LASER COMMUNITY.

Of people and photons

#39

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LASER COMMUNITY. #39

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Dear Readers,

at TRUMPF, we truly believe that the path to a more sustainable world can only lead through innovation rather than abstention. Our mission is therefore to use the innovative power of laser technology to make the world a better place. When it comes to leveraging innovation to create a more sustainable world, lasers offer much more than just a means of boosting efficiency. They also play a vital role in the quest to make industry more environmentally friendly. The current issue therefore features an array of laser applications, each of them highly innovative and cost-effective—and some in surprising areas.

Laser tech continues to play a key part in smoothing the energy transition. Examples here include the production of efficient and inexpensive photovoltaic systems in the solar-power industry, where lasers are reducing the amount of silver found in solar cells and helping to ease recycling. At the same time, TRUMPF laser processes are now being used to etch printed circuit boards in chip manufacture and to clean components in the automotive industry, thereby enabling efficient and environmentally friendly production methods without the use of hazardous chemicals. And even in the world of farming, lasers are becoming more and more common, with applications ranging from laser-based weeding to determining the sex of chickens while still in the egg *(see page 12)*.

Collaboration with automotive supplier Nagel Maschinen- und Werkzeugfabrik is helping to cut air-borne emissions of particulate matter. By equipping its machines with our laser systems, Nagel has now made it possible to manufacture virtually abrasion-free brake disks, which produce substantially fewer particulates and thereby meet the strict requirements of the Euro 7 standard. Based on high-speed laser metal deposition, this process not only improves air quality but also remedies a well-known weakness of electric vehicles: as coated disks do not rust through infrequent use, EV braking performance is no longer impaired. Moreover, the coating extends brake-disk service life many times over. In other words, this marks a real milestone for the automotive industry *(from page 6)*.

At TRUMPF, we are committed to the development of pioneering technology and sustainable solutions that satisfy both ecological and economic concerns. Together, we can create a better and more sustainable world. I invite you to find out more about our innovative approaches and projects on the following pages. So let's shape the future together—in a sustainable and responsible manner.

DR. RER. NAT. HAGEN ZIMER

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

LASER

Trick

OEM brake disks are surprisingly heavy—and highly confidential. Nagel CEO Claus-Ulrich Lott throws a lightweight plastic dummy in the air for our photo on **page 6**.

