LASER COMMUNITY.

Of people and photons

Rare earths are not actually that rare, but they are difficult to mine. Ultrahigh-power lasers will soon make this much easier.

LASER COMMUNITY. *#41*

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Dear Readers,

We stand on the threshold of a new era in laser technology. Industrial lasers with a power of 50 kilowatts and more are now a reality, opening up opportunities that were unthinkable just a few years ago. For TRUMPF, this is a landmark development—and for commercial users of laser technology, a strategic breakthrough.

What does ultrahigh power mean here? For a start, it means much more than merely an increase in wattage. UHP will not only accelerate existing processes but also enable fundamentally new ones. Laser applications once doomed to technological failure are now about to come onstream—from large-format surface processing and new tunneling methods to systems that defend against drone attacks. The commercial possibilities are endless. And that's only the beginning. Indeed, within just a few years, we expect to see the first megawatt laser for industrial applications. *To find out more about the kind of processes made possible by UHP lasers, turn to pages 12 – 18.*

Yet the development of UHP lasers is more than merely a technological milestone. It also comes in response to the concrete needs of our customers in sectors ranging from e-mobility to energy. And our lasers can do more than just weld and cut at lightning speed. With laser-driven X-ray sources, like the one under development for the XProLas project, we can now deliver the beam brilliance of a particle accelerator in a compact format suitable for commercial applications. This technology creates completely new perspectives for research and industry—and at a fraction of the previous cost. In the future, such secondary sources—i.e., X-ray beams generated from a primary laser beam—will enhance the quality analysis of EV batteries and thereby help spur advances in this technology. *Read more about the XProLas project on page 22.*

Innovations such as interferometric nanoparticle tracking analysis (iNTA) show how developments in laser technology make waves far beyond the field of traditional manufacturing. In addition to enhancing quality control in the food and pharmaceutical industries, iNTA could also play a key role in the early detection of cancer and other diseases. Here, at TRUMPF, we understand that technological progress and social responsibility go hand in hand. *Turn to page 20 for our interview with Anna Kashkanova, joint developer of the iNTA method.*

Our mission, together with our customers and partners, is to continually push back the boundaries of technological progress. Our years of experience in this industry have shown us that the best ideas come about when technology responds to the needs of the market. UHP lasers are concrete proof of this.

We wish you pleasant reading!

DR. RER. NAT. HAGEN ZIMER

Chief Executive Officer for Laser Technology
Member of the Managing Board of TRUMPF SE + Co. KG

Julian Rentzsch

Light painting

We've always wanted to create a photo of someone painting a momentary picture with light. Nano-optics expert Anna Kashkanova was on hand to help photographer Anna Schroll shoot the image on **page 20**.

Light wizardry

It was back in 2017 that we first filmed at TRUMPF's advance development department – where, amazingly, engineers were already working on manipulating light beams and light waves. What was magic then is now reality. Read about it on **page 19**.

Light show

Eye treatment was one of the early applications of the laser after its invention in the 1960s. Yet we were still wide-eyed to discover how useful the laser can be in terms of making eyes even more beautiful! Take a look for yourself on **page 31**.

Anna Schroll, TRUMPF, stockfoto/Parilov

LASER

ULTRAHIGH-POWER

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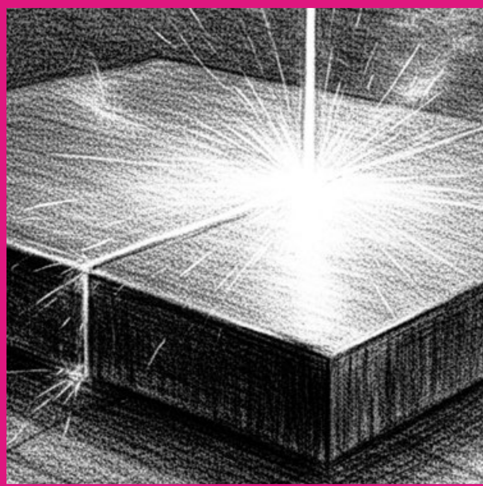

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Die Magaziniker & AI; Bernhard Huber, courtesy of Deutsches Museum in Munich

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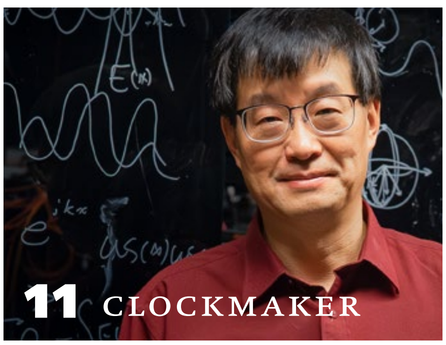
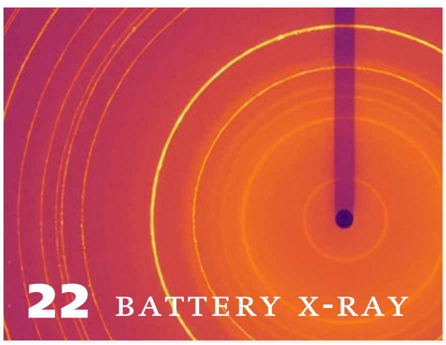
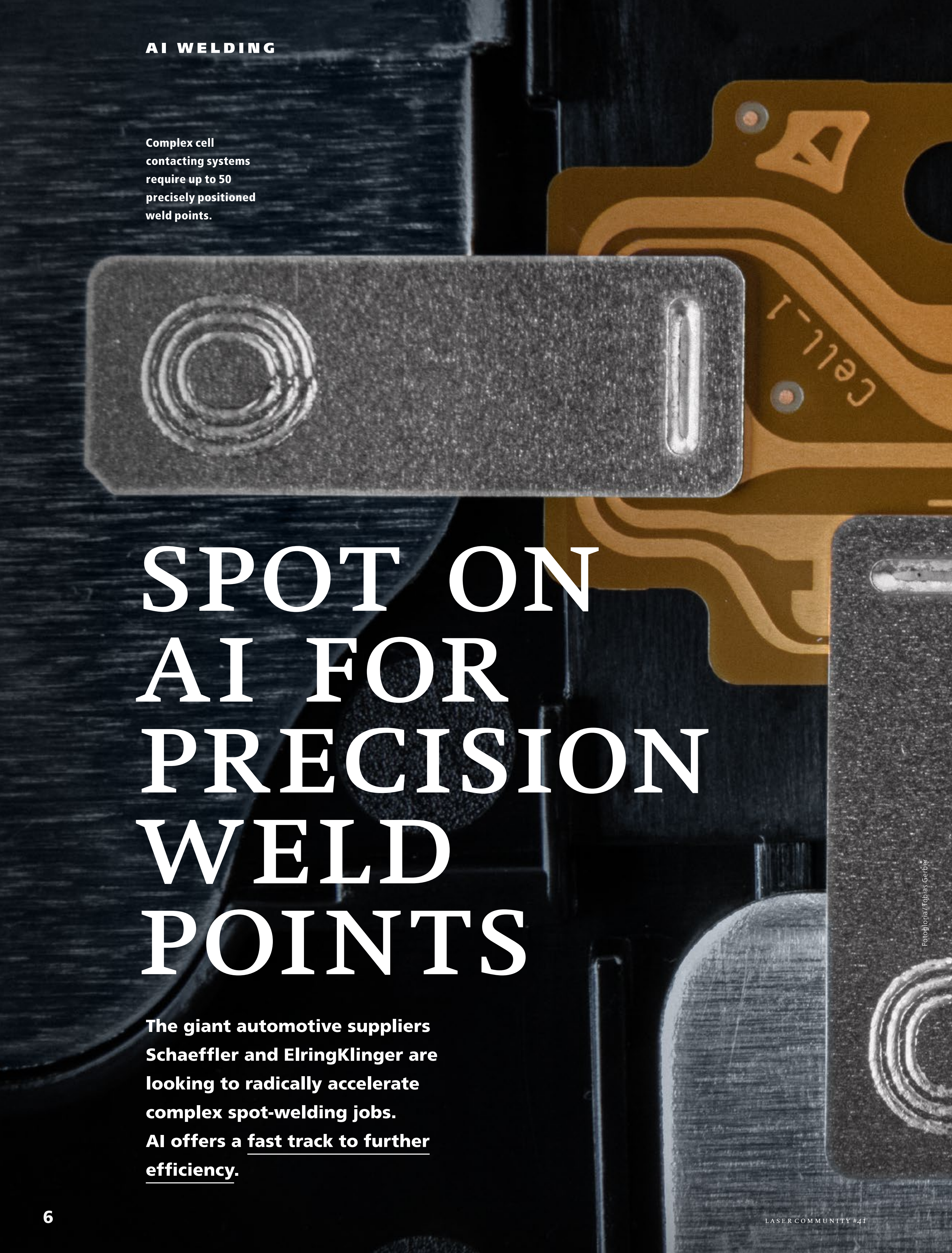




Maximilian Schlosser / Berthold Leibinger Stiftung GmbH, DESY / Martin Etter, Anna Schroll

