruption even more special is the fact that it was a genuine gift to the world. Neither Berners-Lee nor his then employer—CERN—has ever demanded anything in return.

Photonics also possesses an incredibly disruptive power. In this issue, we take a look at the world of glass processing, where TRUMPF has developed a laser process that renders smartphone displays unbreakable even when dropped—something that has befallen me twice! The idea behind this new laser process is not only extremely promising—it is also, and above all, disruptive. It involves focusing the laser beam and also modifying it in such a way as to produce a string of focal points along the direction of propagation. In other words, we stretch the focal point lengthwise, which then enables us to cleave special types of glass in an elegant manner.

At TRUMPF, the laser itself was responsible for one of the greatest disruptions in company history. That was when it displaced the nibbling machine, which was a pet project of ours for many years. For a lot of people, this came as a huge surprise. Back then, barely anyone thought you could cut sheet metal with a laser. As it was, it completely supplanted the existing technology. A perfect example of disruption.

Often, however, disruption only reveals itself over the course of several years. All this time, it is right in front of us, only we never realize—perhaps because we don't have the right antenna. With regard to the laser, once we had realized it would cut sheet metal, it never really occurred to us that it might be better to use a solid-state laser instead of a gas one. And that's although we were well aware of the advantages of the solid-state laser—they were right in front of us almost every day. But somehow, we couldn't see them: we were too fixated on the gas laser. Ultimately, however, we did recognize what had been in front of us all that time. Today, solid-state lasers dominate cutting applications.

In other words, disruption can sometimes take us by surprise, but it often warns us in advance. We just have to be always on the lookout.

DR.-ING. CHRISTIAN SCHMITZ

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Member of the Managing Board of TRUMPF SE + Co. KG
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Easy!

We asked illustrator and automobile expert Timo Müller to draw something on the latest sensor trends in laser machining. Timo's creation—an e-car cruising leisurely toward the sunset—depicts the easy usability of today's generation of sensor systems, on **page 10.**

Banzai!

During our interview, Masahiro Tsukamoto suddenly stood up, strode to the closet, and put on a green cloak—a reference to a manga superhero called "Fullmetal Alchemist." Before settling down with the first volume, you might like to read our feature on **page 8**.

Ahoy!

Luckily, the editorial team has strong links to the model-building scene, made up of nothing less than family men! Mario Bauer, for example, spent his winter evenings creating a container ship, enabling us to illustrate a new 3D-printing technology on **page 6**.

Amani Hussein, Gernot Walter, Timo Müller

LASER COMMUNITY.

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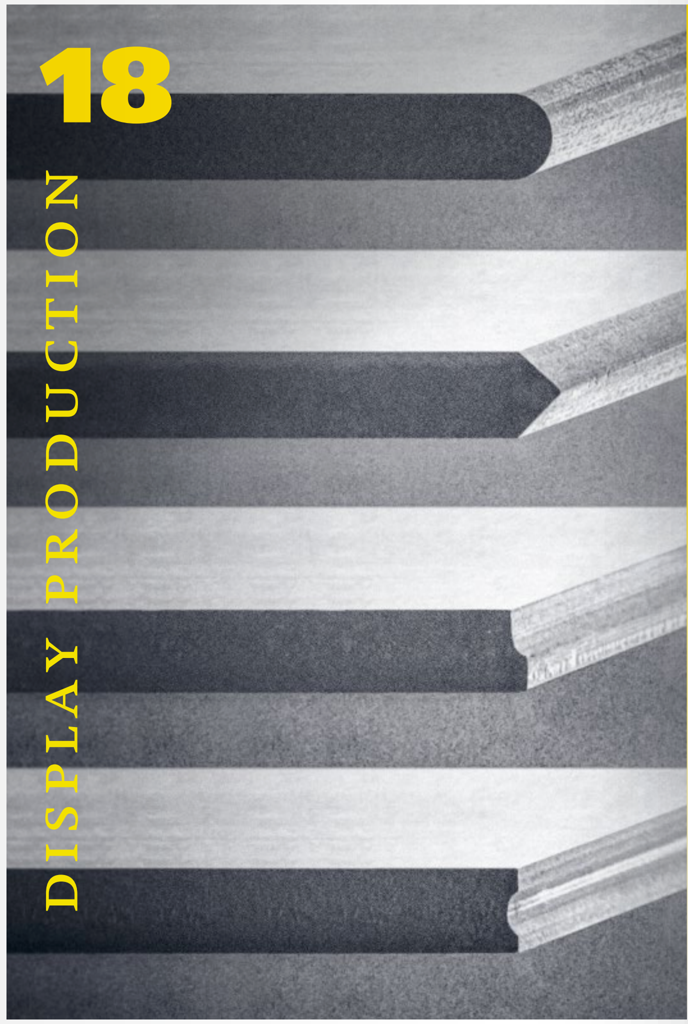

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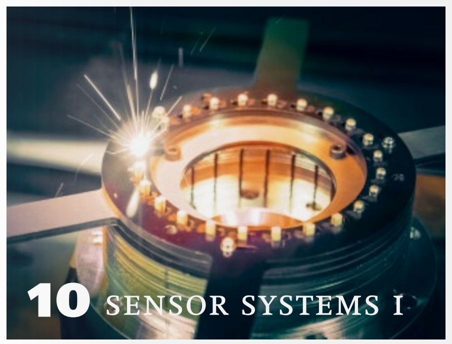

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POWER

Tools for injection-molded parts can now be printed by the container load.

HOT AND READY

Preheating to 500 Celsius and a new machine concept now mean that carbon steel alloys can be used in additive manufacturing.

Injection molding core made of H11 steel: crack-free, 99.9% density and highly polishable. Thanks to its internal cooling channels, the cooling performance is comparable to that of copper cores, but with a much longer service life.

As additive manufacturing continues to boom, a dream has come true for many industries: the ability to produce any shapes to a high quality and at the first attempt—i.e., right the first time. Tool- and die-making could benefit even more massively from this technology—using it, for example, to manufacture tools with internal, flow-optimized cooling channels. The problem is that this sector traditionally works with carbon steels of the type H11 and H13. In an unhardened state, these materials are great for machining and polishing. Unfortunately, the short cooling times during additive manufacturing can cause these steels to partly solidify in an already hardened state. As a result, residual stresses lead to cracking in the hardened steel.

Yet there is a way to use carbon steels in additive manufacturing: simply preheat the substrate plate to a temperature of 500 Celsius. As a result, the component cools down more slowly, and there is less residual stress. Although this method is well known, it is not used in practice. Instead, manufacturers stick to the traditional temperature of 200 Celsius. There are also good reasons for this: lengthy cooling times of up to 20 hours per part (meaning lengthy machine downtimes) and also problems with powder recycling as a result of greater oxidation (meaning high powder costs). Besides, for temperatures above 300 Celsius, more than one temperature controller is required. The answers is, therefore, a new machine concept that exploits the benefits of working at a higher temperature while eliminating its drawbacks. And this is exactly what engineers at TRUMPF have now achieved with the TruPrint 5000.

This machine is fitted with a quick-change build cylinder. As soon as the component is finished, the build cylinder is removed along with the component inside. This component can then be left to cool for as long as required, while the machine—now fitted with a new build cylinder—is already busy producing the next component. As for the problem with powder recycling: before the process begins, the chamber and cylinder are flooded with argon, which minimizes moisture and oxygen content. As a result, powder oxidation is no more of a problem at 500 than it is at 200 Celsius, and powder recyclability remains the same.

Good news, therefore, for friends of carbon steel alloys: long and gentle cooling prevents residual stress cracks in the steel. At the same time, all the desirable properties remain: the 3D-printed parts are as strong as conventionally manufactured ones and can be polished and hardened just as effectively. In other words, tool- and diemakers can now profit from the full potential of additive manufacturing—while we focus on the next challenge!

Gernot Walter, TRUMPF

GLORY

WELL AGED

It was 25 years ago that additive manufacturing with metal was invented.

Back in 1996, three researchers at the Fraunhofer Institute for Laser Technology ILT asked themselves: "Well, are we going to go for it?" Their answer was: "Yes, let's go for it!" Although experts scoffed at their idea, they went ahead and patented their idea for 3D metal printing.

In addition to ingenuity and perseverance, Wilhelm Meiners, Kurt Wissenbach and Andres Gasser also required one other quality to develop this technology: faith in their own idea. Initially, the response to their project was not encouraging. Meiners, now a specialist in additive manufacturing at TRUMPF, recalls the mood: "All the experts back then said it would never work. Apart from us, nobody believed anything would come of it."

In their first working prototype, a scraper tool was used to apply a metal powder, layer by layer. A laser beam then traversed this powder bed, following a predetermined path. Their basic idea of additively manufacturing metal components, layer by layer, has turned a lot of conventional wisdom on its head. For example, it changes the way in which production costs are calculated: complex shapes can now be made at virtually no extra cost—the actual cost depends merely on the volume of the material. And despite being known as 3D printing, the really clever thing about this layer-by-layer technique is that it reduces three-dimensional manufacturing to two dimensions. This opens up a whole new design world: integrated lattices, bionic shapes, internal channels. As a result, metal parts are no longer confined by the requirements of casting, machining and forming. Instead, they become what they should always have been: purely functional shapes.

From the outset, the inventors developed 3D printing for materials actually used in concrete applications, such as cobalt-chromium alloys for dental implants. Medical engineering was one of the first sectors to make substantial use of 3D printing. Others soon followed, including aerospace. Today, additive manufacturing is finding its way into every corner of industry, generating estimated revenues of 2 billion euros in 2019. Back in 1996, this would have been little more than a pipe dream. "If we really wanted to finish a workpiece, we had to stay on in the evening and make sure the scraper didn't get stuck!" Meiners recalls. "It was all pretty hairy. But it worked."

Once laughed at, now laughing themselves: Wilhelm Meiners, Kurt Wissenbach and Andres Gasser, inventors of metal 3D printing, pictured behind the trolley for the first 3D metal printer.

Fraunhofer ILT, Aachen

AHEAD

"RIGHT NOW, THE GREEN LASER IS MAKING THE RUNNING"

Japanese industry needs a laser to work with copper. For Prof. Masahiro Tsukamoto, blue diodes once showed the most promise, but now green is also coming to the fore.

Blue or green? Masahiro Tsukamoto has a cloak in each color.

Professor Tsukamoto, I've heard you possess superhuman powers.

As long as I can get my hands on a laser, I do! *(Laughing)* It's true, my nickname is the "Blue Alchemist." The name comes from a manga superhero called "Fullmetal Alchemist," which is big here in Japan.

Really?