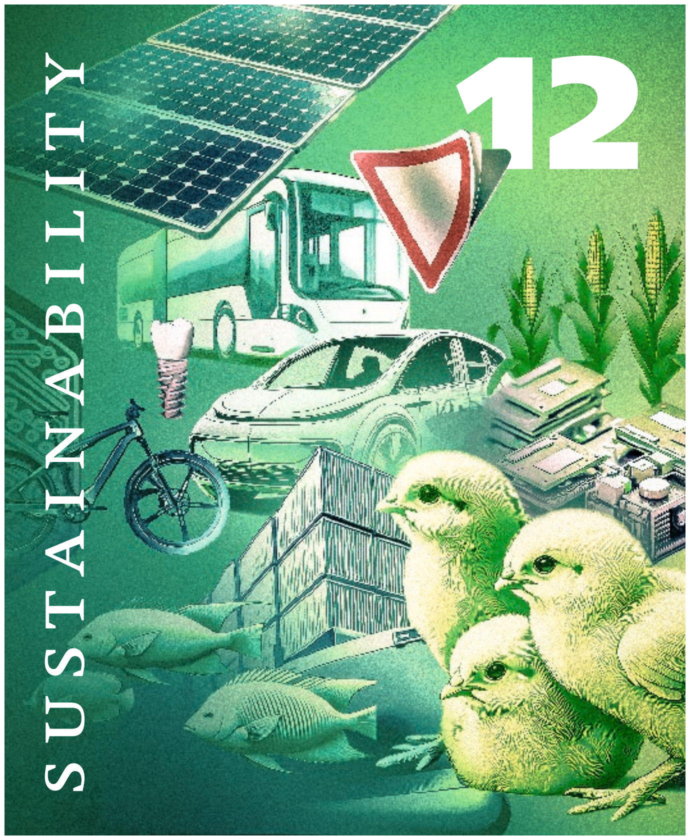
Click

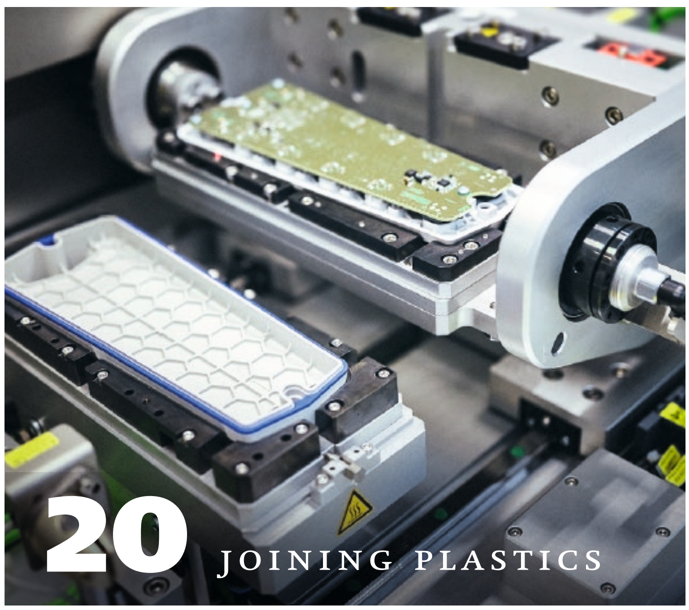
As a rule, award-winning photographer Nicole Franco works for *Netflix, The New York Times* and *National Geographic*. See her great work for us on **page 26**.

Chic

Professor Clara Saraceno gave an extended interview to *Laser Community* in 2019. Back then, Carsten Behler took this wonderful photo. For something similar, turn to **page 11**.

Tobias Gerber, Nicole Franco, Carsten Behler





Tobias Gerber, Die Magaziniker & AI

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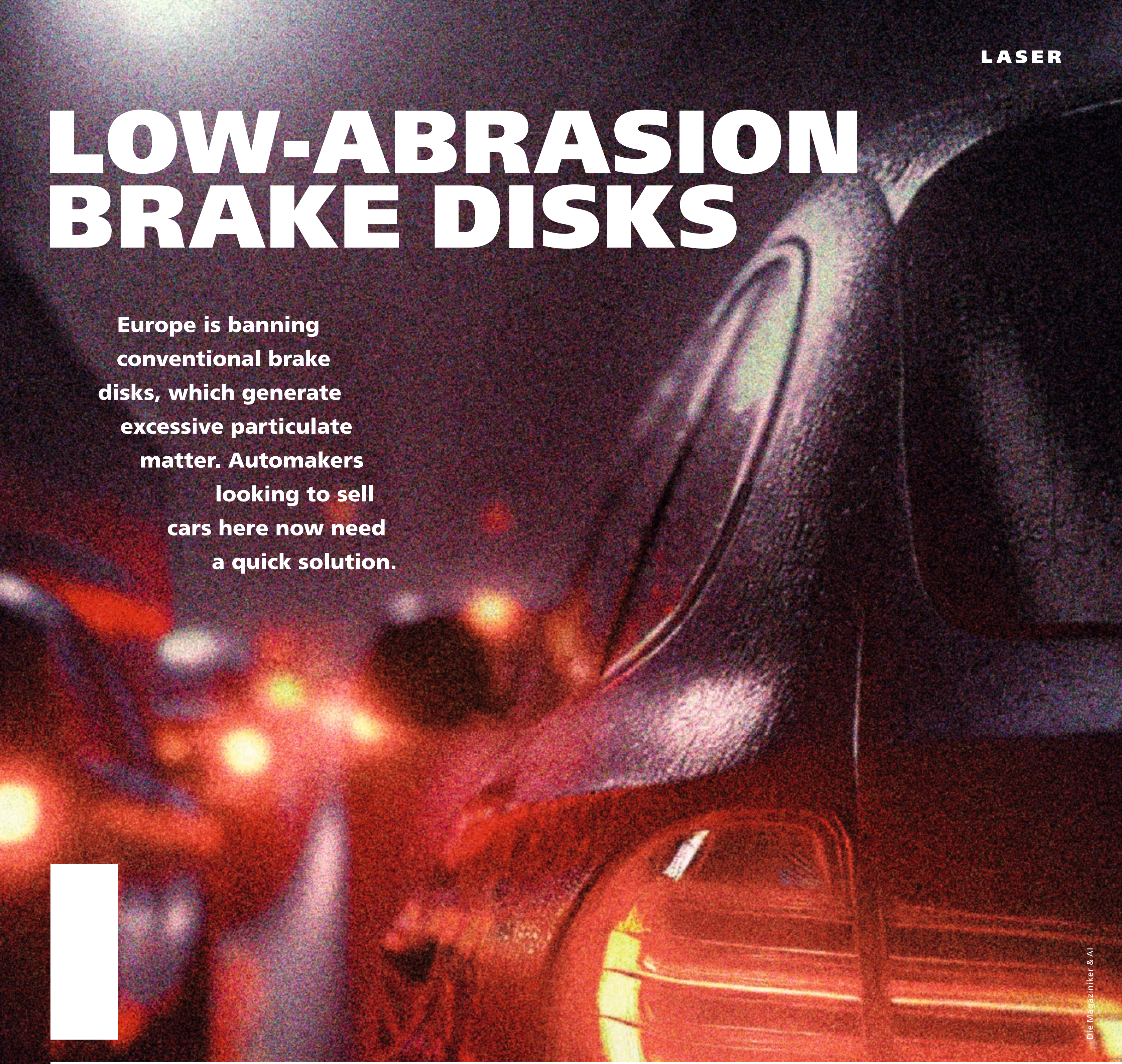
LOW-ABRASION BRAKE DISKS