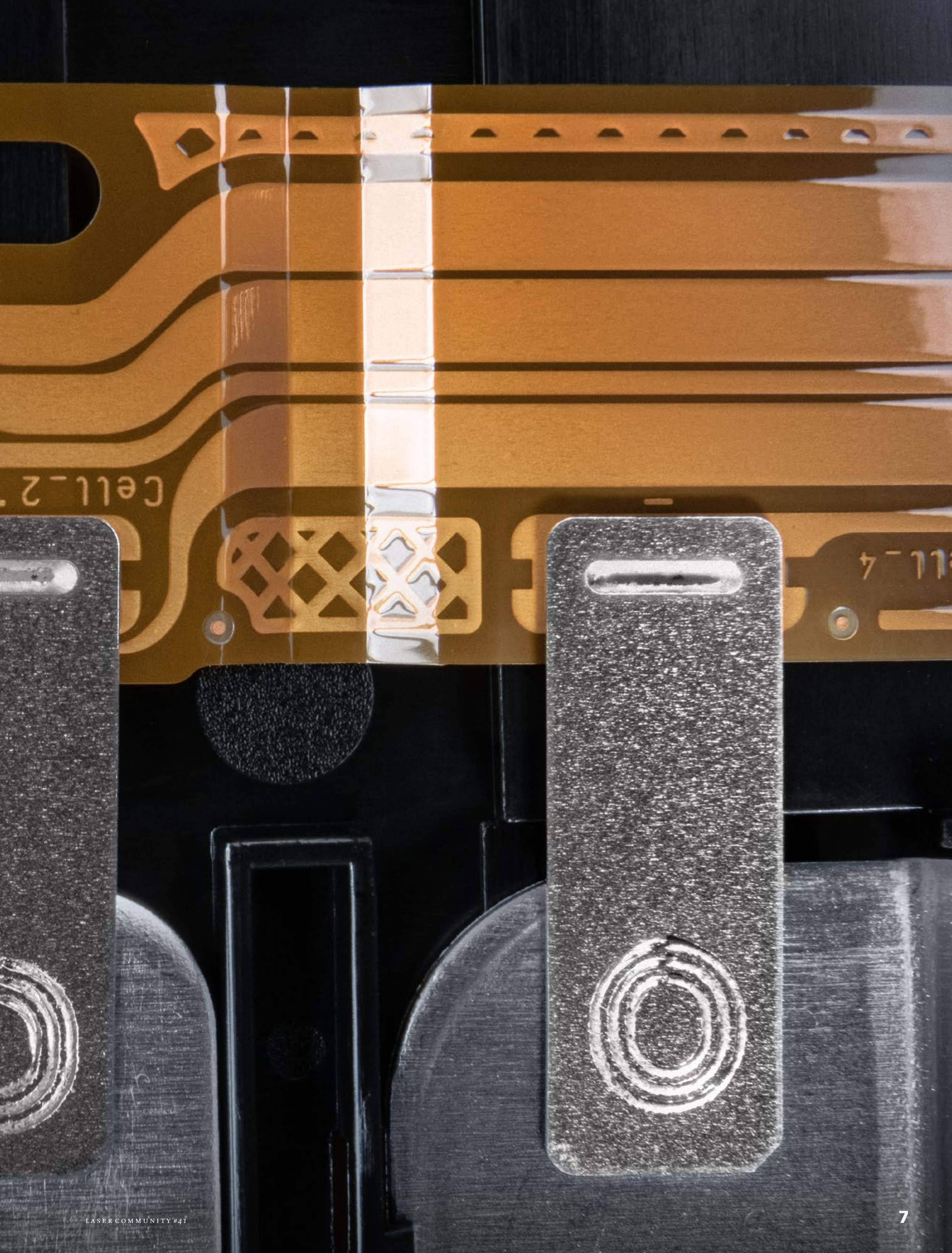


Complex cell contacting systems require up to 50 precisely positioned weld points.

Fotogloria / Tobias Gerber

SPOT ON AI FOR PRECISION WELD POINTS

The giant automotive suppliers Schaeffler and ElringKlinger are looking to radically accelerate complex spot-welding jobs. AI offers a fast track to further efficiency.



"Introduction of the AI filter has enabled us to significantly improve component detection—as shown in a first-pass yield of over 99 percent."

Daniel Weller is a joining technologies expert at German automotive supplier ElringKlinger. He develops joining processes in the field of battery technology. When it comes to welding cell contacting systems (CCS) for electric vehicles, he and his colleagues face a number of challenges. Alongside a desire for more speed, there is also the question of how to accommodate a big range of variants in conjunction with a zero-defect strategy. The components in question are up to two meters long and involve upward of 50 welding positions. "Our job is to develop a stable production process that delivers a consistent level of quality at short cycle times," Weller explains. Until recently, detection of the correct welding position under real production conditions required a lot of know-how plus some clever tricks to tackle problems: varying light conditions, reflections, dust and minor deviations in geometry. Weller looks back and says: "Of course, we got along fine with the previous solution, but TRUMPF's AI-supported EasyModel AI solution now brings considerable speed to weld spot detection and thus to the entire process development."

A FEW TRAINING IMAGES SUFFICE Using TRUMPF's image-processing solution VisionLine Detect, Weller records a few training images of the component and uploads them to the AI cloud. He then marks relevant areas on the images. After just a few photos, the AI model is able to precisely filter relevant from irrelevant areas of the image, binarize the relevant ones (the detected component is displayed in white, the surrounding area in black) and reliably detect the edge of the component, even at short cycle times. For Weller and Elring-Klinger, this means much greater efficiency in feature detection: "It no longer takes days to achieve good results, but merely hours." Equally impressive are the accurate, reproducible results in a mass-production

Dr.-Ing. Daniel Weller,
ElringKlinger AG

"The system works on the principle of 'what you see is what you get'—it's intuitive, fast and zero code."

Fotogloria / Tobias Gerber

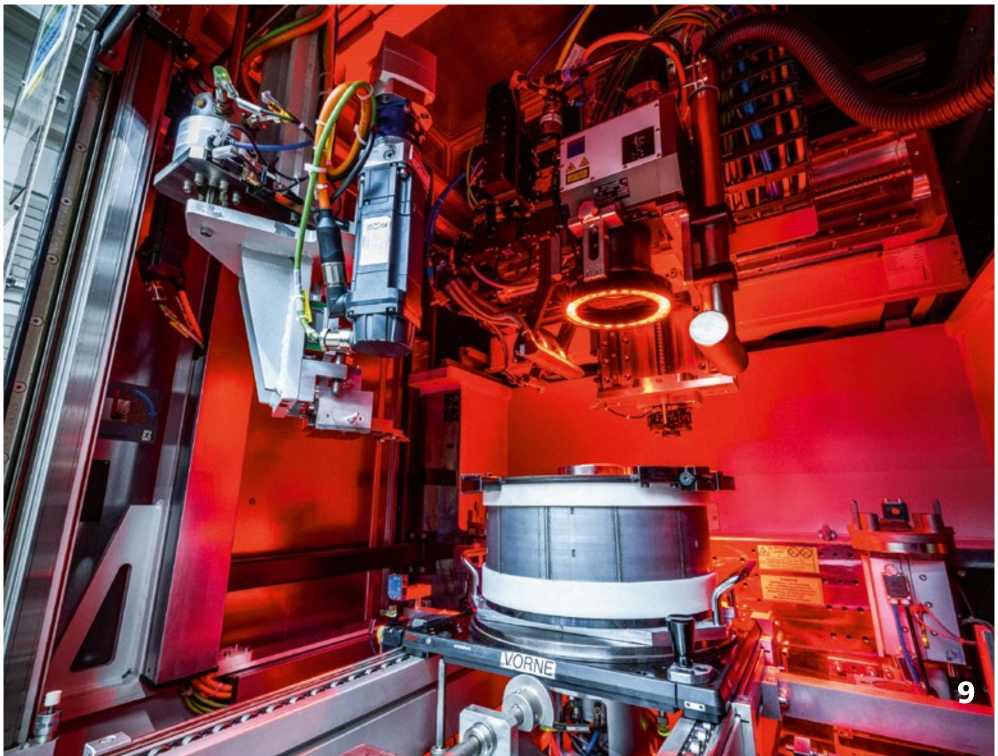
Alexander Fast, Schaeffler AG.

environment, along with the fact that no programming knowledge is required to operate EasyModel AI. “The system works on the principle of ‘what you see is what you get’—it’s intuitive, fast and zero code.”

LEARNING ON THE JOB Germany’s automotive and industrial supplier Schaeffler is likewise using EasyModel AI to accelerate development of new processes and boost production throughput. Alexander Fast works at the company’s Bühl site, developing advanced laser-welding processes for copper in electric motors. “When laser welding copper wire for the stator winding of an electric motor,” he explains, “the problem is that any deviation in the position of the pieces to be joined—including height difference, lateral offset or gap formation—will impact the ability of the equipment to properly detect the component and perform the weld. And we’re talking here about anything from 20 to several hundred weld points, depending on the type of component.” Conventional detection systems, which use grayscale images, tend to struggle here. “In terms of precision and reliability, the AI filter is way better at determining the welding position—even with variations in component characteristics and changing ambient conditions – than anything else currently on the market,” says Fast. “Its introduction has enabled us to significantly improve component detection—as shown in a first-pass yield of over 99 percent.” In addition, the system can statistically analyze the data, meaning that “only values with significant deviation need to be relabeled, and that saves valuable development time.”

EasyModel AI is now being used in production at Schaeffler worldwide. ElringKlinger, meanwhile, has rolled out the AI filter to two further production facilities, alongside its plant for future technologies in Neuffen, as part of the same project. ■

For hairpin welding of stators, EasyModel AI rapidly and precisely detects hundreds of weld points in a mass-production setting.



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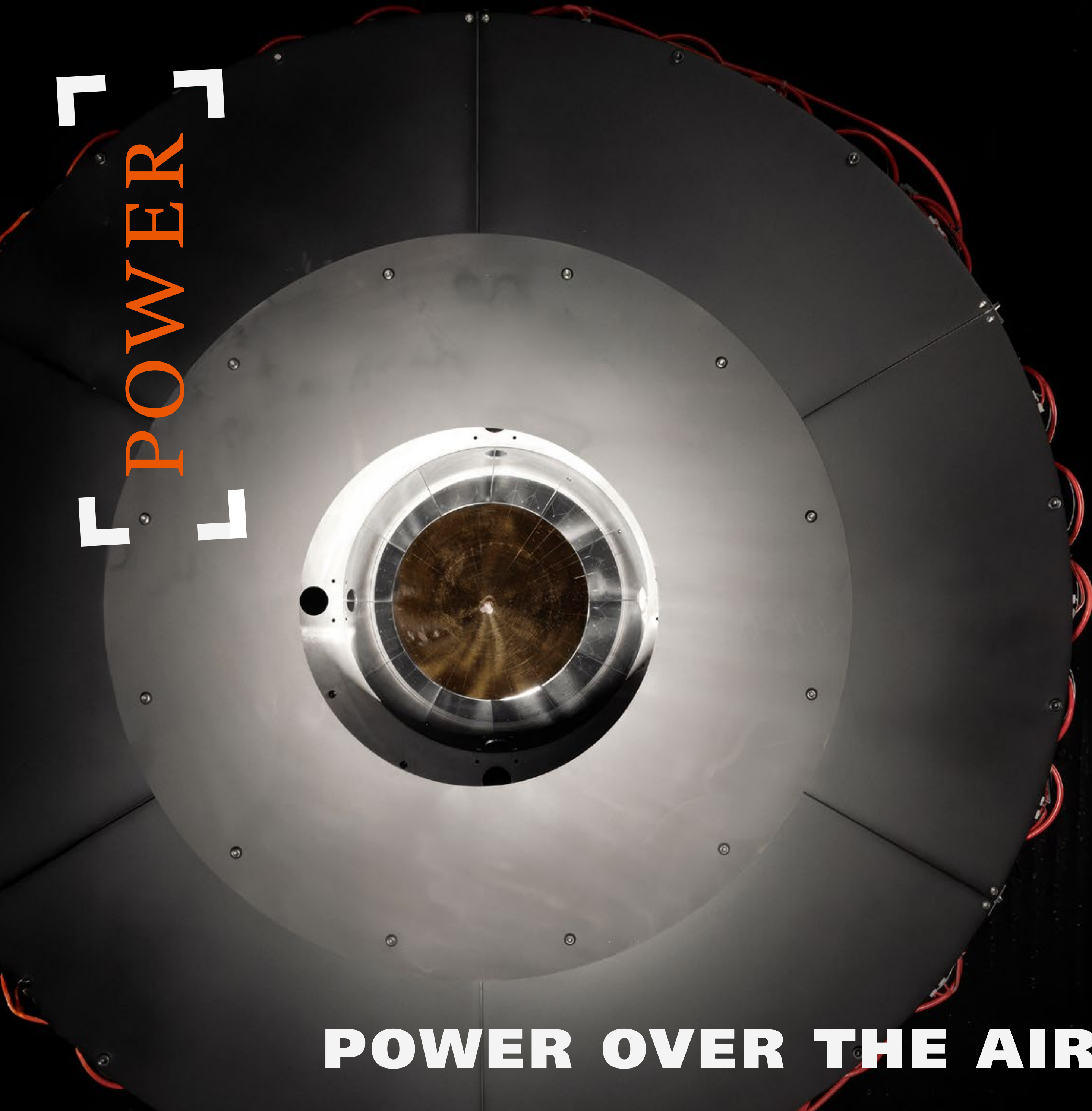
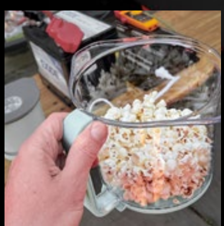