Really! It all goes back to a rather unusual promotion campaign at my university. Our director thought it would be a great idea to show the general public what kind of research we do at my institute. So he arranged for me to give a lecture in a subway station. There I was, on a cold March evening, in the middle of rush hour, standing on a small stage, on the subway platform, telling commuters about my work. It was all supposed to be as colorful and as dynamic as possible, so I wore a blue cloak and said I was like the "Fullmetal Alchemist." After that, the name stuck!

For our interview you're wearing a green cloak, not a blue one!

That's right. It's a new cloak, and it's green, just like the laser in my lab. The reason we have a green laser at the institute is because we're investigating how best to work nonferrous metals such as copper—i.e., how to join and weld them, and how to use them in additive manufacturing. In the past, we've been using blue laser diodes as a beam source, which is great for copper. Hence the nickname "Blue Alchemist." But now I think that a green laser might also be very good for working with nonferrous metals.

Why's that?

Three reasons. Firstly, the blue laser is still at the developmental stage. It's already giving us promising results, and we're on the right track. But the green laser is more advanced, and it's already at a stage where it could be used in industry. Secondly, of course, a green laser has a different wavelength to that of a blue laser. Both are good for joining nonferrous metals such as copper. But we also need to look closely at the precise influence of the wavelength and where there are differences. For this, we use a special X-ray system that enables us to observe the processes in the weld keyhole. And, lastly, we have to think of the customer.

What does the customer say?

We don't know yet. We're going to involve customers in testing so that they can get a feel for both types of laser. If, in the end, they say, "All we need is a stable system—we don't care if it's green or blue," then, for sure, we'll ask ourselves whether it makes sense to continue working on the blue laser, or whether to step up research with the green one.

What are you hoping to achieve with your work?

We want to advance laser technology here in Japan. This means, for example, pooling the expertise of two major Japanese companies: a laser diode manufacturer and a system integrator. In fact, this has led to collaborations that probably wouldn't have happened without our involvement. Unlike in Germany or the U.S., there are no government programs or initiatives for this kind of thing in Japan. But I believe it's vital that different companies should collaborate with the universities.

Why is that?

Japan is a high-tech country, but the world around us is changing fast. With the rise of new applications in fields such as e-mobility, we're having to find ways of processing new materials. For Japanese companies to remain at the forefront of new technology, we need smart ideas for tomorrow's world. My work is all about finding these ideas. And I know that blue or green lasers can help us achieve this.

Hand on heart: blue or green?

It's not our decision which laser will ultimately get the nod—nor that of the laser manufacturers. It's up to industry. Our job is to show companies all the things they can do with laser technology. And when I say show them, I mean that literally. We manufacture components and take them out to companies so that they can see them and touch them. Right now, the green laser is making the running. We'll see if the blue one can catch up. But maybe a hybrid system will turn out to be the best solution. ■

THE INSTITUTE

The Joining and Welding Research Institute of Osaka University in Japan develops laser systems for additive manufacturing (LMD) and for welding copper. In the past, this work has centered on blue diodes. Now, however, tests with a green laser from TRUMPF are about to start.

THE MISSION

Professor Masahiro Tsukamoto and the Joining and Welding Research Institute have a shared goal: to introduce new and efficient manufacturing technologies into Japanese industry. They see themselves as partners and enablers to Japan's corporate world.

THE APPLICATION

In addition to welding components, Prof. Tsukamoto's work involves coating stainless-steel parts with copper. On door handles, for example, a copper coating will kill any pathogens within a short space of time.

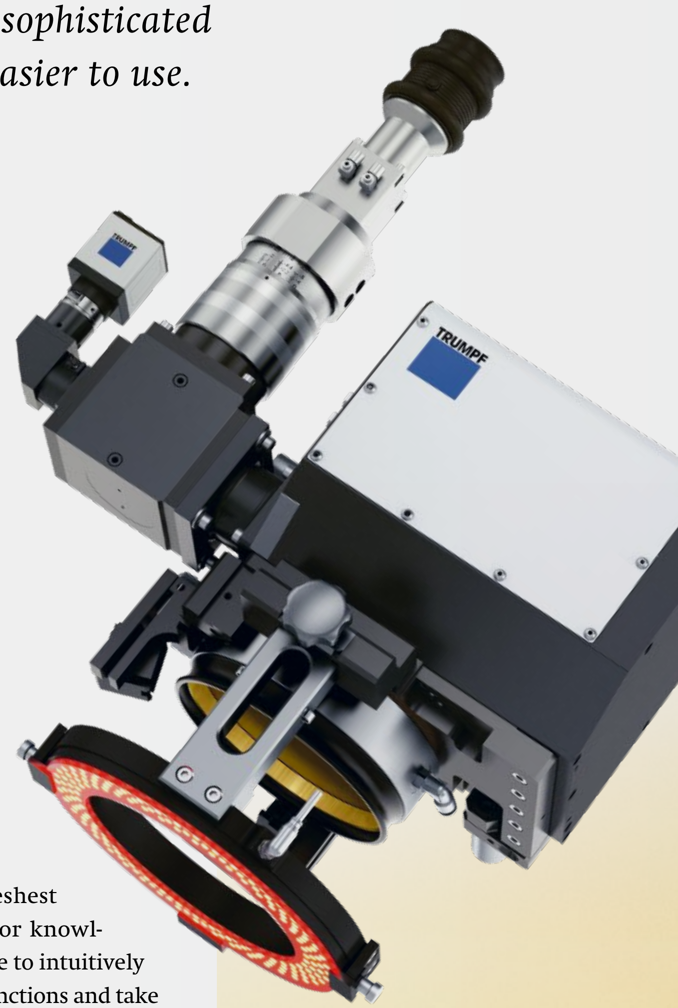
Timo Müller

NICE & EASY

HOW THE BOOM IN E-CARS IS DRIVING THE DEVELOPMENT OF SENSOR TECHNOLOGY FOR LASER PROCESSING.

TRUMPF

Those with an interest in the ongoing automation of the manufacturing industry will be pleased about the recent boom in electromobility. This is leading to new advances in the sensor technology used for laser processing. The result is a new generation of increasingly sophisticated sensor systems that are becoming easier and easier to use. There are three key trends:



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User-friendly operation

The pace with which the automotive industry is currently ramping up for the mass production of e-cars has led to a rash of new plants worldwide, all fitted with high-end technology and preparing to upscale output as fast as they can. In many instances, these plants are having to rely on freshly hired labor—new employees confronted with a vast array of different systems for controlling production machinery. Slowly but surely, this is also having an impact on the design of operator interfaces used in industry. Yet there is more at stake here than merely getting rid of annoying complexity: easy-to-operate production machinery creates a real competitive advantage. In fact, simplicity offers something for everyone. It is what first gives rise to a lot of new technologies; and it eliminates errors and cuts down on training requirements.

People who use industrial interfaces are a broad bunch—diverse in their interests and prior experience, in the work they do, and in the training they have received. They include lab engineers, plant operators and plant supervisors, to name but a few. But each of them needs to be able to properly operate the equipment required to perform their job. The humble smartphone shows that this is a realistic target. And it is precisely this form of menu navigation that TRUMPF has chosen as its paradigm.

EASY IS BEST Even the freshest of first-time users with no prior knowledge—a young child, say—is able to intuitively understand basic smartphone functions and take a photo, for example, or make a call. It's all but impossible not to get it right. Sadly, it's a different story for those operating the systems used in laser processing. As a rule, the menu navigation does little to explain itself. At best, it will refer you to the user manual. It also lacks reminders designed to prevent operating errors ("Do you really want to …?"). And if the user wants to set up a new position, they have to think through the entire process all on their own.

It was with this in mind that TRUMPF develops designed the interface for the VisionLine positioning sensor. This features a basic vertical wizard to provide step-by-step support with the setup of new jobs. It also incorporates a clearly structured horizontal menu with details. It is impossible to forget a single step. And, at the end, the whole setup is automatically saved under a self-explanatory name. Even those with no knowledge of image processing can achieve results quickly and easily with the VisionLine interface.

ACCESSIBLE

NAME: VisionLine

JOB: Camera-based image processing // determines position of component // adjusts a welding or marking laser accordingly

PIONEERING FEATURE: Genuinely intuitive user interface

Automatic sensor setup

The next time someone asks you why you are using these particular sensor parameters, ask them a question in return: Why does the peacock fan its tail? It's because of evolution.

The quest to determine the right parameters involves a mixture of thought, experience, and plain trial and error. Yet as soon as there are more than three or four values in play, this method reaches its limits. This is when we find ourselves in an asymmetric, multidimensional parameter space. In particular, the manufacturing processes used in the e-mobility sector require sensors that can handle this type of complex measurement task—and that can be easily set up to do so.

IN NEED OF A GREEN "A" Take the example of image adjustment for the OCT sensors that are used to monitor hairpin welds on stators or are installed in control units. There are several ways in which image problems can occur with OCT sensors: contours can become interrupted, multiple reflections disturb the image, or lines fade or simply disappear. The result is that the image is not good enough to enable a satisfactory measurement. In turn, this means that the evaluation software is unable to determine whether a weld seam is in the right position or of an adequate quality. So how do you produce a clear image? Similar to a good-quality SLR camera, the OCT sensor has parameters that can be set manually: exposure time, thresholds, frequencies, scaling factors, reference values and so on. All in all, there are 22 parameters with, in some cases, hundreds of gradations. Somewhere within this 22-dimensional space, there is a point at which all the various OCT parameters are perfectly set for the current component position. But where is it? SLR cameras have a green "A" setting for this situation—i.e., an automatic setting that reliably produces good results.

TRUMPF has adopted the same approach and, with the help of a so-called evolutionary algorithm, created a green "A" setting for the OCT sensor. This does, on a much smaller scale, what nature has been doing since the beginning of life. Nature lets individuals compete with one another, procreate, and mutate randomly, watching all the time to see what happens. After millions of years of evolution, this produces, for example, a peacock. Fortunately, in the case of the OCT algorithm, this all takes much less time—namely 15 seconds.