Europe is banning conventional brake disks, which generate excessive particulate matter. Automakers looking to sell cars here now need a quick solution.



Die Magaziniker & AI

It's not the exhaust that spews out most of the dirt. In fact, up to 70 percent of the particulate matter (PM) emissions generated by modern automobiles come from tire and road abrasion as well as braking. This applies to electric vehicles too. According to estimates by the European Environment Agency (EEA), around 250,000 European citizens die prematurely each year as a result of excessive PM emissions. In the past, the European Union has merely regulated exhaust emissions of gasoline and diesel vehicles. With the introduction of Euro 7, the latest European emission standard, it is now tackling the particulate matter generated by tires and brakes. This means that automakers intending to sell new vehicles in the EU through 2026—and that's all of them—now need to find a way of reducing brake disk abrasion by 80 percent.

A TOUGH NUT Dr. Claus-Ulrich Lott is CEO of Nagel Maschinen- und Werkzeugfabrik in Nürtingen. He strides through the light and airy older wing of the main factory, outlining the steps the company took to develop a new solution. "What kind of process were we looking for? First of all, you need compliance with Euro 7. That means little or no abrasion. Second, it has to be cheap. Brake disks are a mass-produced item; a couple of cents difference in unit price can make all the difference. And third, the process must fit into an existing production operation as seamlessly as possible."

Lott comes to a halt in front of a test facility for brake disk manufacture. "We've opted to develop a machine that gives brake disks an ultrahard coating." On the rotary table, a car brake disk

MADE EASY

Machines from Nagel use LMD to produce practically abrasion-free brake disks. Two beam-shaping tricks have helped optimize this process.

Claus-Ulrich Lott plays with dummy brake disks manufactured additively from plastic.

Tobias Gerber

made of cast iron is spinning beneath the optics of a laser and seven powder feed nozzles. Within the high-speed laser metal deposition (HS-LMD) cell—known as NaCoat—the disk is coated with two layers: first, a 0.1-millimeter-thick bonding layer of stainless steel; and, on top of that, a 0.2-millimeter-thick functional layer studded with ultra-hard carbide particles. “The entire process takes just 30 seconds,” Lott explains. “Under the microscope, the surface now looks like a chocolate bar with nuts sticking out of it. That’s the carbide particles projecting from the surface. A further step is therefore required to reduce brake abrasion.” →

A disk laser on the left powers two high-speed coating machines. On the right, the disks are given a final polish.