POWER OVER THE AIR

The US military has used a laser to transmit electrical energy almost nine kilometers through the atmosphere.



A wireless snack: The receiver (above) converts laser light back into electricity, which is then used to power a popcorn machine.

DARPA—in essence, the R & D wing of the US Department of Defense—is known for futuristic projects, some of which have since become reality: the Internet, AI, humanoid robots, drones. DARPA was running projects in all these fields at a time when most people had never even heard of them. Most recently, in June 2025, a team of researchers in the New Mexico desert successfully demonstrated the wireless transmission of electrical energy over a substantial distance.

A fiber laser, equipped with low-scatter optics, was trained on a receiver roughly ten centimeters in diameter and located at a distance of 8.6 kilometers. The receiver captured the laser beam with a parabolic mirror and directed the light onto small, ring-shaped solar cells arranged in a concentric pattern, which converted it into direct current. Within 30 seconds, 800 watts of power had been transmitted over the air. This amounts to around 20 percent of the electricity required to drive the laser beam. The researchers then used this energy to cook a bowl of popcorn.

In the first instance, however, the intended use is military—to power drones in-flight from the ground, thereby enabling them to remain in the air for extended periods or even permanently. In parallel, researchers also have a civil application in mind: photovoltaic systems in orbit. Using lasers, space-based solar power plants could provide people on Earth with gigawatts of electricity. ■

DARPA

GLORY

HIS HEAD IS OLDER THAN HIS FEET

Jun Ye knows this because he has built the world's most accurate clock.

After work, Jun Ye and his dog often take long walks in the shadow of the Rocky Mountains. A physics professor at the University of Colorado Boulder, Ye likes nothing better than to muse on the topics that continue to fascinate him: the connections between gravity and time, and between mass and space. As he explains: "If I raise my hand with my wristwatch, time passes a little faster up there. That's because it's now further away from the earth, and the force of gravity has decreased ever so slightly. And it's also why my head is a little older than my feet!"

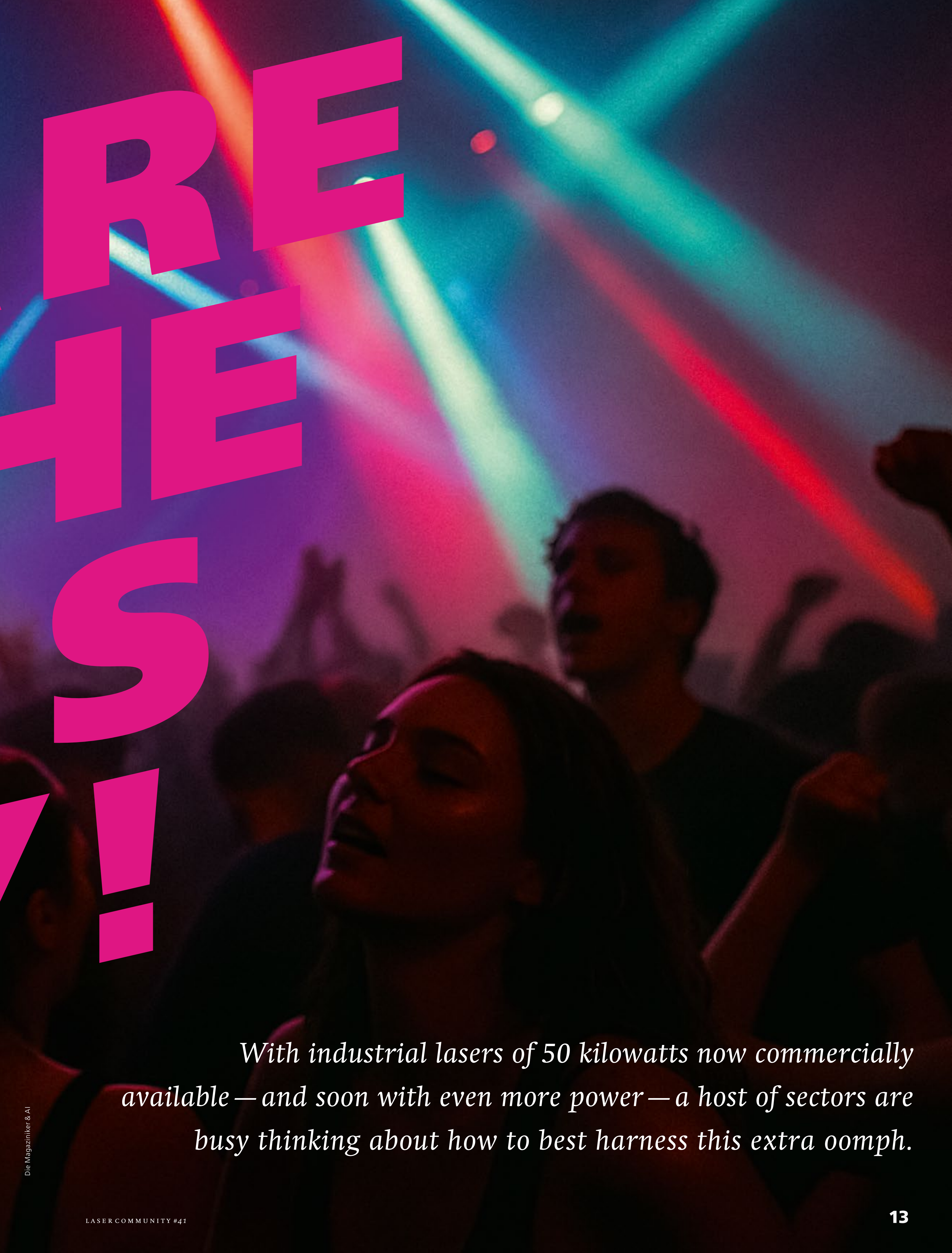
To measure such tiny time differences, Ye and his team have built a new kind of optical atomic clock, which loses less than a second over billions of years. A bundle of laser beams trap strontium atoms in an optical lattice and cool them to near absolute zero. Another laser measures the regular oscillations of these atoms—tick-tock—and thereby marks out time.

This optical atomic clock will be used in the development of quantum computers and in the field of astrophysics. Ye also dreams of other things during his walks: "I would love to solve the mystery of whether time really does flow continuously."

For his groundbreaking development, Jun Ye received the prestigious Berthold Leibinger Zukunftspreis in summer 2025. ■

On walks in the Rocky Mountains, Zukunftspreis winner Jun Ye likes to spend time reflecting upon how time really passes.

PREPA FOR TH 50-PLU PARTY



RE HE S !

With industrial lasers of 50 kilowatts now commercially available — and soon with even more power — a host of sectors are busy thinking about how to best harness this extra oomph.

Die Magaziniker & AI

ANYONE WITH AN INTEREST IN LASER PROCESSING NEEDS TO GET USED TO A NEW ABBREVIATION: UHP.

UHP stands for ultrahigh power—a technology that is set to take industrial laser processing to the next dimension. A laser is designated as UHP when it consistently delivers at least 50 kilowatts of average power with a brilliant beam quality. “Okay,” you might be thinking, “so we now have 50 instead of 30.” But here, as elsewhere, this extra quantity will create a platform for a whole new level of quality. For many potential applications, 50 kilowatts from a clean and extremely reliable fiber laser mark a major milestone (see following pages). Over the past few decades, universities and research institutes have produced numerous application concepts—surface cleaning, for example, or cavitation blasting—that have never found their way into actual manufacturing due to a lack of reliable laser power. High time to dig all those papers out!

Basically, there are three options here: (1) Doing the same processes as before, only much faster. (2) Processing a number of large areas at the same time. (3) Developing completely new applications that make use of this immense power.

ONE MEGAWATT AHOY! And with forecasts predicting a steady, linear increase in average power, the laser-processing industry can start preparing for even more punch. Indeed, over the next five to seven years, we can expect to see the first industrial laser cracking the one-megawatt mark. In other words, this technology just keeps on pushing the envelope—not least because laser power is also becoming more affordable. Back in 2008, one watt of laser power would have set you back around 100 euros. By 2017, the price had dropped to 55 euros per watt. Today, you can practically pay for that in pocket change. And, according to industry experts, this downward price trend will continue.

REASONS FOR THE BOOM What’s behind the new demand for UHP? On the one hand, there are the technological advances in laser manufacture itself. For example, new-design oval fibers can now withstand substantially greater pump power without failing. At the same time, optical components such as cladding mode strippers along with new mirror coatings and beam-shaping techniques (see page 19) tame the raw power and make it available for the desired application. On the other hand, it is also down to the increase in EV manufacturing in China and government support for the laser technology that this requires. Both have unleashed huge growth in the market for beam-source components and optics, triggering a sharp drop in prices. Finally, many of the other factors that previously hindered an industrial use of UHP have also shifted. In particular, not only has the electricity required to produce high laser power become cheaper; it can also be sourced without the need for a large power plant, as more and more factories are now supplying themselves from on-site photovoltaic installations. And the fact that today’s fiber lasers are more efficient also eases operation.