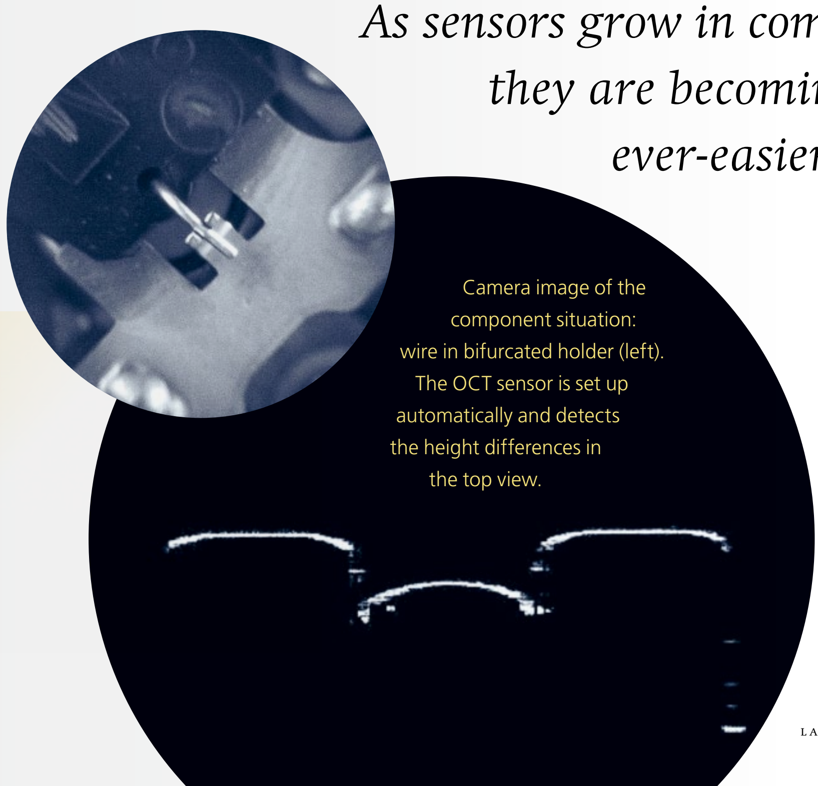
{2}

THE FIGHT FOR SURVIVAL Each random set of 22 OCT image parameters constitutes an individual. On the basis of this parameter set, an image is then produced. This is checked by an evaluation program developed by TRUMPF, which determines how well the parameter set has "survived" in its natural habitat. The next random set of parameters enters the arena, and so on. The fittest among the parameter sets produce offspring and hand on a mix of their respective advantages to the next generation. And then the evolutionary game begins again, over many generations. Were it to continue in this way, however, this would result in more and more extreme and thus error-prone offspring; i.e., the parameter values would tend toward local minima and end up in an evolutionary impasse. Every now and again, the algorithm therefore lets them randomly mutate, within certain limits. This reinvigorates the evolutionary process and brings fresh combinatory possibilities into the mix.

In the end, it produces a combination of parameters that no human being would ever have devised—in some cases, with values defined to several decimal places. The operator using the OCT sensor remains unaware of the struggle for survival—the competition, procreation and mutation—among all the individual parameter sets. For the operator, it's merely a click of a button and a 15-second wait until the evolutionary process is complete and the system delivers the optimal camera setting for the current component position.

Moreover, this really is the optimal setting. With an SLR camera, the green "A" is there to help amateur photographers take good pictures. A professional, on the other hand, would prefer to adjust the settings manually. In the case of the OCT sensor, this is different. Here, the evolutionary algorithm regularly outperforms the professionals—all at the mere click of a mouse.

As sensors grow in complexity, they are becoming ever-easier to use.



Camera image of the component situation: wire in bifurcated holder (left). The OCT sensor is set up automatically and detects the height differences in the top view.

HELPFUL

NAME: OCT sensor

JOB: Monitors and adjusts weld seams in 3D scanner welding // detects from above whether parts to be joined are flush during, for example, hairpin welding

PIONEERING FEATURE: Uses evolutionary AI to calibrate its own camera

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AUTONOMOUS

NAME: Online seam control

JOB: Non-contact monitoring of joint gaps // regulates the seam position during laser welding, e.g., for hairpin welds

PIONEERING FEATURE: Knows when good is good enough // helps avoid unnecessary rejects

The sensor steers a course between a failure to detect rejects and an excessive need for post-processing.

{3}

Autonomous parameterization

Electric-car manufacturers currently face a dilemma: laser welding is often used only at the very end of a process, when most of the value has already been added to a component—the battery, for example, or the stator. In other words, a mistake at this stage, meaning that the component is rejected, can be very costly. On the other hand, there's nothing worse than overly responsive sensor continually reporting an error—"Beep! Please eject and rework!"—just because one in a hundred joint gaps is not absolutely perfect. Given the production volumes in the e-car industry, a post-processing rate of even one percent would bring the process to a standstill. In such a situation, it can help to step back and take a deep breath. After all, in manufacturing, as in everyday life, being a perfectionist can hold you back. Sometimes, "good enough" really is good enough.

This is a lesson that TRUMPF has taken to heart. Sensor systems such as VisionLine or SeamLine Pro serve to monitor a range of component properties, such as joint gaps, and adjust the system parameters accordingly. This helps production managers steer a course between a failure to detect rejects and an excessive need for post-processing. The latest trend in sensor technology is active process logic (APL). This is what can turn an apparent reject into a well-finished component.

GOOD ENOUGH APL functions according to the principle of open-loop control. For a component requiring, say, 200 welds, the sensor measures the joint gap before each spot weld. If necessary, the sensor system adjusts the weld at this particular point according to the measurement result. Should the sensor detect, for example, improper alignment—either horizontally or vertically—between two copper rods that are to be welded together, it adjusts the laser system, modifying laser energy, reducing speed, ordering two extra passes or a different pattern, and so on.

Whether for standard or unusual welds, users can lab test which strategy leads to a "good enough" result. These values are then logged in a table, which the sensor software consults during each measurement in order to extract the benchmark value.

This upstream quality assurance based on APL has become standard practice in the electric-car industry, where it has helped eliminate rejects and dramatically increase output. As with the two trends above (user-friendly operation and automatic sensor setup), other industries are now discovering that this new technology can help them close productivity gaps. ■

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Tobias Gerber | Fotogloria

REINVENTING THE WHEEL

A laser sensor to measure speed and position in any kind of production process? No problem. Apart from the price, that is. Heiko Krebs from Sick AG refused to bow to conventional wisdom—and was ultimately proved right.

Heiko Krebs leans back and floats a question: “What would be even better than a high-tech non-contact sensor? Easy: a high-tech non-contact sensor that’s low cost! But is that even possible?” Krebs is senior vice president for product management at Sick, a sensor specialist in Donaueschingen in southern Germany. His work revolves around small measuring wheels that roll along on surfaces and measure the speed or dimensions of passing workpieces. Anyone with an interest in sensor technology for industrial systems can call Krebs. He has customers from every corner of industry. What they all share is a desire to automate production and process equipment. What they all need is a steady stream of real and reliable production data for plant control and quality assurance. Data that answer questions of the following type: Are all sheet metal/polystyrene/packaging materials properly cut to length and width? How quickly, in what position and at what intervals are they traveling along conveyors? Hundreds of thousands—if not millions—of measuring wheels are used for this purpose. Measuring-wheel encoders count the number of revolutions and, on this basis, calculate the speed and position of passing items. Naturally, there have long been non-contact sensor systems that use a laser to scan items and thereby generate the same information. But they are technically sophisticated and therefore expensive. Furthermore, they require the use of a class 3 laser, which means the installation of safety equipment and a need for specially trained personnel—in other words, no end of bother for the plant operator. And all this, despite the fact that there is already a perfectly workable solution for most areas—namely, the aforementioned measuring-wheel encoders.

WHY REINVENT THE WHEEL? Not only do measuring wheels work exceptionally well, they are also inexpensive. In other words, Krebs could have left it at that. Nonetheless, it would still be great to be able to get precise measurements without any contact between sensor and object. Just a mere exchange of photons is all that would be required—nothing more.

Krebs hesitates: “Measuring-wheel encoders definitely have a place on the market. They’re reliable, and they’re cheap. But they also have their drawbacks.” And it was this that made him realize, some ten years ago, that the last word had not yet been spoken.

There are two sides to every question. And the downside of the measuring wheels is the need for contact. Very often, this is not a problem; on occasion, however, it is. The wheels can leave unwelcome grooves in soft materials such as film or foil. Or they can lose their grip on polystyrene or insulating materials, which leads to slippage and therefore to inaccurate measurements. Contact also leads to wear. Over time, abrasion alters the diameter of the measuring wheel and thereby its accuracy: all the things that a laser-based non-contact sensor would, by its very nature, prevent. “Everyone said they were too expensive, and that there wasn’t sufficient demand,” Krebs recalls. “But we knew better.”

LIKE A COMPUTER MOUSE Krebs began looking for people to whom he could present his vision for a low-cost laser encoder, people who might give him useful tips. This led to a meeting with Ralph Gudde from Eindhoven. Back then, Gudde was working for Philips, in the Photonics Division. This became part of the TRUMPF Group in 2019 and now operates as an independent company under the name of TRUMPF Photonic Components, where Gudde is vice president for marketing and sales. The company manufactures tiny, easy-fit laser diodes and photodiodes for use in consumer products such as smartphones, office printers and computer mice: a mass product, where price is king. Gudde showed Krebs a small VCSEL with an integrated photodiode, along with a lens and circuitry, which was approaching market release. In a flash, Krebs realized that this would sidestep the safety problem of the class 3 laser. After all, nobody needs special training in order to use a computer mouse.

The question was whether a laser diode would do the job. Gudde thought it would—provided the measurements were made in a different way to what was then standard practice. Instead of measuring the distance traveled, his idea was to measure the interference of the laser light waves—a self-mixing interference (SMI) measurement. Here, a VCSEL shines an infrared laser beam onto the surface of a passing item—be it of metal, plastic or any other material. An optical resonator captures the reflection of the laser beam and mixes it with light in the resonator. A photodiode then measures the resulting interference, thereby enabling the system to calculate the speed of movement on the basis of the difference in frequency. In turn, the direction of movement can be inferred from the modulation of the wavelength. In other words, the sensor detects the speed and direction of the item directly and its position and extension indirectly.

EQUIPPED WITH A CLASS 1 LASER, THIS SENSOR IS NO MORE DANGEROUS THAN A COMPUTER MOUSE.

Tobias Gerber | Fotogloria

Suddenly, customers began contacting Heiko Krebs with new and once impossible requests, such as measuring plastics still hot from the extruder. No problem for the non-contact laser.

For this purpose, it requires light but very little power. Indeed, a harmless class 1 laser is perfectly adequate for this purpose. Krebs returned from the meeting with a spring in his step.

Tobias Gerber | Fotogloria

GETTING A GRIP ON SOFT ITEMS Development began soon after. “Together, we came up with a process algorithm that evaluates signal quality quickly and extremely precisely,” Krebs explains. “Even at speeds of ten meters per second, we still have a resolution of four micrometers and a measurement accuracy of 0.1 percent. That means we’re able to measure a length of one meter to an accuracy of one millimeter. And that’s for a price that is substantially closer to low-cost contact solutions than anything else on the market right now.” Good news, in other words, for customers who would like to swap their measuring-wheel encoders for more-accurate laser sensors. All of a sudden, Krebs started hearing from customers who had never been able to obtain precise data with conventional technology. This included plastic manufacturers, whose products, fresh from the extruder, are too soft for the measuring wheels to grip. Or cable manufacturers who had always had issues with the accuracy of measuring wheels. “We had a lot of requests for applications that we hadn’t even thought of before,” says Krebs with a smile. “Now all of these customers can measure items that weren’t covered by conventional sensor technology. And, best of all, this non-contact process can be adapted very easily to specific requirements. All you need to do is modify the software. So not only do we reach more customers, but we can also provide them with something tailored much more closely to their needs.” With a contented look, he balances the Speetec, a laser encoder the size of a chocolate bar, in the palm of his hand. “It’s just so cheap and so versatile!”