The disk is now placed in a NaGrind grinding machine. This polishes it smooth with 36 diamond tools. The result is an ultrahard brake disk with a carbide layer around ten times harder than a standard cast-iron disk and a much longer service life.

IT'S ALL IN THE BEAM "The idea of giving the disks an ultrahard coating was a no-brainer," says Lott. "The only question was how to achieve this." Three options were quickly rejected: electrochemical coating—too dirty; thermal coating—too slow; and cold spraying—too expensive, and unsuitable for some types of disk. Lott opted for the high-speed version of laser metal deposition (HS-LMD), which provides a clean and fast process. "It's when you start putting a good idea into practice that the problems begin," says Lott with a smile. "Cast iron, for example, is not easy to coat." In simple terms, it's difficult to get the layers to stick. So a lot of powder is required. "Powder accounts for around 60 to 70 percent of the manufacturing costs in brake disk production," he explains. "It's therefore crucial to achieve a high level of powder efficiency—i.e., the machine must make best possible use of the powder."

How did Nagel increase powder efficiency? "We teamed up with TRUMPF. They use two special tricks to shape the beam." With BrightLine Weld, the laser power is distributed between the core and ring zones, each individually controllable—similar to a shower head with a central nozzle and surrounding jets. This enables a precise regulation of energy and heat input, meaning minimal distortion to the brake disk and a much thinner coating—and therefore less powder. The second game-changer was to incorporate TRUMPF's bifocal module, which likewise reduces powder use. Using a portion of the laser beam, the cast-iron brake disk is gently heated just before the powder nozzles begin their work. This causes the powder to stick to the surface rather than bouncing off and ending up as expensive waste. During coating, the machine utilizes as much as 94 percent of the powder available. In other words, Nagel now has an economical method for producing low-abrasion, Euro 7-compliant brake disks.

SOLVES EV RUST PROBLEM What's more, there's also a special bonus for electric vehicles. Not only will they zip through the city equipped with hard-coated brake disks that deliver radically reduced PM emissions. In addition, a brake disk treated in this way makes an EV safer. This is because a coated disk does not rust—which is especially good news for electric vehicles. In everyday driving, electric cars generally make use of regenerative braking as a way of recuperating energy. This works by creating a resistance in the powertrain, which thereby slows the vehicle down. As a result, the brake disks of an EV are rarely used and soon develop a coating of rust. "If you're driving on the highway at high speed and need to make an emergency stop, brake disks with surface corrosion can pose a real safety threat," Lott explains. "Stripping all the rust particles off the disk can significantly extend braking distance." However, with brake disks equipped with a hard-material coating, this won't be a problem anymore.

WEALTHY AND HEALTHY It is two years since Lott became managing director at Nagel. During this time, he has reoriented the company toward machines for brake disk production. "In the past, our business was heavily dependent on the internal combustion engine and is now declining appreciably. Our solution for Euro 7-compliant brake disks offers a product suitable for all types of drive and, at the same time, enables us to stay in the industry we know best." The order book is proving him right. In the first six months of the year, Nagel delivered a double-digit number of machines for the series production of brake disks. Automotive manufacturers and suppliers are now busy gearing up for the big transition to Euro 7. The first vehicles fitted with hard-coated brake disks will be hitting the road by the end of 2025. Comprehensive trials with test vehicles are already underway. Lott is visibly proud of the company's success, but he also strikes a serious note: "And there's something else too. Our machines mean that people will be exposed to lower PM emissions and will therefore live healthier lives. For me, that's great to know." ■

Contact: Nagel Maschinen- und Werkzeugfabrik GmbH, Claus-Ulrich Lott, phone: +49 7022 605-0, brakedisc@nagel.com

“The economic efficiency of the coating process depends on using as little powder as possible.”