UPSHOT Industries such as shipbuilding and offshore wind have been clamoring for more laser power for years. For that reason, UHP will rapidly become established there. Meanwhile, many other sectors will now look to profit from UHP, including those that have never really used lasers in the past. The range of opportunities is immense. The following pages present UHP projects at varying stages of maturity. These are the players who have come to the 50-plus party. ■

Contact: Mauritz Möller, Head of Global Business Development Mobility at TRUMPF,
phone: +49 7156 303-34604, mauritz.moeller@trumpf.com

Mining rare earths

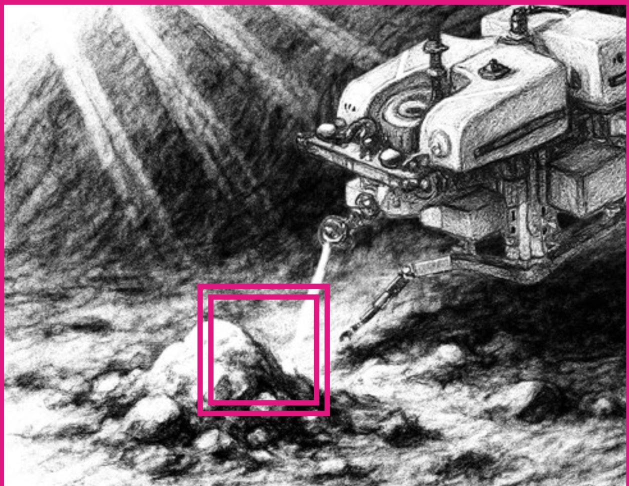
The extraction of rare earths is an arduous and immensely complicated procedure. Thanks to a new leaching process, deposits can be now exploited much more quickly. A UHP laser bores myriad channels in the rock. These are filled with special alkali solutions that absorb the rare earths. The enriched solution is then recovered and the rare earths separated.

Crushing rock

With the emergence of UHP lasers, a whole new field of application has emerged: mining and boring.

Geothermal drilling and tunnel boring

An integrated UHP laser assists a mechanical drill head during boring. The laser is fired at the rock, triggering a series of thermal shocks—i.e., a sudden, stark change in temperature—enabling the drill to penetrate more quickly. In geothermal drilling, operators can now bore ten times faster and pass through harder and deeper layers. This vertical technique is also being trialed in horizontal tunnel construction—resulting here, too, in a tenfold increase in speed.



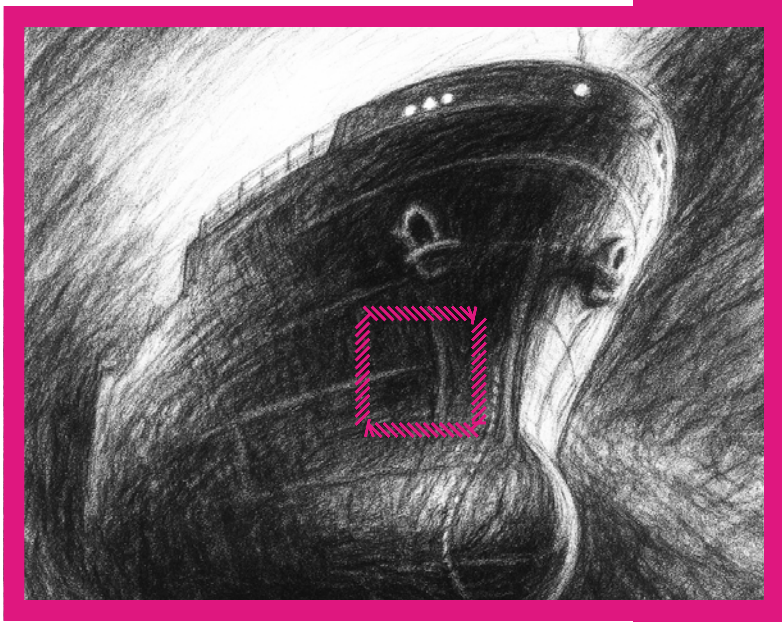
Deep-sea mining

Valuable materials such as cobalt, precious metals and rare earths can be extracted from the seabed. Deep beneath a supply ship, autonomous vehicles transport pieces of rock to an underwater UHP laser. In a process known as cavitation, a laser beam bores holes into the rock, vaporizing the surrounding water. This breaks the rock into small pieces, which are then transported to the surface.

Die Magaziniker & AI

Cleaning ship hulls

Biofouling on marine hulls—e.g., barnacles, mussels, algae—greatly increases drag and therefore fuel consumption. Using large-profile irradiation with UHP lasers, this can be removed in an economical and environmentally friendly manner either in dry dock or underwater.



Surface processing

Beam shaping enlarges the focal point of a UHP laser into a profile of one square meter. This boosts process times by several orders of magnitude.

Processing glass

A variety of laser-based methods are used to surface-process glass. With a UHP laser, there is so much power on tap that, even when used in wide focus, there is enough to process a large area simultaneously, thereby speeding up production. This includes the conditioning of architectural glass, where a laser is used to alter the microstructure of the surface. This results in less heat-inducing infrared light passing through the pane, thus significantly reducing the energy required for air conditioning.

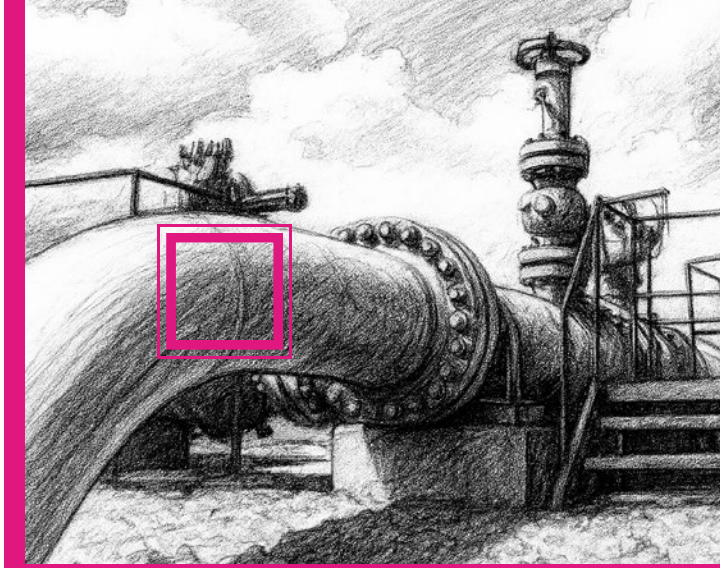
High-speed coating

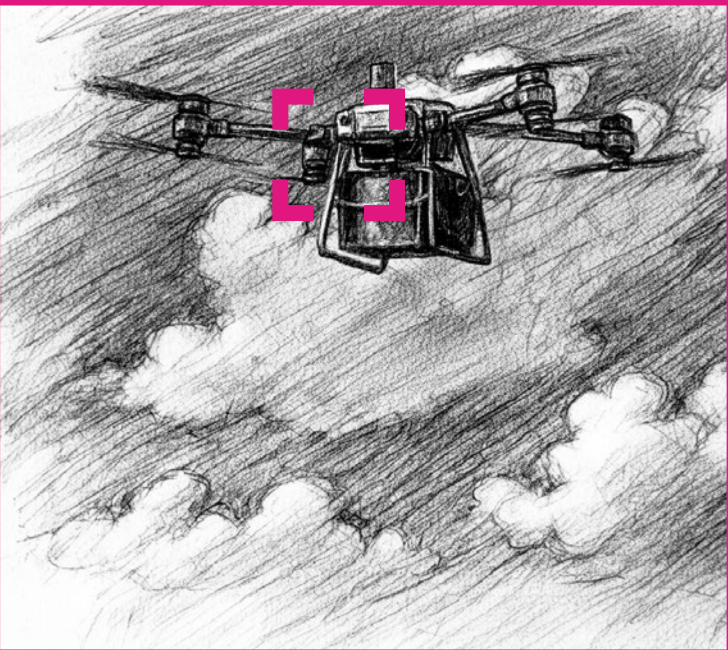
Functional coatings applied via laser metal deposition (LMD) enhance components. Yet process time and powder consumption are often prohibitive. In applications such as the rotary coating of brake discs with ultrahard carbide, the use of a UHP laser can boost speed and limit powder use. Here, a portion of the beam heats the surface so that more powder adheres, while the rest melts the powder.

Die Magaziniker & AI

Coating H_2 pipelines

By 2045, Europe is aiming to retrofit 45,000 kilometers of natural-gas pipeline to carry hydrogen. Yet H_2 is an extremely volatile gas. To prevent it leaking from the pipes, these must be given an external ceramic barrier coating. One option here is to use high-speed LMD with mobile UHP lasers equipped with special pipe optics.



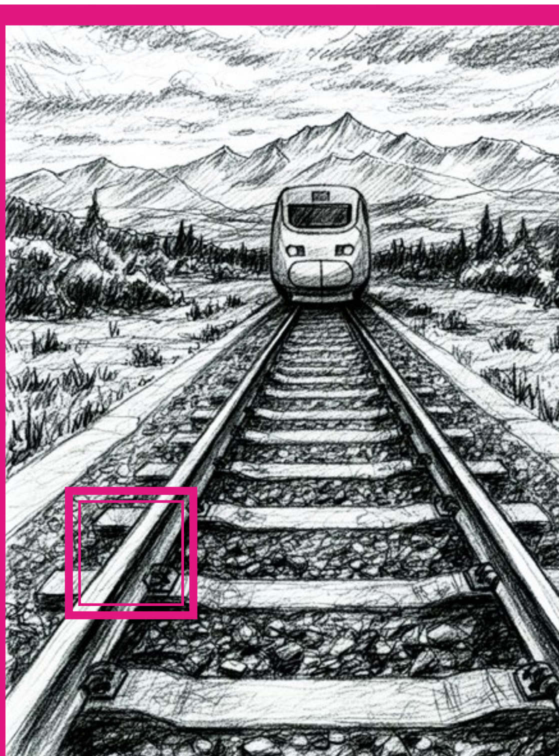


Mobile applications

No one says UHP laser sources must only be used inside. In fact, some of the best ideas are for outdoors.