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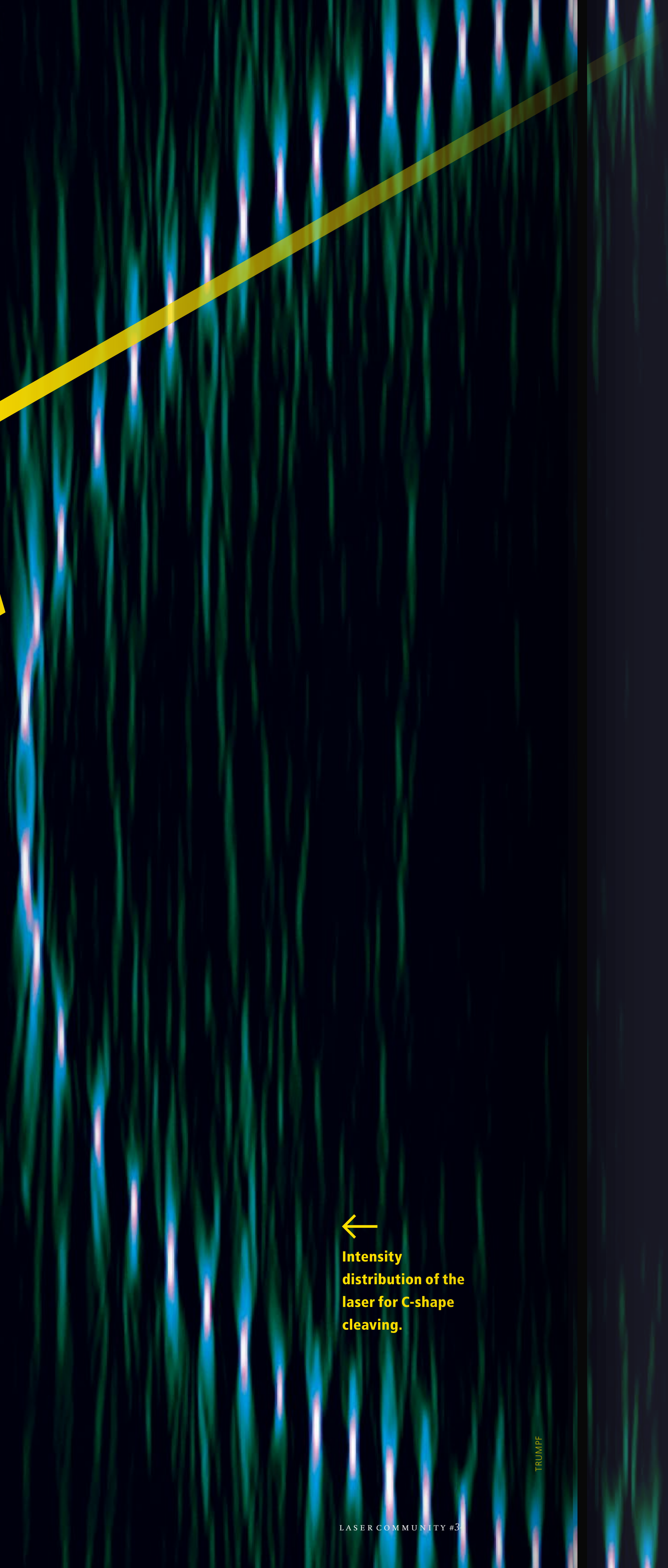
GIVE ME A C!

"Disruption" is a word that trips lightly off the tongue. In this case, however, we really have achieved something disruptive: holographic splitting is a technique that has enabled the creation of perfectly rounded, C-shaped glass edges. In one fell swoop, it has rendered obsolete all previous glass-cleaving processes. For display manufacturers, it's a real boon: it means higher throughput, greater resistance to breakage, less post-processing, and hardly any rejects.



← **Intensity distribution of the laser for C-shape cleaving.**

TRUMPF

AUTHOR: DR. MAX KAHMANN

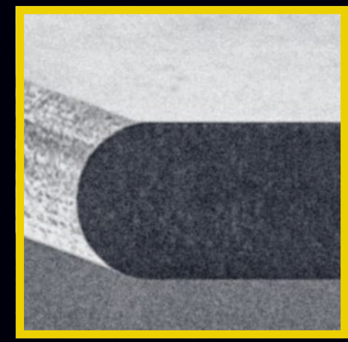
A smartphone tumbles to the floor, the display cracks. "Blast, not again!" cries the clumsy owner. Talk to an expert, and they'll explain that all the forces of the impact were concentrated in the inner angle of the display, where they propagated through a small volume of the brittle material, causing it to crack. Today, in the age of Gorilla Glass and superhard surfaces, the question of whether your smartphone survives this fall depends essentially on whether it lands on the thin edge of the glass display. The edge of a smartphone display has two angles: the *alpha* (α) angle, which is the outer angle that is formed where the surface of the glass meets the edge; opposite this is the supplementary *beta* (β) angle, which is the inner angle formed where the surface of glass meets the edge. *α* determines β, and the size of β determines how resistant the edge is to stress. If β is large, the forces of impact rapidly spread across a large volume, without causing any damage. If β is small, these forces are concentrated in a small volume and cause the glass to break at this point. Which is when you say "Blast!"

AN ENDLESS ROUND OF POST-PROCESSING Once the display glass has been cut, a substantial degree of post-processing is still required. To cleave the glass, it is first scored then broken along this line in a controlled manner. These days, more and more manufacturers are switching to fast laser-cutting processes. However, this also entails an endless round of post-processing, which accounts for as much as 90 percent of the entire effort that goes into display manufacture: grinding, polishing, coating, hardening, roughening, bonding. The displays are moved from station to station, where they are mechanically processed, turned over, mechanically processed, and then cleaned after each step. Worst of all, during each of these steps, vast quantities of the wafer-thin glass get broken.

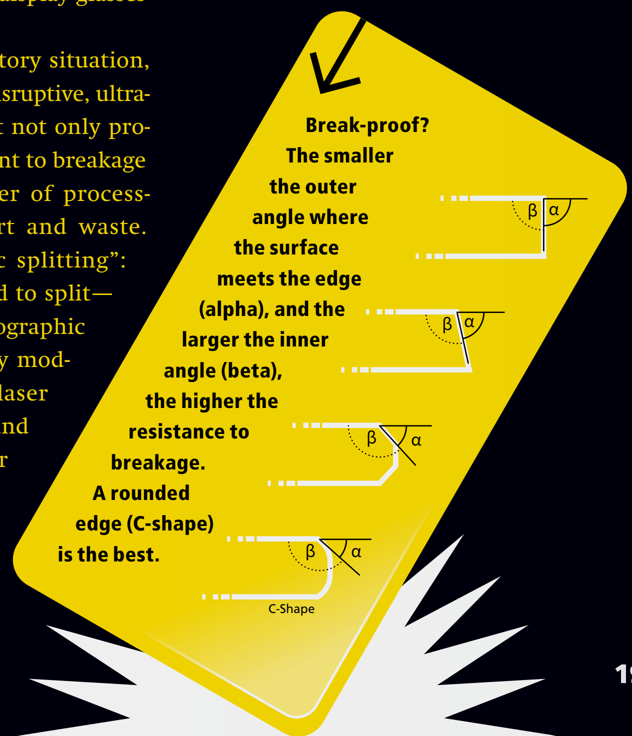
THE DISPLAY DILEMMA Manufacturers can either choose to accept this enormous wastage. Or they can ensure that displays are more resistant to breakage, which not only reduces the need for post-processing but benefits the consumer. Traditionally, this is achieved by machining the edge of the display to create either a bevel (grind, polish) or, even better, a chamfer top and bottom (grind, polish; turn over; grind, polish). However, this adds even more steps to the seemingly endless round of post-processing. Moreover, even with this method of creating an edge more resistant to breakage, a lot of display glasses still end up getting rejected.

To resolve this unsatisfactory situation, TRUMPF has come up with a disruptive, ultrashort-pulse laser process that not only produces displays that are resistant to breakage but also reduces the number of processing steps and thereby effort and waste. It is known as "holographic splitting": splitting because light is used to split—or cleave—the glass, and holographic because the process precisely modulates the intensity of the laser at different points in space and thereby the shape and contour of the cleavage in all three dimensions. And this, at long last, is what enables the creation of perfectly

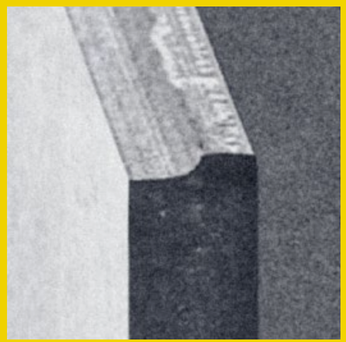
The C-cut leaves a perfectly smooth edge without the need for polishing.

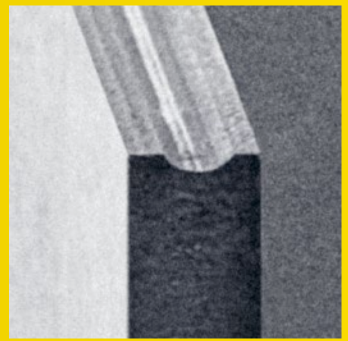


Manufacturers face huge wastage and an endless round of post-processing.

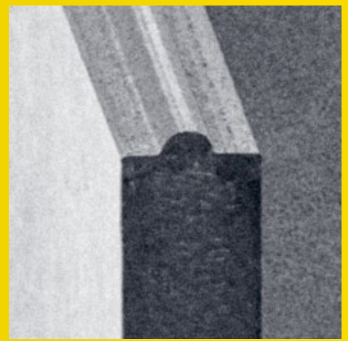


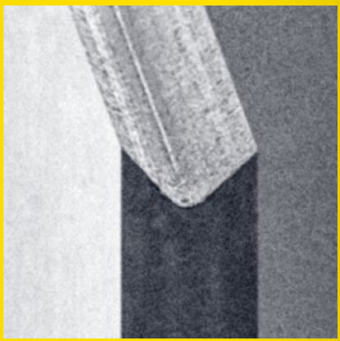
With wave optics, it is possible to create edges of all contours in glass and other transparent materials.