Claus-Ulrich Lott, CEO of Nagel Maschinen- und Werkzeugfabrik GmbH

Tobias Gerber

IN 3 STEPS TO A EURO 7-COMPLIANT BRAKE DISK

THE BEST WAY TO SLICE AND DICE A NUCLEAR POWER PLANT

A beam will do it — quickly and cheaply.

Tests show that the laser cutter also works well underwater.

Current nuclear reactors have a lifespan of, at most, around 40 years. After that, the plant has to be decommissioned in what is *(a)* time-consuming, *(b)* complicated and *(c)*expensive process. Highly specialized companies must be called in to dismantle those areas of the plant contaminated with radioactivity.

Band saws, plasma cutters and water jets are the methods of choice to tackle these often thick and complex structures. Yet such tools have only a limited efficacy and require regular maintenance when used in the nuclear sector. What's more, such work is *(d)* dangerous. Alternative technologies that will enhance worker safety are therefore required.

French company Onet is now investigating a new approach. As part of the EU-funded LD-Safe project, Onet has developed a laser system for dismantling nuclear power plants. At the Onet Laser Technocenter, the company is currently testing its performance when cutting steel parts. The Onet system is divided into three sections, only one of which is located within the radioactive zone: first, a shipping container housing the laser source, a 16-kilowatt infrared TruDisk Laser from TRUMPF; second, a control area, housed in a second container, to monitor and regulate the laser system; and, third, the radioactive zone itself, where a robotic arm guides the laser used to cut up contaminated parts.

A laser light cable up to 200 meters in length guides the laser beam to the cutting head. Inclusion of a special beam coupler from TRUMPF ensures that the beam remains focused over such a long distance. This setup ensures that the majority of system components do not become radioactively contaminated.

The laser is able to cut stainless steel parts up to 200 millimeters' thick in air or up to 100 millimeters' thick underwater. This process, which Onet has now validated for industrial use, will face big demand. Over the period to 2050, some 250 power plants worldwide are scheduled to come off grid. All of them will need to be stripped down as quickly and as cost-effectively as possible. ■

Gernot Walter, Onet Technologies

GLORY

FROM WATER RESEARCH TO PIONEERING LASER

After many years of researching an apparently niche beam source, Clara Saraceno is now developing the best femtosecond laser that industry has ever seen.

It all started with water. “No one really understands water. It’s such an integral part of our everyday lives, yet nobody understands it. I found that fascinating,” explains Clara Saraceno, Professor of Photonics and Ultrafast Laser Science at Ruhr University Bochum. That was in an interview with *Laser Community* in 2019. Back then, she was working on a brand-new measuring device in the terahertz range. Developed for the biochemists in her research group, it was designed to help them take a fresh look at water. This meant doing something that was not really possible: she had to focus a terahertz laser beam. In the end, Saraceno accomplished this with the help of an infrared femtosecond laser—plus a box of electro-optical tricks such as nonlinear crystal conversion.

This achievement now forms the basis of Saraceno’s next major project at Ruhr University Bochum. This time, her development is intended for industry. The project revolves around a radical new design for an ultrashort pulse laser, which will deliver femtosecond pulses at a wavelength of 2.1 micrometers and at a repetition rate in the gigahertz range. Such a technology has great potential in the field of material processing, providing high ablation rates at a comparatively low energy input. Known as Giga2u, it will be ideal for processing polymers and glass.

Asked about her stellar career, Clara Saraceno points to a mixture of good fortune and a readiness to take risks. Right now, she’s pondering whether to turn the Giga2u project into a start-up venture. In January 2024, Clara Saraceno was awarded the Harold E. Edgerton Award in High-Speed Optics by SPIE, the International Society for Optics and Photonics, for her “groundbreaking contributions to the development of ultrafast high-power lasers and laser-driven terahertz sources.”

Professor Clara Saraceno’s lab is developing a new type of laser for processing polymers and glass.