Defending against combat drones

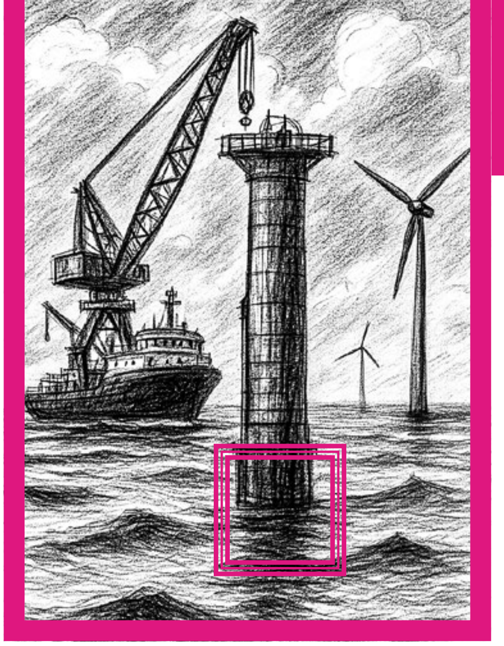
Drones are being increasingly used as weapons of war. Yet shooting them down often costs far more than the drone itself. Armies are now turning to UHP lasers, which offer safe and cost-effective defense against combat drones. Compact in design, such systems can be installed on ships and vehicles.



Repairing railroad tracks

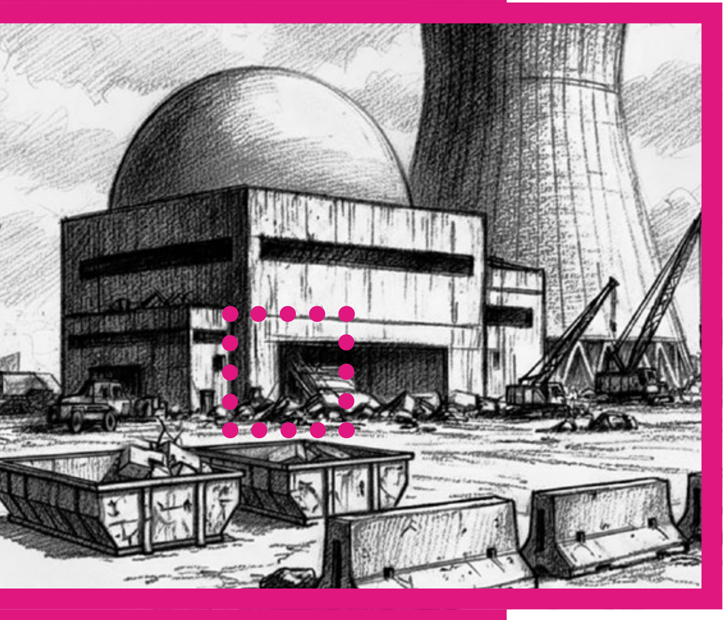
Over time, the surface of railroad tracks becomes cracked and uneven. The rumbling noise when trains pass over increases, and the resulting damage eventually destroys the rails. A vehicle equipped with a UHP laser can melt and harden the surface as it travels along the rails. As a result, trains run more quietly, and the tracks last longer.

Die Magaziniker & AI



Offshore and marine

Of all industries, the cry for UHP lasers has been loudest from the offshore and shipbuilding sectors. Both would dearly love to shift from submerged arc welding, which is not only slow and energy-intensive but also requires a lot of post-processing. For example, UHP would speed up welding work on the steel monopiles for offshore wind turbines by a factor of ten.

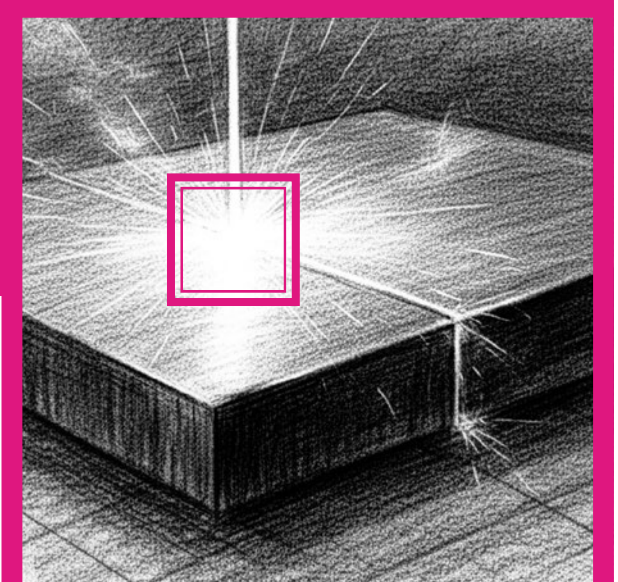


Thick components

For evident reasons, greater power offers the option to cut and weld thicker parts.

Decommissioning nuclear power plants

In Germany alone, 17 nuclear plants await decommissioning. In sum, that means 500,000 metric tons of thick steel and concrete—10,000 of which are contaminated. Robot-guided UHP lasers are used primarily in radioactive zones—for example, in the water-filled cooling tanks.



Cutting thick steel

With a UHP laser, it is possible to cut stainless steel parts of 400 millimeters in thickness at a rate of two meters per minute. In the past, manufacturers have had to use plasma cutting to handle parts this thick. UHP gives them a faster and more energy-efficient alternative.

Die Magaziniker & AI

{ Your perfectly shaped beam }

→ **Need a poster?**
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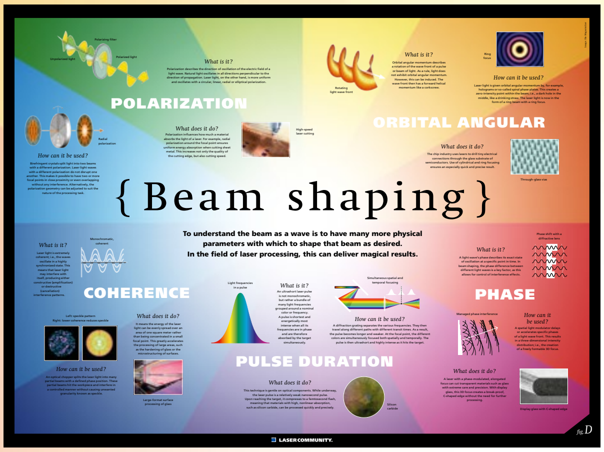
laser.community@trumpf.com



Often, an ultrahigh-power laser will fully unleash its power only when the beam has been manipulated. Thinking of laser light as a wave reveals the many ways in which its physical properties can be exploited. Our poster explains how the following tweaks produce magical effects in material processing:

- → *Modified polarization increases the absorption of metals.*
- → *Optical chopping for a large-format laser focus.*
- → *Orbital angular momentum results in a smooth ring beam.*
- → *Playing with pulse duration overcomes limits in surface processing.*
- → *Manipulating the light phase creates a 3D focus in all shapes.*

“iNTA IS LIKE FORENSICS FOR NANOPARTICLES!”

The iNTA system gives new insight into the world of nanoparticles, a breakthrough that could play a key role in the early diagnosis of various diseases. This is made possible by nano-optics expert Anna Kashkanova, the clever use of a laser, and special software.

Anna Kashkanova, what can iNTA be used for?
In the future, in quality control for medicines, vaccines and food. At present, we’re busy publicizing the method to find out what other applications it might have.

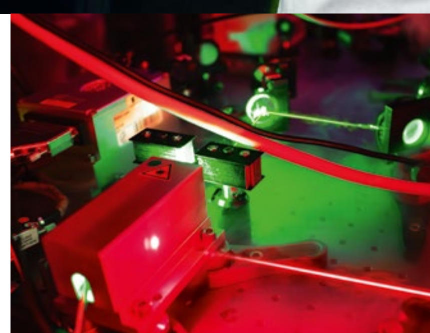
What’s so special about nanoparticles?
A lot. They are everywhere. For a start, they are a fundamental part of both the natural and man-made world. Many viruses, for example, are nanoparticles, as well as microplastic in our environment. In addition, there are engineered nanoparticles for medicines and vaccines. But we are particularly interested in biological nanoparticles, called extracellular vesicles. Diseased cells such as cancer cells secrete many more of these particles. This finding could be significant in the early detection of various diseases. That is why the next step is to detect nanoparticles and distinguish between them. With iNTA, we are leading the way and setting a real milestone in research!

Wow! And this couldn’t be done before?
No. For the past decade, the common method used over the last ten years has been NTA, or nanoparticle tracking analysis. Researchers examine the size, size distribution and concentration of the particles in their natural environment, such as in a drop of blood. For the analysis, the researcher exploits two properties. The first is that the particles scatter light. A cover glass with a sample of nanoparticles in liquid is placed above the objective of a microscope. A laser beam illuminates the sample from below, and the particles scatter the light. But a part of the light is reflected by the cover glass. This creates a strong light beam that overpowers the scattering of the particles. To counteract this, the researchers position a camera to the side of the lens. This collects the scattered light, and the particles are visible in the image as a dot pattern. Alone, however, this is not enough to tell us more about the particles. Here comes the second property into play: the particles move randomly. This is called Brownian motion, which the camera records frame by frame. The smaller the size of the particles, the faster the individual dots are seen to move. However, NTA has weaknesses: Smaller particles scatter less light, which makes them harder to see. As a result, the camera requires longer to record each image of the particles. And fewer frames per second make the measurement inaccurate.

And you can do this better?
iNTA can. We combine interferometric scattering microscopy (iSCAT) with NTA. Unlike NTA, we use the light that is reflected by the glass. When the faint scattered light meets this strong reflection from the cover glass, they interfere with each other—they combine. That makes the nanoparticles more visible. This alone simplifies the determination of particle size, but iNTA goes one step further. Due to the interference, in the recording with iNTA we see the particles in the form of rings. Similar to the ripples that are produced when raindrops hit a puddle. This makes it easier to determine particle size. We have developed specialized software that enables us to calculate the center point of the rings. This marks the particle’s position to a degree of accuracy in the nanometer range. Using this point, we can track the motion of the particle more precisely—and therefore determine its size more accurately.

But that wasn’t the real milestone, was it?
Correct. With iNTA, we can do something like forensics for nanoparticles. With interference we can make conclusions about their composition. To do this, we measure the degree to which the particles scatter light. Gold particles, for example scatter a lot of light. Biological nanoparticles less. Using this information and the size of the particle, we calculate the refractive index. This provides an optical fingerprint of the material and enables us to reliably distinguish nanoparticles. ■

PRIZEWINNING For the groundbreaking development of the iNTA method, the team of the Max Planck Institute for the Science of Light under the direction of Vahid Sandoghdar (left) won the first prize in the Berthold Leibinger Innovationspreis 2025.