A step edge for a glue-free, push-tight connection for smartphone displays (bottom).





Further options include tongue-and-groove and other joints for displays and, for example, glazed facades (left and above).

rounded, C-shaped edges in a single step. In the case of the C-cut, the α angle is exactly the right size. Indeed, it is impossible to make the edge of the glass any more resistant to breakage.

This technology is based on a conception of light that is correct from a physical point of view but extremely complex from a mathematical one. Rather than being regarded as a beam—a simplified picture that was long sufficient for most purposes in the field of laser processing—light is thought of here as a succession of propagating waves. The most important consequence of this is that the focal point of the laser is now seen not as a spot but rather as a modifiable zone of intensity. With the right methods of calculation and the appropriate technical means (see opposite page), it is possible to distribute this focal point within three-dimensional space at will. It can be stretched, squashed, curved, bent, or split into any number of individual zones. When cleaving glass, for example, the focal zone is stretched to a length that corresponds to the thickness of the glass being cleaved. This process was previously state of the art, but now we have given it an update: the focal zone is no longer straight, but rather curved in the shape of the letter C. The lens traverses the glass, so that the laser light shines through it from above, thereby creating an internal, perpendicular, C-shaped fault line, without the need to turn over the glass. It is then placed in an etching solution, which causes the glass to cleave extremely cleanly along the cut edge, so that no additional polishing is required. The perfect C-cut!

BETTER AND BETTER! Display manufacturers who use holographic splitting are able to produce more displays in less time. They save on complex post-processing steps that demand a lot of cleaning in between, and they obtain better results than with previous processes. As well as being an attractive feature for the consumer, this enhanced resistance to breakage also benefits the manufacturer. Since each display has this protective C-shape from birth, it remains intact during further production and handling steps. This not only drastically reduces the number of rejects, it also means that grippers and other handling equipment do not need to be so sensitive, thereby reducing the complexity of manufacturing systems.

What's more, this type of cut is not restricted to the C-shape. In principle, an edge of any shape or contour can be produced in any transparent, brittle material. For example, TRUMPF is currently working on creating mortise grooves in glass, so that smartphone displays would no longer have to be bonded, but could simply be snapped into place. This would mean fewer production steps, another few micrometers shaved off the thickness, another few milligrams of weight saved, one source of error fewer, and a longer service life. And that's just the beginning of what wave optics can create with glass! ■

Dr. Max Kahmann
Head of Advance Development Laser Applications at TRUMPF Laser- und Systemtechnik GmbH. He is a specialist in glass cutting and other USP laser applications.

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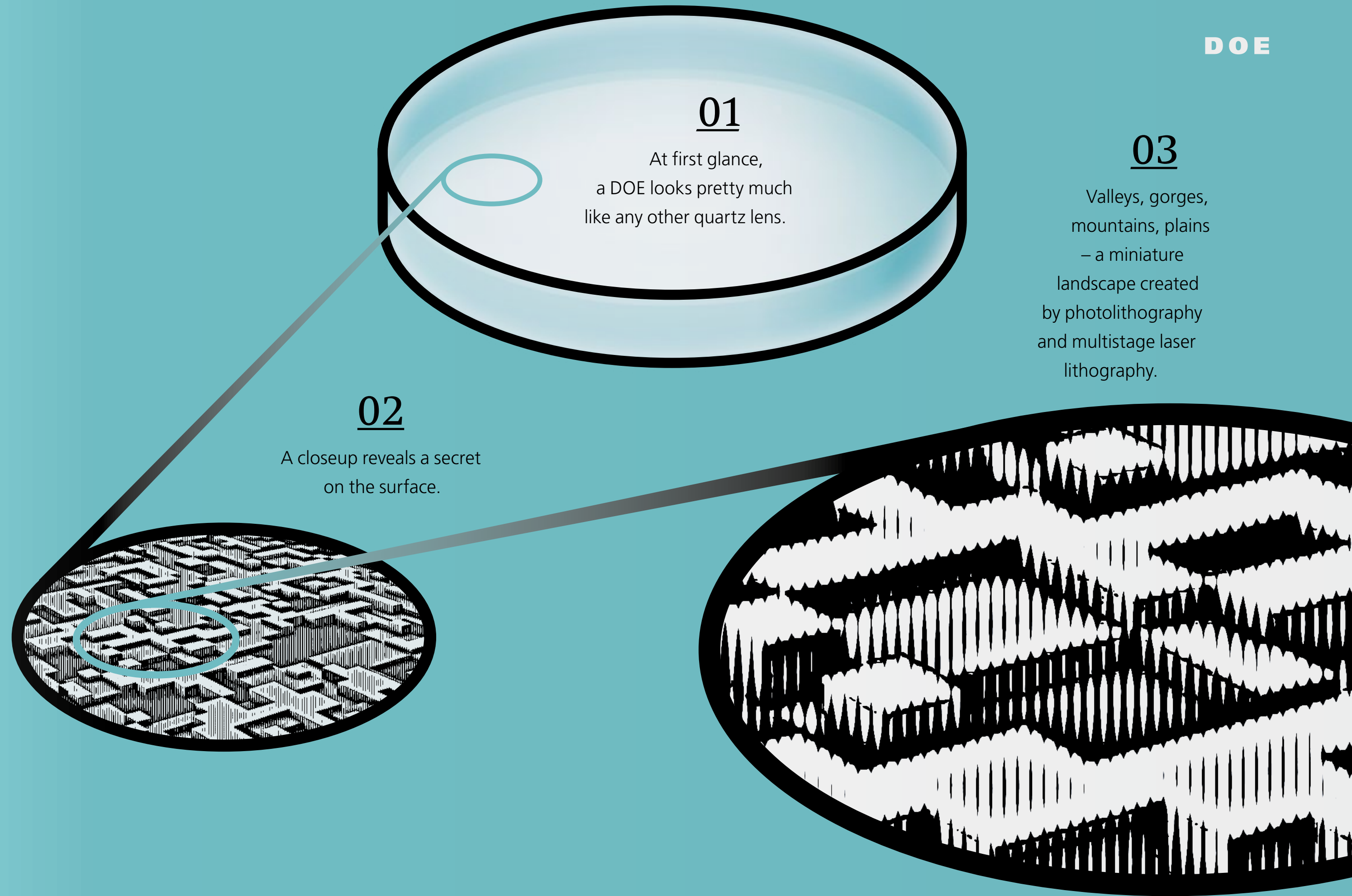
TRUMPF

Gernot Walter



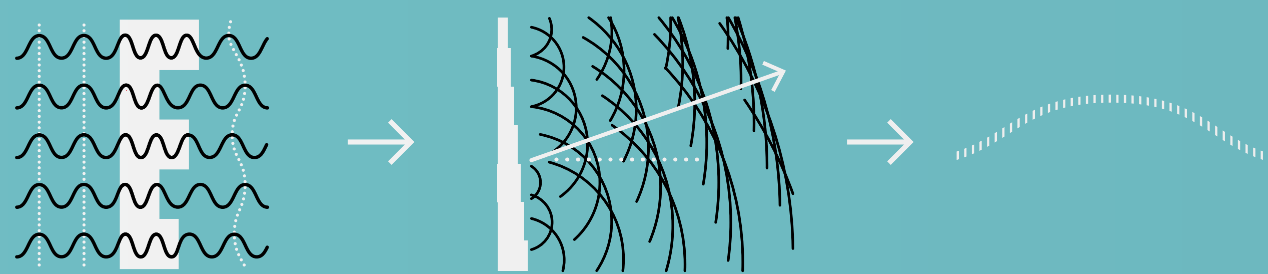
The wonder lens

Diffractive optical elements (DOEs) bring wave optics into the world of laser processing. The focal point of a laser beam can be split and formed into any shape.

Phase change

Interference

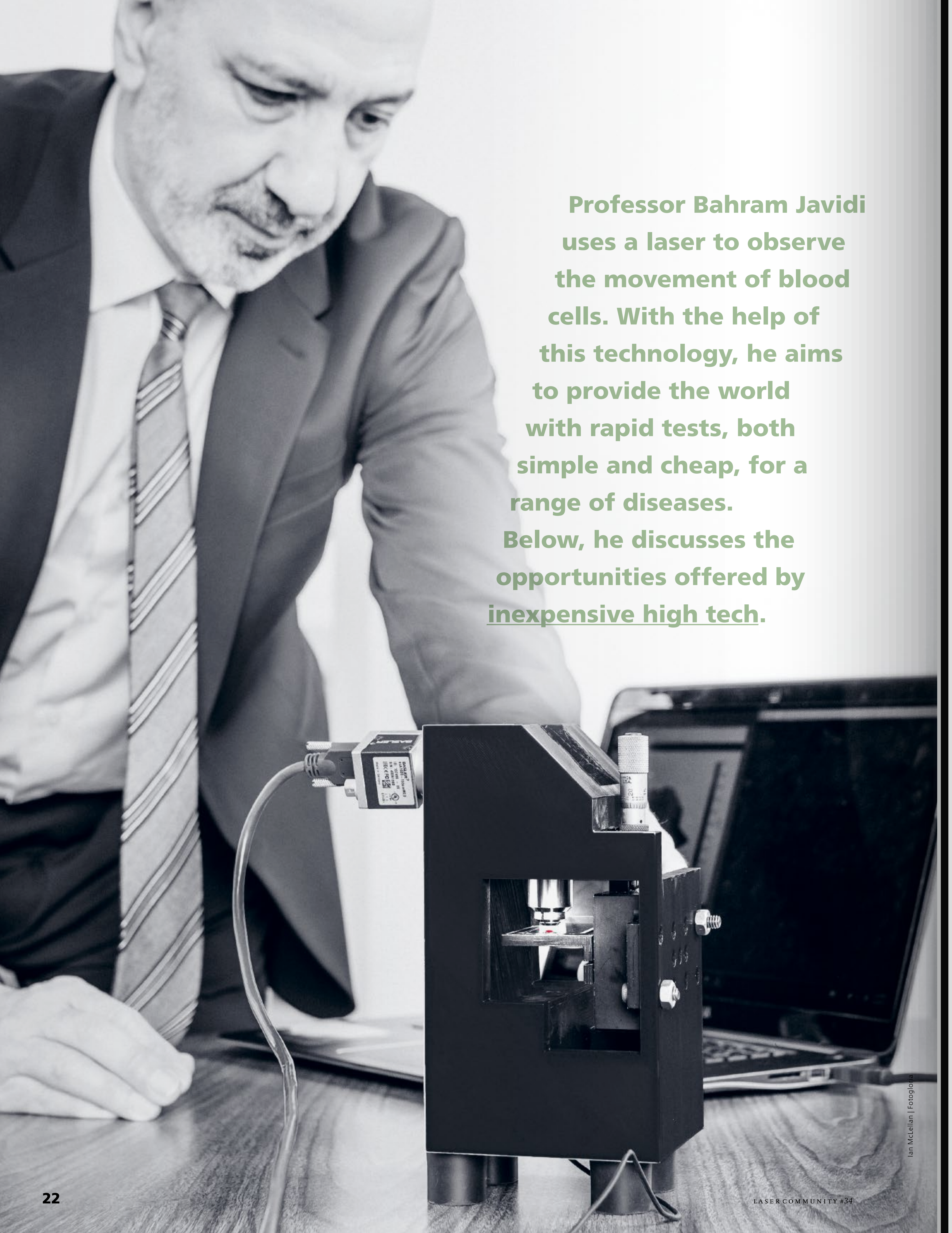
Focal shape



Light waves travel different distances through the lens. This causes their phase to change in relation to each another.