Carsten Behler

WITH LASER TECH A MORE SUSTAIN-ABLE WORLD

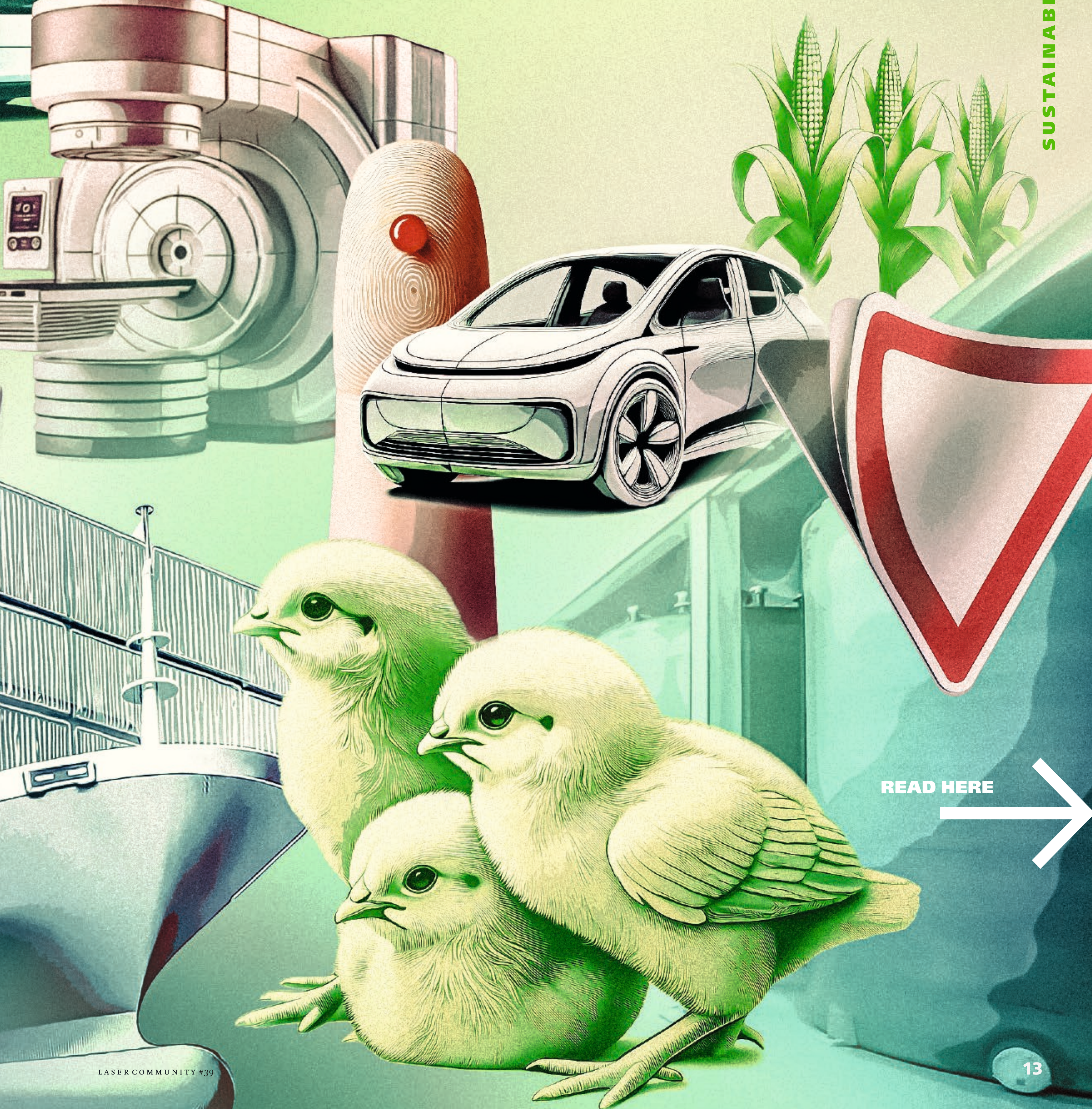
Do it with Light!

Turning talk about sustainability into concrete action: 18 examples of how lasers make the world a better place.

Die Magaziniker & AI, Gernot Walter

Efficiency, efficiency! Since 2006, every single issue of *Laser Community* has shown how industrial lasers can boost manufacturing efficiency. And who wouldn't want to become more efficient? Achieving more with less: that's the name of the game, with the winner the one who can produce goods more cheaply than their neighbor. The fact that this can help conserve the earth's resources has long been an added bonus.