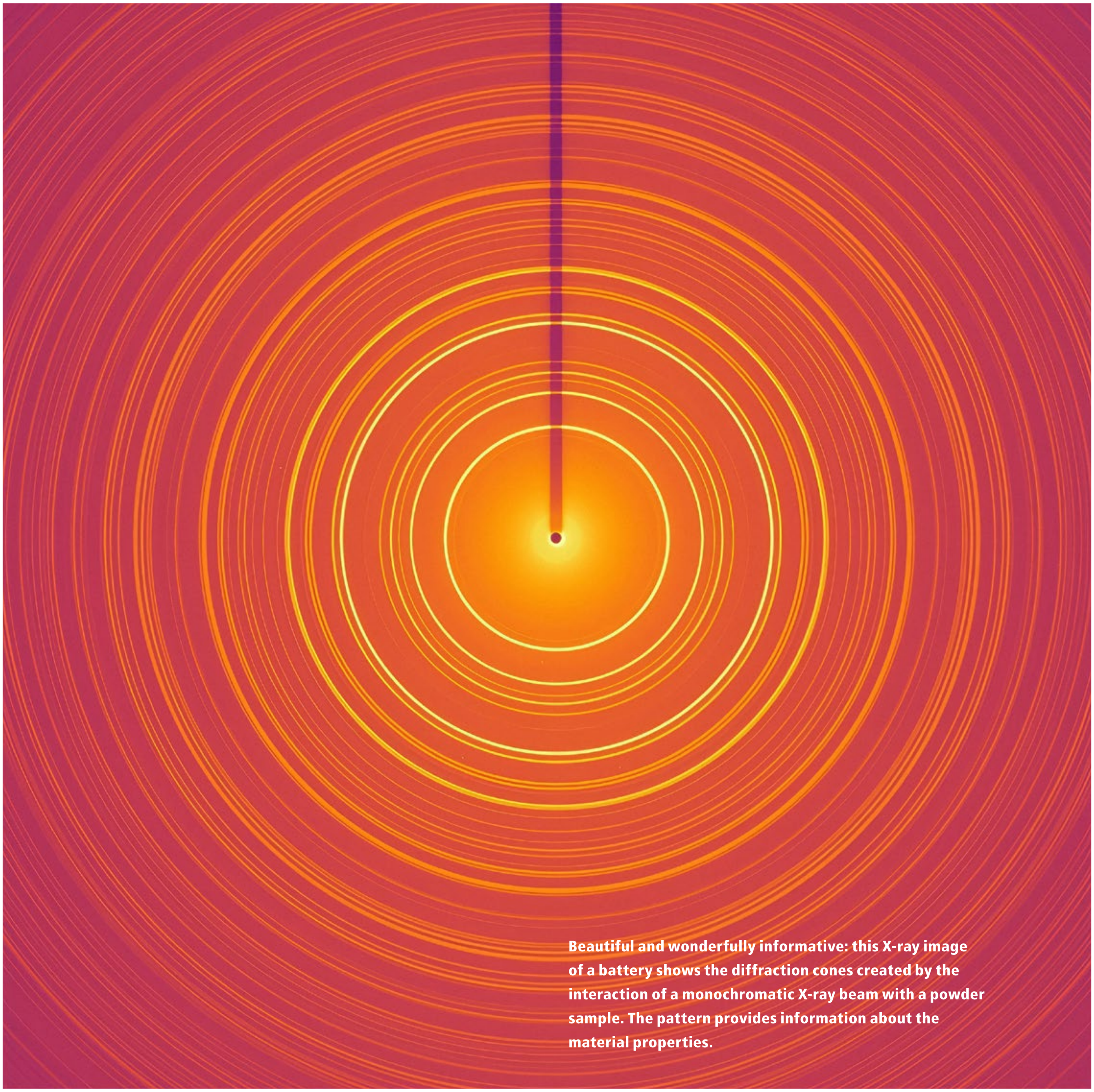


Anna Schroll, Maximilian Schlosser / Berthold Leibinger Stiftung

CHANCE DISCOVERY While analyzing gold nanoparticles, Anna Kashkanova and her colleague Martin Blessing discovered that they could determine the size of nanoparticles more precisely using interference than with conventional methods.

COMPLETELY FOCUSED The iNTA instrument uses a second laser for the reliable analysis of the nanoparticles. As the sensor of a "focus lock" system, it detects the slightest movements of the cover glass, which are electronically readjusted for optimal camera focus.

X-ray view of a battery interior



Beautiful and wonderfully informative: this X-ray image of a battery shows the diffraction cones created by the interaction of a monochromatic X-ray beam with a powder sample. The pattern provides information about the material properties.

DESY / Martin Etter

The EV industry would love to extend battery life, increase capacity and further reduce charging times. For that, however, they need to be able to look inside the battery itself. To make this economically viable, a project team is building the first ever small-format brilliant X-ray source.

The lifeblood of electric mobility is the battery—or, more precisely, its durability, energy density and charging behavior. All three depend on the electrochemical performance of the cathode and anode materials in the battery cell. This, in turn, is negatively impacted by impurities and minute changes in the crystalline structure of these complex materials. Using X-rays and X-ray microscopy, it is possible to track in real time how batteries age over charging and discharging cycles.

X-ray technology serves to image and quantify such processes at the atomic level and at a high temporal resolution, showing how and when strains occur during the charging cycle. Yet this requires very high beam brilliance—i.e., extremely intense X-rays that are focused in one direction on a small area. Production of these is well beyond the capabilities of conventional medical X-ray sources. Conventionally, this requires a synchrotron. In this type of particle accelerator, which can be hundreds of meters in length, electrons are accelerated to practically the speed of light and then deflected along a special path by magnetic fields. This causes them to emit extremely brilliant X-rays. Yet for battery manufacturers, research and analysis time at a synchrotron facility is both difficult and expensive to obtain—and therefore not a feasible option.

TENFOLD BEAM BRILLIANCE However, recent advances in X-ray technology promise to provide a much more flexible solution. In the state-funded XProLas project, research partners under the leadership of TRUMPF are busy developing a laser-driven X-ray source that delivers unprecedented beam brilliance. This will reach a new order of magnitude and outstrip today's technology by a factor of ten. The new laser source is intended for use in quality assurance and further development of EV batteries. And, best of all, the entire system costs only a fraction of a synchrotron, occupies the space of a generously sized mobile home and will be suitable for industrial use.

The key component used in the generation of X-rays is an ultrashort-pulse (USP) laser. This fires high-energy pulses at a target—in this case, either a wheel coated with liquid metal that rotates in a tin bath or a fine, continuous jet of liquid metal. The energy in the laser beam causes electrons to be stripped from the atoms of the metal, thereby generating an extremely hot plasma and accelerating the electrons to practically the speed of light—as in a synchrotron, but over a much shorter distance. As the electrons decelerate within the electromagnetic field of the atomic nuclei, this generates hard, short-wave X-rays. To roll back the boundaries of this technology, XProLas has taken the very latest USP laser from TRUMPF and, in a world first, slashed pulse duration from one picosecond to below 50 femtoseconds. This tweak has catapulted peak power from 10 to 200 gigawatts.

HOW HAVE THEY BEEN ABLE TO SHORTEN PULSE DURATION? A lot of applied physics has gone into this massive reduction. A basic rule says that any shortening in pulse duration is accompanied by a broadening of its color spectrum. Here, XProLas exploits nonlinear effects that occur at high light intensities. A laser beam is fired at a gas-filled chamber. The gas therein reacts in a nonlinear way—i.e., disproportionately—to changes in the field strength of the laser pulse. The result is that photons move from the infrared spectral range of the laser to other frequency ranges, thus generating new colors and broadening the color spectrum.

This doesn't yet result in a shorter pulse, as the frequencies are still not synchronized. They still "chirp" to one other, like the voices in a canon. This chirping is eliminated by downstream pulse compression, which involves passing the pulse through a set of dispersive mirrors. These mirrors comprise a number of layers, meaning that different light colors penetrate the mirror to varying depths before being reflected. This equalizes the difference in propagation times, so that all the frequencies arrive at the end of the pulse at the same time—and the pulse becomes shorter.

THREE X-RAY SOURCES UNDER DEVELOPMENT When harnessed to suitable beam-guidance optics, these hard X-rays will yield nanometer-precise images, extremely short exposure times and measurements of atomic processes over minuscule time spans. Three functional lab-based X-ray sources are to be created at different XProLas locations by the end of 2026. These will be used for X-ray diffractometry and various other X-ray analysis techniques, with a focus on cathode materials from partner BASF. Other possible applications include high-resolution imaging of nanostructures in microchips.

This is also good news for battery manufacturers. The new X-ray sources will not only improve data quality and lower detectability thresholds. They will also open up completely new experimental opportunities for the further development of EV batteries—and do so in an industry-friendly format. So get ready for a new generation of batteries! ■

Author **Torsten Mans** is responsible for Secondary Sources at TRUMPF.

FOUR BEAMS FOR GIGA-STAMPINGS

With its gigastamping strategy for large components, Gestamp is revolutionizing vehicle body construction: larger structural components, less weight, greater efficiency. But laser welding, of all things, threatened to spoil the party — until a shaped beam from multifocus optics saved the day.

Fotogloria / Luis Cerdeira

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Miguel Angel Ferrandez, Material Joining and R & D Tokyo/Bilbao director at Gestamp, stands in Bilbao and states the obvious: “The fewer components a vehicle needs, the faster it can be manufactured and assembled.” Ferrandez heads up the development of new car body structures at Gestamp, a multinational automotive components company. Based on this simple insight, he and his team have developed a consistent efficiency strategy for vehicle body construction called Ges-Gigastamping®: Instead of stamping many smaller components and then laboriously welding them together, Gestamp presses large car body components such as door rings, floor panels, side frames and rear wall modules in one piece. Huge high-performance presses with several thousand tons of pressing force rumble in plants around the world, warm-forming high-strength steels into large structural components. Thanks to material savings in non-load-bearing areas, the components are noticeably lighter overall than those assembled from multiple parts—creating more sustainable vehicles and good for the range of electric cars! They are also more crash-proof—good for future occupants! And stamping saves its customers time, labor, space and energy in assembly because many handling and processing steps are eliminated.

Miguel Angel Ferrandez (right) implements multifocus technology at Gestamp.