As a result of this phase change, the light waves interfere with one another. This forms a predetermined pattern.

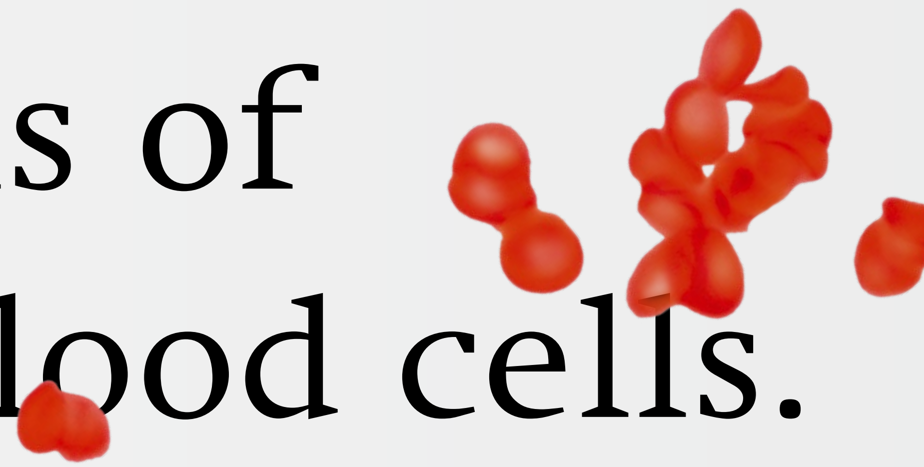
At the target point, this interference pattern results in a modulated zone of intensity; i.e., the focus of the laser can be split and formed into any shape.



Ian McLellan | Fotoglo

Professor Bahram Javidi uses a laser to observe the movement of blood cells. With the help of this technology, he aims to provide the world with rapid tests, both simple and cheap, for a range of diseases. Below, he discusses the opportunities offered by inexpensive high tech.

"Many diseases modify tiny details of our blood cells. Using laser light, we can detect this."



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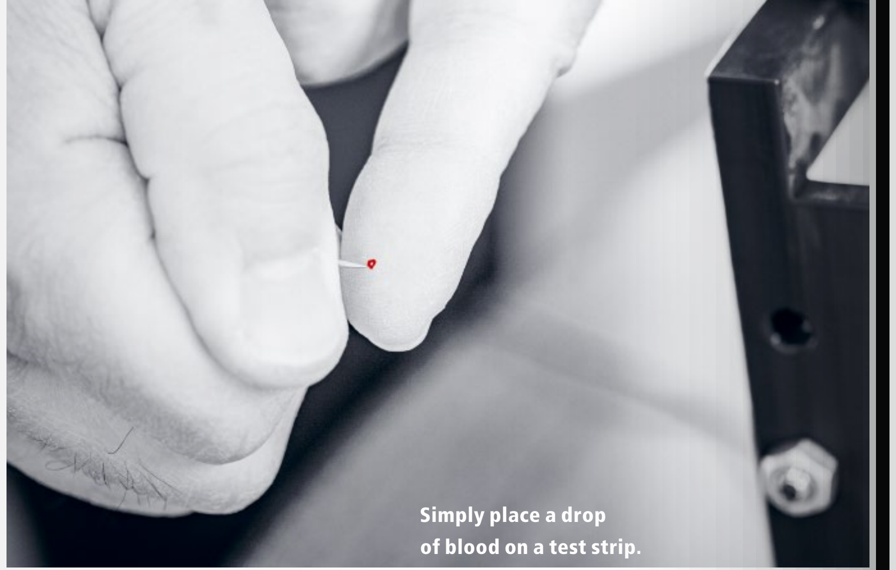
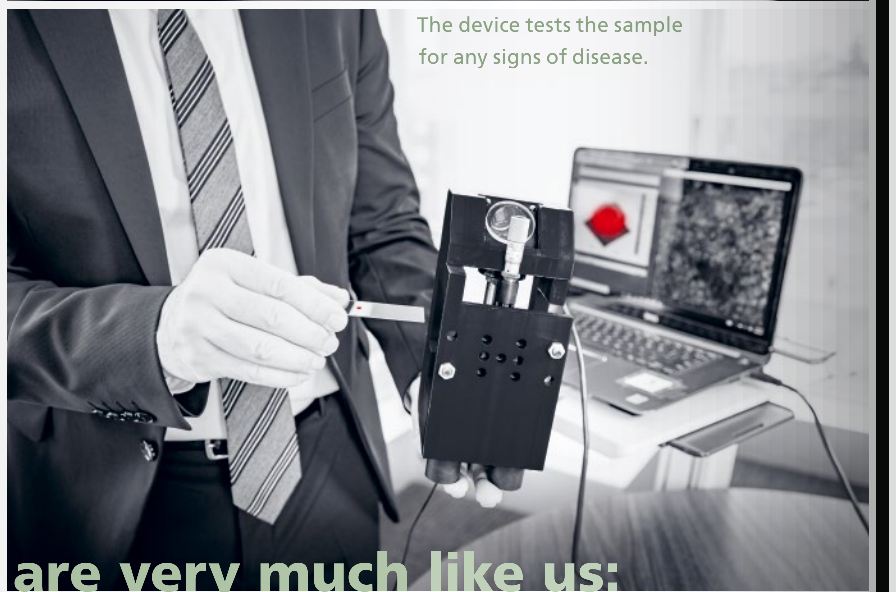


Simply place a drop of blood on a test strip.



The device tests the sample for any signs of disease.

P

Professor Javidi, how will we diagnose disease in the future?
Well, in certain cases, with the help of digital holographic microscopy.

Sounds a bit like science fiction. Tell us more!
The idea comes from the field of information optics. This covers techniques used to identify objects within a broad horizon. Light can convey a lot of information about an object. I thought it might also work on a smaller scale and therefore applied it to biomedicine—or, more specifically, to diagnostics. Many diseases, when they're raging inside us, modify tiny details of our blood cells. With the help of laser technology, we can detect these changes and thereby ascertain whether the patient is suffering from a particular disease.

That's amazing! And how do you examine the cells in a patient's body?
All we need for the test is a drop of blood. This goes onto a glass slide or something similar, which is then illuminated with a laser. This process is recorded by camera, and our own algorithms then determine whether there is an infection. That's quicker than the tests used now.

Okay, so now tell us exactly how digital holographic microscopy works!
It's really quite simple. First, the light from the laser diode illuminates the red blood cells, and these are then magnified by the objective lens of the microscope. The light from the laser is also reflected by the front and back surface of the glass slide. These two reflected beams become superimposed upon one another and form a digital hologram. And this is the information that we then record. This tells us the optical path length and refractive index. A software program then performs a kind of digital inversion of this diffraction. This produces a spatial model—i.e., a 3D image—of the cell. The software then analyzes this hologram for any signs of disease.

"Blood cells are very much like us: if all is well, they have their own characteristic rhythm; if something's wrong, they can slow down."

What kind of signs might these be?
First of all, we had to find out which of the characteristics of a cell can be modified. There are heaps of possibilities here, ranging from cell volume to surface area to the ratio of roundness to length. Using machine-learning methods, we were able to extract a lot more characteristics. Some of these are very mathematical, others seem counterintuitive at first sight but then prove highly practical. In the case of Covid-19, for example, we discovered that the coronavirus modifies the volume of red blood cells. This is very easy to measure. I then asked my son, who's studying medicine, whether he could explain this. His hunch is that Covid-19 deprives the cells of oxygen and that this could be a reason for the change in volume. It also helps here to take a dynamic look at the cells.

Dynamic?
Yes, we film the red blood cells. Then you can see even more characteristics. Cells are like little beating hearts—but on the nanoscale. Compared to a healthy red blood cell, a diseased cell, such as one infected with Covid-19, may exhibit an altered rigidity and fluctuate differently over time. That was an interesting discovery. Blood cells are very much like us: if all is well, they have their own characteristic rhythm; if something's wrong, they can slow down.

Which diseases have you been able to detect so far?
We've experimented with Covid-19, malaria, diabetes and sickle cell anemia, an inherited blood disorder.

Ian McLellan | Fotogloria

Ian McLellan | Fotogloria

You've reiterated how easy this method is. Why is that so important?
Right now, we're still refining this technology in the lab. But, obviously, rapid tests need to be suitable for everyday use—and also portable and cheap. When we perfected our test for malaria, we already knew that the method would be no use at all if it only worked in a well-stocked lab. Remember, the disease is more prevalent in remote countries with low standards of medical care. But, of course, industrialized countries will also enjoy the benefits of these tests—in the case of Covid-19, for example.

That means you don't need a hospital or a medical practice?
Not necessarily. You could just as well place the device on a chair or a desk. Granted, it would still need some kind of power source; but, if necessary, this could come from a laptop or cellphone battery. The essential thing is that the technology stays as cheap and simple as possible.

A portable holographic microscope that will fit in a rucksack—that doesn't sound very cheap at all …
But it is! We put a lot of effort into making the components as simple and inexpensive as possible. Otherwise, the price would have made it prohibitive for developing countries.

How were you able to keep the components so cheap?
We've learned from the manufacturing sector how to make everything smaller. The housing, for example, is produced with a 3D printer. This makes it very compact. The lens is simple to produce, the laser a standard device. And, thanks to advances in optoelectronics and optics, prices for camera components have fallen drastically. I remember the situation over 20 years ago. Back then, I bought a CCD camera from Kodak. It cost almost 30,000 U.S. dollars. It was a huge, monstrous thing! But now the camera's as cheap as a webcam.

Where do you see further potential for this technology?
I think it has a lot of potential in drug testing. If we can record and observe cell changes, we should also be able to see the effect of drugs on cells. This would help verify that new drugs don't have any harmful effects. We haven't tried this out yet, but I imagine it would work. What's more, the Covid pandemic has taught us the significance of viral mutations. This is another area where holographic technology might help.