PURPOSELY SUSTAINABLE Yet our climate, environment and society remain under threat. We therefore need to find a more sustainable way of doing business and living with our fellow creatures. In more and more countries, this is now required by law. In other words, what was once an added bonus should now become an intended effect. The following pages showcase examples of laser tech that turn sustainability from a side effect into part of the plan. ▪



READ HERE

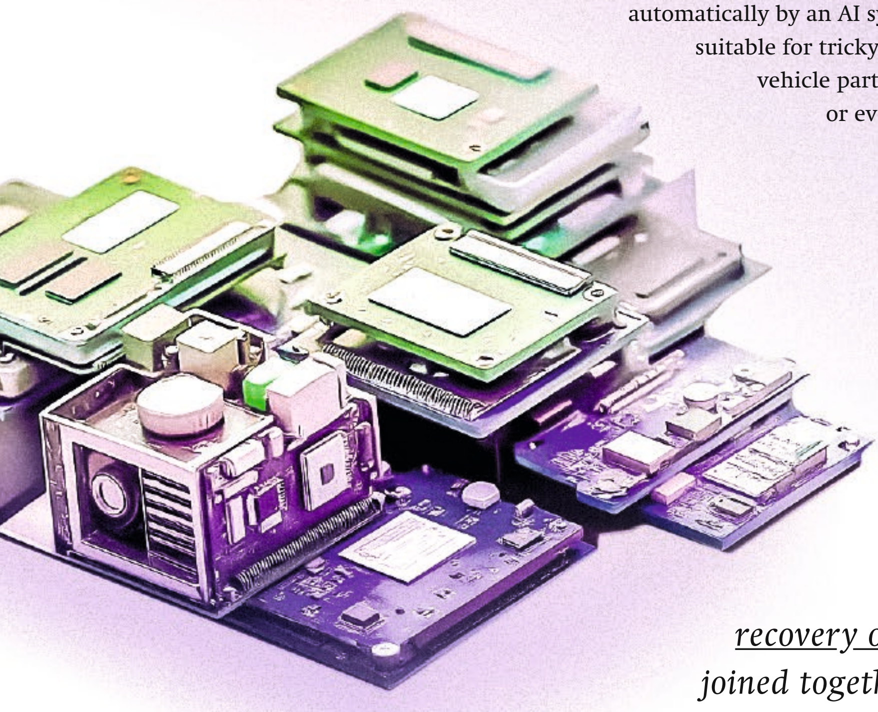
RECYCLING

RECOATING TRAFFIC SIGNS

Old aluminum traffic signs that are out of date or have become illegible still get tossed onto the scrap heap—from where they are melted down, rolled out, cut into shape and then used to make new signs. In Germany alone, 1.6 million traffic signs meet this fate each year. But why such waste? Why not just reuse them? The problem is a special reflective film on the signs, which is practically impossible to remove. Nothing is really up to the job—machining, sandblasting, abrading; not even chemical or thermal ablation. A team at Aalen University has now tried a laser, which effortlessly removes any type of film without leaving a residue. What's more, new film coatings adhere without any difficulty. This process works quickest of all with a CO_2 laser. Now only the film residue has to be thrown away, not the whole sign.

FINDING TREASURE IN SCRAP

In theory, we strip things down to their components and then recycle the materials without any loss in quality. In reality, we end up with a huge pile of scrap, which then has to be separated and sorted according to type. Now, however, the Fraunhofer Institute for Laser Technology ILT has developed a new process: a sensor uses laser emission spectroscopy to identify the chemical composition of the scrap as it passes by on a conveyor belt. Downstream, the scrap is then sorted by human hand or automatically by an AI system. The laser method is also suitable for tricky items such as electronic scrap and vehicle parts. It can identify minuscule amounts or even alloys of valuable raw materials such as molybdenum, cobalt and tungsten. Thanks to the new laser detector, a lot more materials will now be recycled.