PROTECTIVE COATING IN THE WAY

However, the gigastamping parts also place higher demands on joining processes and laser welding is an alternative to be used. “And we definitely want to continue laser welding! It’s five times faster than spot welding and the seams are much more stable,” Ferrandez emphasizes. In gigastamping production, Gestamp uses press-hardened steels with aluminum-silicon coating that provide corrosion protection, but hinder laser welding. The main challenge with coated steel is avoiding the need for ablative processes, which add time and complexity.

MULTIFOCUS MAKES IT POSSIBLE

Ferrandez first asks himself what can be done and then TRUMPF. After a few attempts, the engineers there know how to solve the problem: with laser beam shaping in multifocus optics. It sounds simple, but it’s almost like magic: the optics first divide the beam into four parts with equal energy input. Each of the four beams is then split into a core beam and a ring beam. And then the following happens during welding: The four ring beams calm the molten pool and prevent splashes. Meanwhile, the four core beams mix the coating homogeneously and in a controlled manner in the molten pool. It’s like dough: The more stirrers mix the mixture, the fewer lumps there are. The end result is stable seams with high hardness and tensile strength.

AND THEY LOOK GOOD, TOO “Thanks to TRUMPF’s laser technology and Gestamp’s joint development efforts, we can now weld coated materials safely and efficiently, eliminating the need to remove protective coatings and simplifying the entire process. And the seams are nice and smooth, too,” says Fernandez. “Vehicle body components have what are known as semivisible surfaces—a nice detail that customers appreciate,” explains Ferrandez, continuing: “But what is more important to us in multifocus welding is the high speed, the metallurgical seam quality and—crucial in vehicle body construction—significantly better accessibility. Unlike spot welding, which only allows for a top and bottom, the laser beam has no such limitation.”

Alongside the multifocus technology, Gestamp implemented its proprietary joining solutions Ges-Wire® and G-Weld Overlap. With G-Weld Overlap, using remote laser systems, Gestamp developed a G-shaped weld joint that enables up to five times faster welding speeds, significantly improving production efficiency and quality. ■

Bernhard Huber, courtesy of Deutsches Museum in Munich

“SOMETHING AS MUNDANE AS THE LIGHT BULB REVOLUTIONIZED PHYSICS!”

Alexander Lucas explains to museum visitors how light works. As someone who studied physics, he is well aware of the difficulty of this task. Yet, as he explains, a well-founded lack of knowledge is better than unfounded half-knowledge.

Alexander Lucas, please explain the fundamentals of quantum optics!

Do you know the basics? Without that, it's going to be difficult!

But that's your job: explaining the nature of light to the layperson, as an exhibition guide at, for example, the Deutsches Museum in Munich!

Yes, my topics do include quantum optics and how our understanding of light and matter has impacted research and society over time. These are complex ideas and difficult to get across, particularly in the short time I have available for a guided tour. Unfortunately, it takes more than five minutes to explain what a Bose-Einstein condensate is, or how a quantum computer works, if you haven't spent at least a semester studying quantum mechanics! But I do believe that a good exhibition can help present the groundbreaking discoveries that have been made in this field.

How much knowledge do museum visitors already have?

My impression is that their knowledge is pretty sketchy on the whole. Very few people understand light in the way that we in the physics community talk about it. That said, in the case of some questions, even the experts are stumped.

Can you give us an example?

Well, take the laser. Its discovery goes back to the idea of stimulated emission, which Albert Einstein formulated in 1917, long before the laser was invented. Einstein predicted that if an incident photon interacts with an atom already excited with the same energy as the incident photon, that atom will emit a second photon with exactly the same energy, phase and direction as the incident photon. But if you ask why the second photon has exactly the same direction as the incident photon, I've never been able to find anyone who can answer this question. Not even people who are involved with lasers in a professional capacity. And I still don't know the answer myself! Amazingly, however, you can still build a laser without understanding its physical principles in detail.

Why is there a lack of knowledge here?

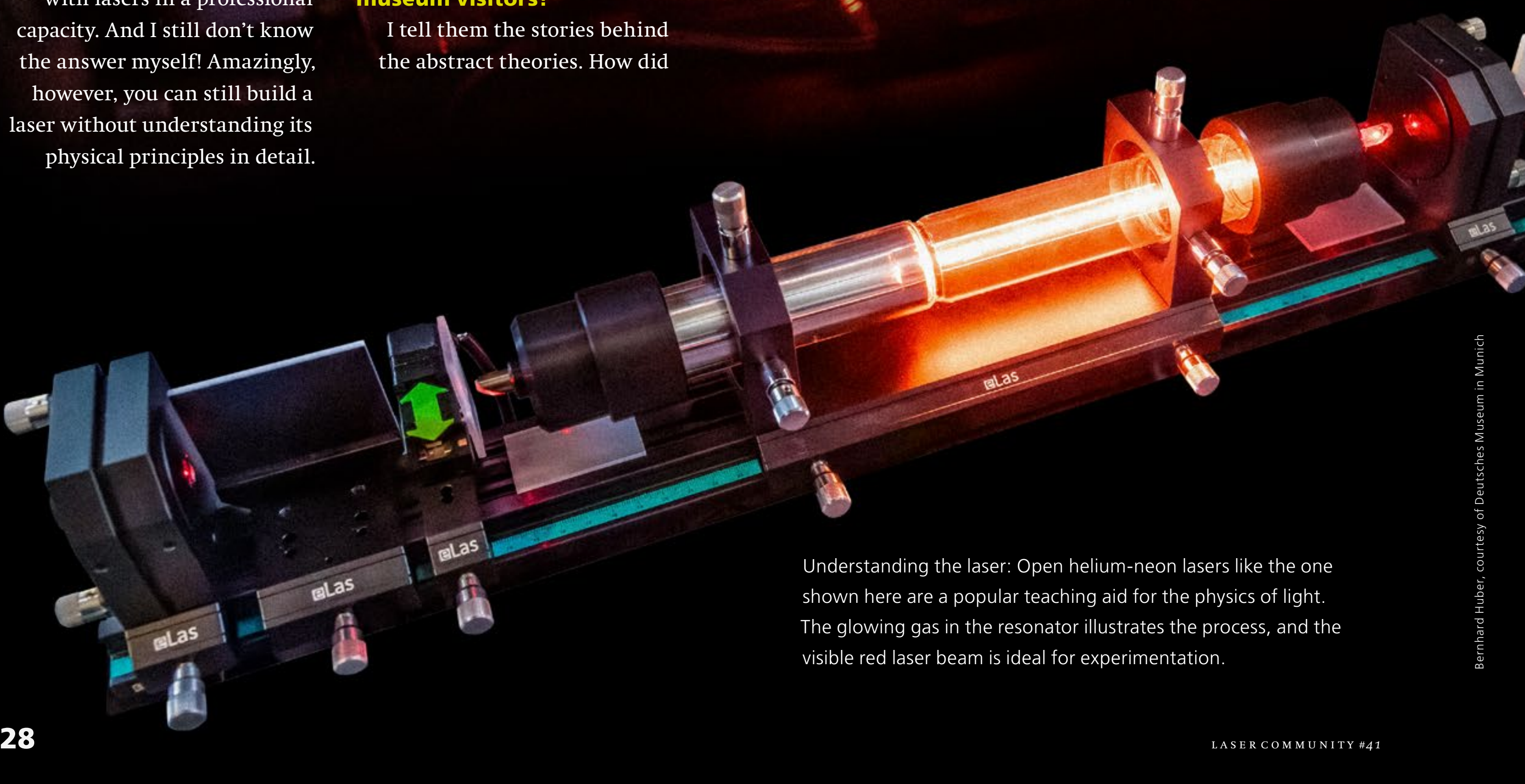
I think we're overwhelmed by such topics—understandably so, because they're beyond our realm of experience. For me, it's just fascinating to think about light precisely because the phenomena behind it can't be grasped by our senses. The nature of light is so strange that I have difficulty intuitively understanding the latest explanations for it. Take Richard Feynman's idea that light on its journey from source to destination takes all the possible paths in the universe. You quickly reach a point where you say: Hey guys, this is starting to sound like Harry Potter! Even as a physicist, you need to spend a lot of time thinking about it. Otherwise, you can end up with a false picture of the way things are. Even a university degree won't protect you here, because this is a subject that explodes our normal way of thinking.

OK, but if even physicists begin to struggle, how do you explain light to museum visitors?

I tell them the stories behind the abstract theories. How did James Clerk Maxwell, Albert Einstein and Max Planck come up with their ideas? Sometimes in unexpected ways. And sometimes via a great many steps before it was recognized that, for example, electromagnetic waves and light are the same thing. It was a long journey before Planck came up with his radiation law, which would provide the basis for quantum physics. My aim is to give some idea of what an exciting period the three decades between 1900 and 1930 actually were. It was during this time that, for example, the theory of relativity was formulated. And to show people what an amazing intellectual achievement this involved. It's crazy to think how the fundamentals of physics were turned upside down over such a short period of time. Without such visionary thinkers, we wouldn't have lasers, computers or even much more mundane inventions such as the microwave oven.