How?
In the event of a mutation, the chemically based rapid tests that we have now might suddenly become less reliable and effective, meaning that new ones would have to be developed as quickly as possible. Assuming that ours would continue to work —although, to be fair, the opposite is also conceivable—all we would have to do, in the event of a mutation, is to program a software update. In fact, if our system of cell measurement remains effective, it might even be enough simply to retrain the existing software on the basis of new parameters. In other words, countries that cannot afford to wait wouldn't have to cease testing until new test kits arrive. We could simply send them the new parameters by email. Once these are downloaded, the test would then work as before. That said, these are all assumptions that we need to explore in more detail. ■

"In the event of a virus mutation, a simple software update may well suffice to detect it."

Bahram Javidi is a professor in the Department of Electrical & Computer Engineering at the University of Connecticut. He has received numerous awards and honors for his pioneering work on transformative approaches to optical imaging, including the QEOD Prize, awarded by the European Physical Society, and the Joseph Fraunhofer Award / Robert M. Burley Prize, awarded by Optica, formerly the Optical Society (OSA).

TIGHT AS A DRUM!

Developer Christian Buse has cooked up a new welding strategy for automotive supplier Benteler.

Electric vehicles: Metalworking specialist Benteler first developed a new method of laser welding for stainless steel—and then applied it to aluminum.

← High-speed, gastight welding: the seams on this cooling plate for battery housings are so tight they even prevent the passage of gases.

Stefan Hobmaier, Daniel Goldhahn | Fotogloria

The metal housing is the least spectacular part of an e-car battery, though not as trivial as it might seem. This is because the battery housing has a vital role to play: in normal operation, it protects the sensitive electronics inside against moisture and other weather conditions, thus ensuring a consistently high performance; in the event of a crash, it prevents the escape of flammable and toxic substances. The key feature of this type of battery housing are the weld seams, which must be gastight. And for these to be gastight, they must be free of pores and inclusions. In an ideal world, it would be possible to manufacture these housings at high speed. And this is where Benteler enters the equation.

ALUMINUM IS LIGHTWEIGHT BUT EXPENSIVE

Christian Buse is an R&D team leader at the Automotive Division of Benteler, a major automotive supplier based in Paderborn, Germany. He and his team spend their days thinking about ways of improving metalworking processes. "The beauty of the current situation in the e-mobility sector," he explains, "is that there's still big scope for improvement. So there are plenty of areas we can take a fresh look at." And this includes ways of bettering the battery housing. At present, friction-stir welding is used to make the housing gastight. In this process, a rotating tool is applied with force to the parts being joined. This generates friction and thereby heat. It is an agonizingly slow process in a mass-production setting, but it is chosen because the housings are conventionally made of aluminum alloy, a material that is notoriously difficult to work. For the industry, aluminum is the logical choice, because it is lightweight, which is always a desirable property for e-cars.

"However, we noticed that our customers were looking for alternatives to aluminum—housings made of steel or of a hybrid design," Buse explains. "So we opted

"So now we've got two excellent processes for welding battery housings: one for steel, and one for aluminum. Whichever comes out on top—we'll be ready!"

for stainless steel." There are several reasons for this: stainless steel is resistant to corrosion, for example, and has a high melting point, which can be a lifesaver in a vehicle fire. What clinches the argument, however, is something else: "Stainless steel is very easy to weld by laser, and we know that a laser process will deliver fast and reliable results, while meeting the standards for gastight seams." Back then, when the idea was first hatched, Buse had no idea where it would lead.

GOOD ENOUGH FOR BOTH First of all, Buse contacted TRUMPF. A history of development partnerships has forged strong links between the two companies. Having suggested a fully automated bending process, efforts were then turned to the key challenge of accelerating the welding process. TRUMPF engineers recommended the use of BrightLine Weld to do this. The focusing optics of this system split the beam of a disk laser between the ring and core of a laser light cable, virtually eliminating spatter, even at high welding speeds. Reducing spatter ensures there is enough material to form a strong weld seam. "And that cuts the need for post-processing," Buse explains. "And, most important of all, the seams are gastight!"

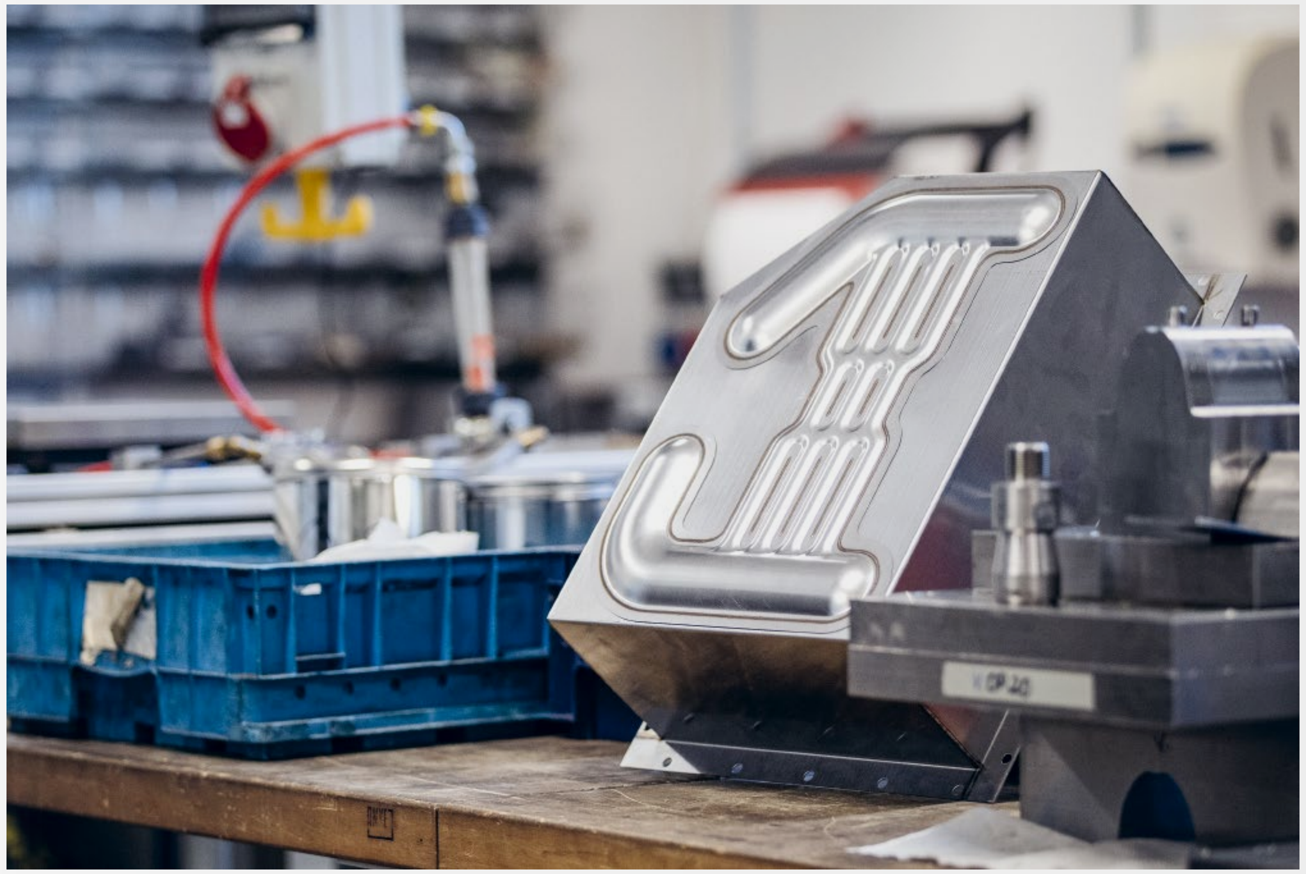
The success of the welding process with stainless steel then encouraged Buse and his team to take another look at aluminum. "We had a hunch that the concept for the new battery housing in stainless steel could also be used to laser-weld aluminum to a gastight standard. That would give us additional weight savings, and aluminum is popular in e-car construction anyway, particularly among our customers. So we thought, why not!"

SPOT ON WITH ALUMINUM! Once again, Buse turned to TRUMPF. This time, however, it took more than BrightLine Weld to deliver gastight seams produced at speed. Buse's team had an idea: by keeping the keyhole open for longer, this would provide any contaminants with enough time to vaporize and escape. In addition, it would also prevent vapor channels from collapsing and thereby forming pores or trapping gas, which was always the big problem when laser welding with aluminum.