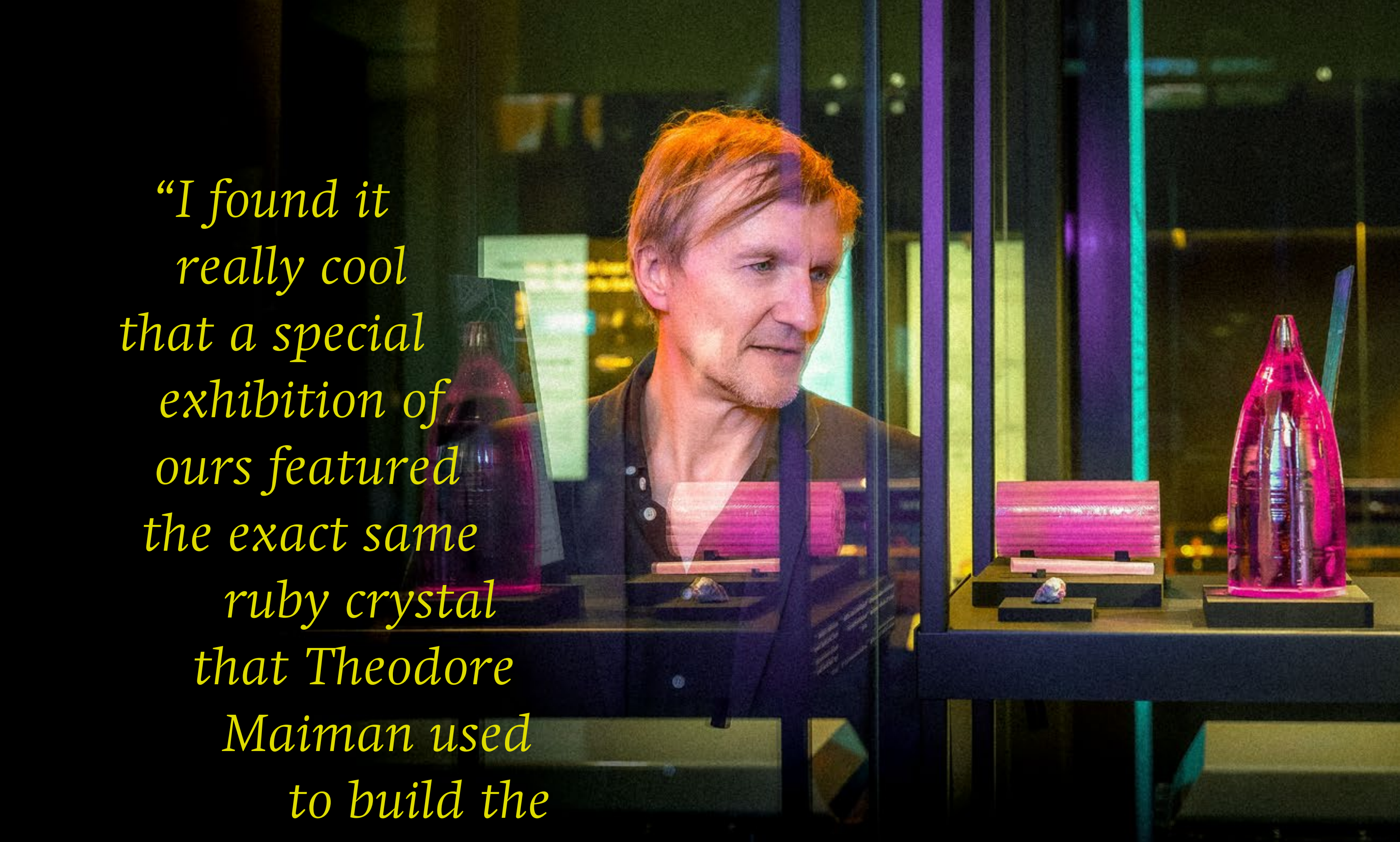
What do visitors like best?

Hearing about how it all began. In other words, how it came to be understood that light can be described as a wave, and how it was discovered that the colors of light that we see are only a small part of the entire electromagnetic spectrum. I think people find that exciting. Or the question of how Max Planck came up with the idea of quantizing energy. This only arose because he was commissioned by the Physikalisch-Technische Reichsanstalt—the Imperial Physical Technical Institute in Berlin—to study the radiation characteristics of light bulbs and thereby discover the best amperage for optimum luminosity. But Plank's measurements didn't perfectly match the theories of the time. More out of desperation, he then made the revolutionary assumption that energy is emitted not continuously but rather in



Understanding the laser: Open helium-neon lasers like the one shown here are a popular teaching aid for the physics of light. The glowing gas in the resonator illustrates the process, and the visible red laser beam is ideal for experimentation.

Bernhard Huber, courtesy of Deutsches Museum in Munich



"I found it really cool that a special exhibition of ours featured the exact same ruby crystal that Theodore Maiman used to build the world's first working laser."

Alexander Lucas studied physics at RWTH Aachen University and wrote his diploma thesis at the Fraunhofer Institute for Laser Technology ILT. It was during a summer session at the University of California, Berkeley, that he discovered there are other ways of conveying scientific knowledge. Although he would have made a good teacher, he initially went into management consultancy and related areas before becoming a museum guide. He regularly leads tours of the Deutsches Museum in Munich, one of the largest science and technology museums in the world.

quantized packets, the energy of which is proportional to the frequency of the radiation. In other words, it was something as mundane as the light bulb that revolutionized physics. I try to describe all these connections in a such a dynamic way that visitors can transport themselves back to that time. And the early part of the story is not so difficult to understand. You don't have to bend your picture of space and time all that much. That comes later!

What role do the exhibits play in all this?

There are a lot of science centers that showcase current scientific and technical knowledge. Museums do this, too, but here the *historical* dimension of science plays a bigger role. Using artifacts from the period, we try to convey this side of things. I think that when you see the original, the historical reference is much more present. An object like this has an aura that an illustration on a display board can't match. For example, I found it really cool that a special exhibition of ours featured the exact same ruby crystal that Theodore Maiman used to build the world's first working laser.

What do you hope to achieve with your guided tours?

I want our visitors to rediscover a sense of wonder at the world's infinite complexity, and the importance of science for our understanding of it and for a strong economy. The history of light is a perfect example of this. And the real icing on the cake is when people begin exploring for themselves, instead of simply waiting for YouTube to add another item to their playlist. Personally, I find that wonderfully enriching.

And you think it works?

Well, that's what I hope, at least. It would be nice to think that my guided tours might provide people with an incentive to engage with ideas about light. Or, at the very least, that people will come and see the exhibition and then perhaps have a *better* sense of their lack of knowledge about how light works rather than knowing nothing about it at all! ■

Mexico

OVERVIEW OF THE ECONOMY

Mexico has recently become **the most important trading partner of the US**, profiting immensely from the trend among global US corporations to reshore production to North America.

Mexico's industrial base is dominated by **the automotive, aerospace, electronics and advanced manufacturing sectors**.

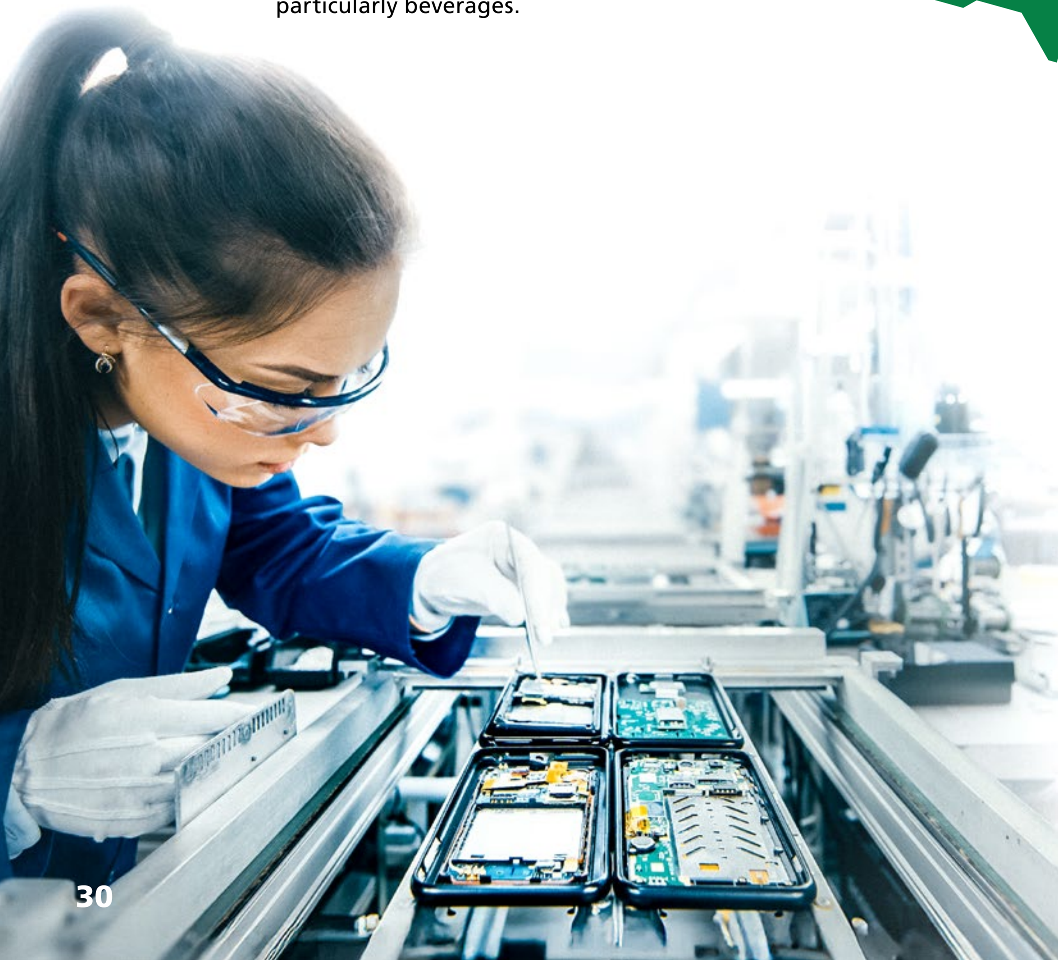
Two further pillars of the economy are **tourism and food exports**, particularly beverages.

WELCOME TO MEXICO, LAND OF LASER TECH!

131 million inhabitants

17% Industry as a proportion of GDP

14,000 US dollars Nominal GDP per capita



LASER LAND

Major investment in Mexico by multinational corporations is accelerating **the use of advanced manufacturing methods**, including a whole range of laser-based processes. This is attracting further investment from high-tech areas such as the electric vehicle (EV) industry and even semiconductors. **Innovation hubs** such as the Centro de Ingeniería y Desarrollo Industrial (CIDESI) near Mexico City develop customized laser applications for domestic companies.

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WHERE'S THE LASER?

AdobeStock/Davidbenito

In the flutter of an eyelash. Of all the many tweaks designed to primp the human body, false eyelashes are—as rule—some of the most discreet. Advances in manufacturing over the past two decades have turned this ornamental eyewear into a cheap mass-produced article popular around the world. Two properties are key when it comes to gaining and edge over market rivals: appearance and adhesion—the lashes should look good and stay stuck for the duration. To achieve this, more and more manufacturers are using UV lasers to create tiny grooves on the surface where false eyelashes are glued to real ones. This increases the area of adhesion, making it easier to apply the lashes more precisely and stop them clumping with the adhesive. In addition, the microgrooves create a stronger bond, meaning the eyelashes stay fluttering for longer. ■

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A nail …

… lies on the highway across the Golden Gate Bridge. Amazingly, a new laser telescope developed at the University of Science and Technology of China in Hefei is capable of detecting objects this small from a distance of over 1,000 meters. This is useful, for example, for the remote inspection of tall buildings or bridges, where a rapid scan can detect fine cracks or damage to the facade. Behind the new system is a technology known as active intensity interferometry. A total of eight infrared lasers are shone at the target; and two telescopes capture the reflected light. Based on minuscule differences in these signals, an image is generated with a resolution up to 14 times greater than that produced by conventional telescopes with the same optical parameters.

unsplash/Denys Nevozhai