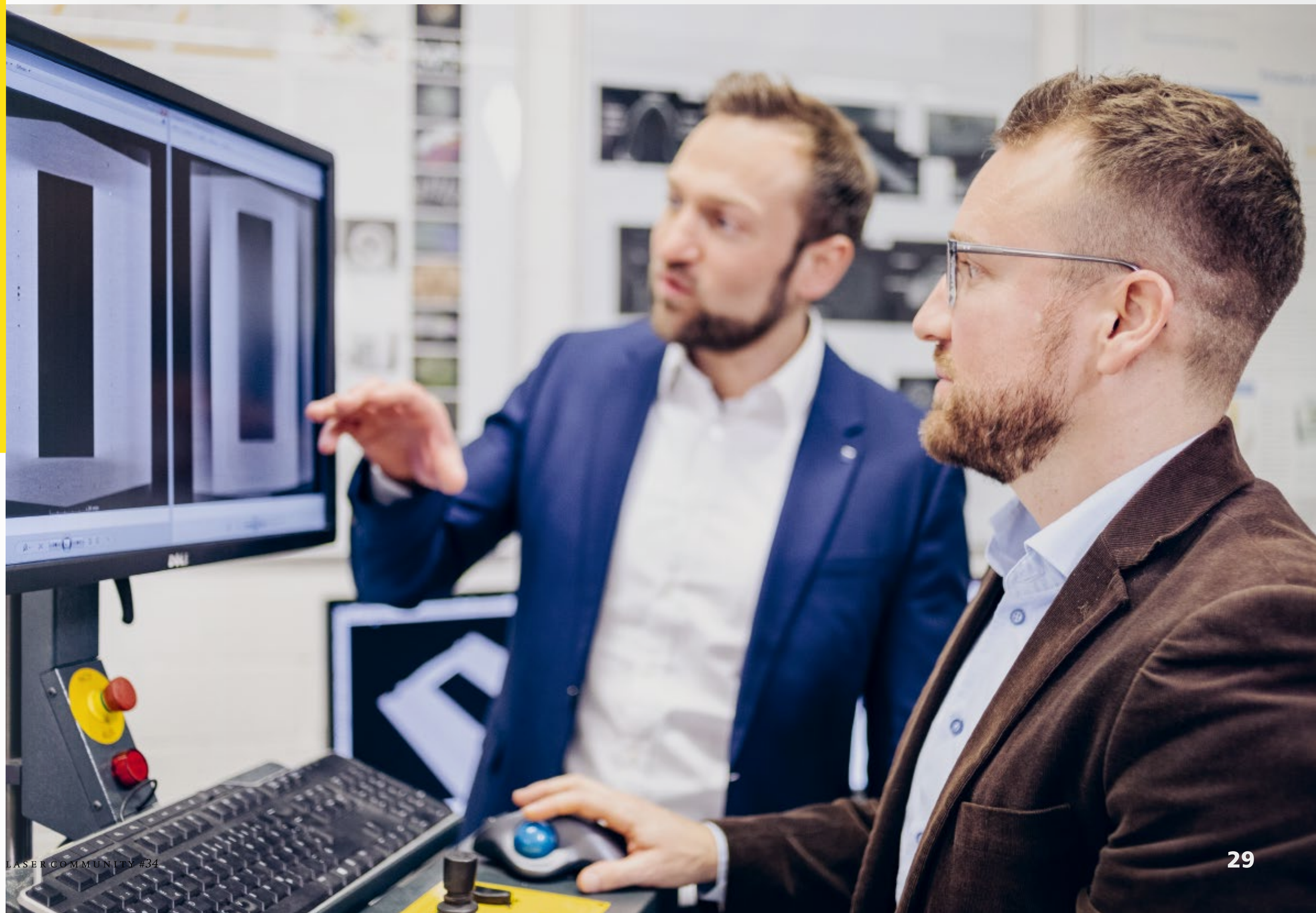
To solve this challenge, engineers at TRUMPF built a new multifocal system that splits the laser beam into four spots. First of all, BrightLine Weld splits the beam between the ring and the core—which was what made the process faster with stainless steel. Then the multifocal optics further split the ring-core beam into four individual spots and position them on the workpiece in such a way that they all land in the weld pool. This ensures that the keyhole remains open. To remove the very last impurities, the laser makes another pass on the basis of a few other parameters. This produces a weld that is without pores or inclusions and therefore gastight.

Buse and his team could hardly believe their luck. To be on the safe side, they ran a whole series of tests. The results were clear: they had developed a high-speed process for laser welding gastight seams with aluminum! "So now we've got two excellent processes for welding battery housings: one for steel, and one for aluminum," says Buse. "Whichever comes out on top—we'll be ready!"

Contact: Benteler Automobiltechnik GmbH, Christian Buse, Team Leader Structural Technologies R&D;
phone: +49 5254 81-303245; christian.buse@benteler.com



Above: The new laser-welding approach for stainless-steel battery housings has worked so well that Benteler decided to try it for aluminum, which is recalcitrant but well established in the market.
Below: The somewhat modified aluminum process withstands the critical gaze of Buse (right).



Stefan Hobmaier, Daniel Goldhahn | Fotogloria

BUZZ LIKE A FLY

DISRUPTIVE INNOVATION—THAT NEW BUZZWORD—CAN TRANSFORM OUR LIVES. THERE ARE SOME PROBLEMS, HOWEVER, THAT EVEN THE LASER CAN'T SOLVE.

In the past, Athanassios Kaliudis, editor-in-chief of Laser Community, has written regularly about the role of the laser in pop culture. This is his last column for the magazine.

San Francisco, January 2007: Steve Jobs is onstage, offering the world its first view of the iPhone. It is the birth of the modern smartphone—and the death knell of the keypad cellphone. A disruptive innovation? Absolutely!

Science fiction is full of disruptive inventions. One of my favorites is teleportation. Wouldn't it be great to be able to move instantaneously, at the push of a button, from Stuttgart to New York, without having to cross the space between? There would be no more need for planes, trains or cars! A genuinely disruptive innovation!

However, as André Delambre was to discover to his cost, teleportation can be a tricky matter. In his short story "The Fly," originally published by Playboy magazine in 1957 and subsequently filmed twice, author George Langelaan describes the attempts of research scientist Delambre to transport matter through space. Following a number of failed attempts, he succeeds and then resolves to try it out on himself—with fatal results. During transportation, a fly happens to enter the transmitter pod with him. This results in the creation of two hybrid beings: a human with the head of a fly, and fly with assorted human body parts. In an attempt to reverse this process, the fly-headed creature also acquires some features of the family cat, which had disappeared during a previous experiment with the transmitter pod. Delambre's wife sees no way out but to kill the disfigured scientist with the help of a hydraulic press. In the end, even the fly, despite initially escaping, is crushed between two stones. Thankfully, pure science fiction.

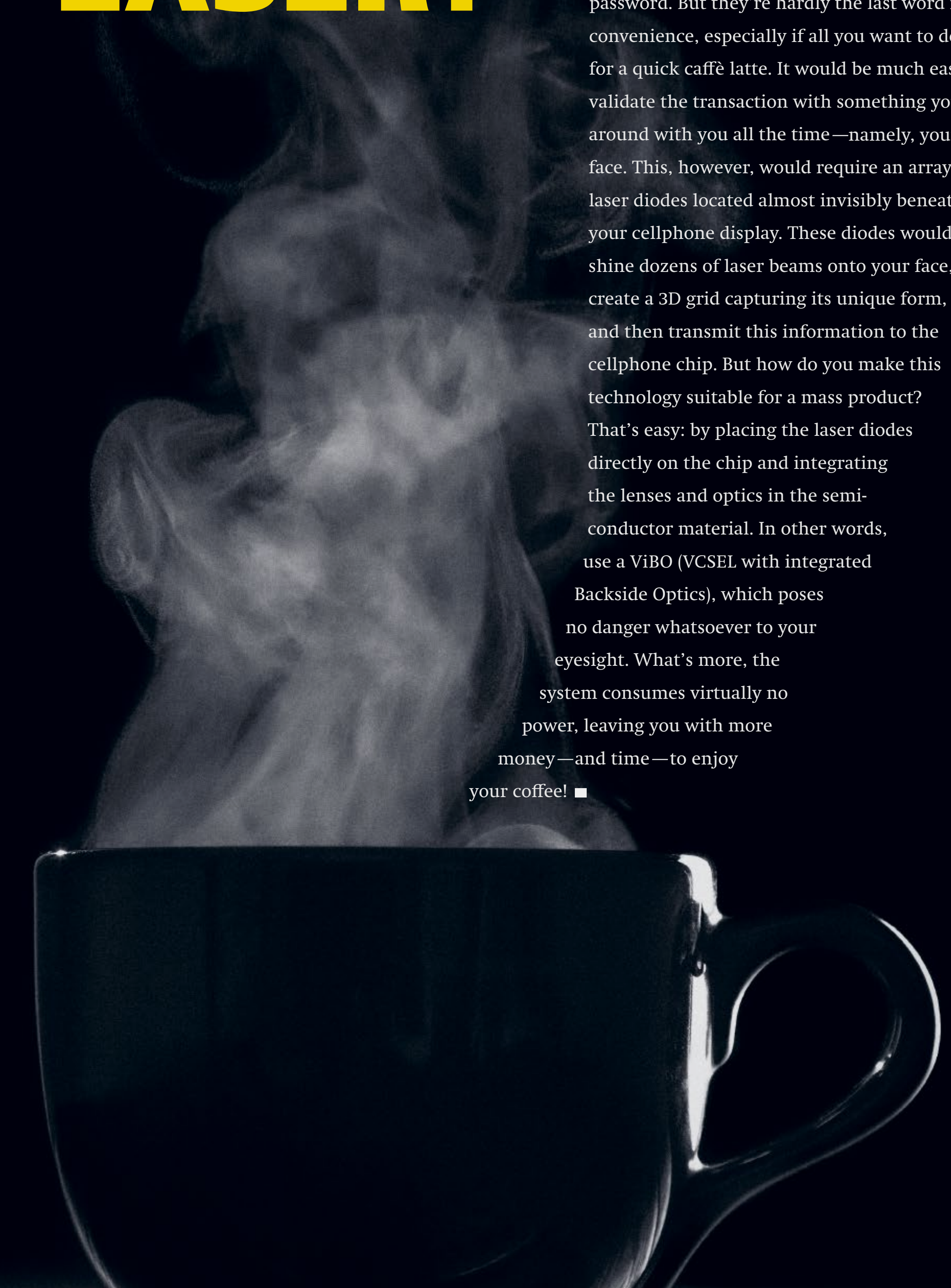
At this point in the column, I usually turn to some institute or other that is currently working on a solution to this precise problem, based on laser technology. Yet, even today, the dream of teleportation remains just that—pure science fiction. And, given Delambre's fate, that is perhaps just as well.

I don't know if Steve Jobs was a laser enthusiast, but I'm pretty sure that had he read this magazine, he would have become one. A new development from TRUMPF may sound like science fiction, but it is a classic example of disruptive technology: an innovative process that renders smartphone displays indestructible (page 22). Amazing!

Magazines, too, can be subject to disruptive events. This will be the last "Pop" column to appear in *Laser Community*. Shooting off to another galaxy, faster than the speed of light, it will free up space for new content! ■

What topics would you like to read about here in the future? Let us know: media@trumpf.com

Gernot Walter



WHERE'S THE LASER?

In your coffee to go: A variety of protocols help make cellphone payments secure: transaction authentication numbers, two-factor authentication and, of course, your own personal password. But they're hardly the last word in convenience, especially if all you want to do is pay for a quick caffè latte. It would be much easier to validate the transaction with something you carry around with you all the time—namely, your own face. This, however, would require an array of laser diodes located almost invisibly beneath your cellphone display. These diodes would shine dozens of laser beams onto your face, create a 3D grid capturing its unique form, and then transmit this information to the cellphone chip. But how do you make this technology suitable for a mass product? That's easy: by placing the laser diodes directly on the chip and integrating the lenses and optics in the semiconductor material. In other words, use a ViBO (VCSEL with integrated Backside Optics), which poses no danger whatsoever to your eyesight. What's more, the system consumes virtually no power, leaving you with more money—and time—to enjoy your coffee! ■

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ONE KILOMETER

is the average height of the atmospheric boundary layer that separates the surface of the earth from the earth's atmosphere. At the Concordia research station in Antarctica, ESA is currently using two light-detection and ranging (LIDAR) instruments to investigate winds, aerosols and clouds in this boundary layer. During the winter months, a pulsed laser is fired vertically into the night sky every five minutes for a duration of 60 seconds. The green laser light is reflected by particles in the boundary layer, and sensors detect the scattered light. This data offers clues about the Antarctic climate and climate change.

ESA-IPEV-PNRA / S. Thoolen