The biggest problem for recycling is how to separate materials. The easier it is to strip down used appliances and other items into small parts, the more effective the recovery of raw materials becomes. Yet a lot of what is joined together in manufacturing is not easy to separate.

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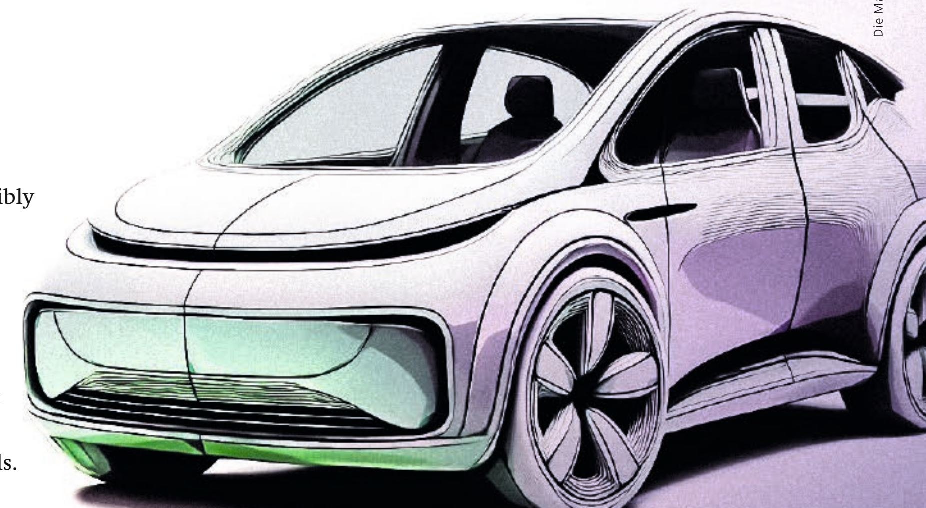

RECYCLING EV BATTERY REJECTS

The quality requirements for electric car batteries are incredibly high. This can lead to a lot of waste during production. The electrodes, for example, are manufactured by coating a foil with valuable metals such as lithium, cobalt and nickel. Here, too, quality does not always meet the requisite standards, meaning that kilometers of coated foil can end up in the trash—along with all the valuable raw materials. However, laser technology can help: a laser beam removes the wafer-thin coating, creating a powder that can then be collected and recycled to recover the raw materials.

CONSERVING RESOURCES

The ideal way to conserve resources has always been to achieve at least the same output from a reduced input. It is no exaggeration to say that laser processing has exemplified this approach for many decades now.

LESS FUEL FOR SHIPPING

Underwater, a ship's hull becomes rapidly colonized by all manner of microorganisms, algae, plants, mollusks and barnacles. Initially, this marine life forms a thin film, then a layer of growth known as biofouling. A coating of less than a millimeter in thickness can increase fuel consumption for a container ship by up to 60 percent. For a long time, researchers struggled to come up with a viable answer to this problem. Now, however, they have provided the shipping industry with not one but two laser-based solutions. A German team has shown that the beam from a diode laser used underwater will safely remove biofouling in its entirety. At present, the researchers are developing a robot to inspect the hulls of ships in port and laser them accordingly. The second idea is to prevent biofouling in the first place. This involves using a laser to create a texture on the surface of the hull that actively hinders fouling or prevents it completely.

DUST-FREE PV MODULES

For many countries, large solar farms are the most efficient way to generate electricity, particularly in desert regions. The desert, however, also means dust. In such conditions, the output of a photovoltaic module can fall by up to 30 percent within a month. In other words, this layer of dust requires regular removal with a brush and water—partly by hand, partly by an automated system. The brushes, however, often leave minuscule scratches that reduce the performance of the PV modules. And water can be hard to come by in the desert. The solution is to use overlapping laser beams to create a surface pattern that repels dust in a manner similar to the lotus effect. Tests show that this reduces the amount of dust accumulating on PV modules by 85 percent. This means that solar farms save on cleaning and also use a lot less water. At the same time, the power yield and service life of the PV modules increase.

LOW-ENERGY DRYING OF BATTERY ELECTRODES

The most energy-intensive step in the production of lithium-ion batteries is drying the wet-coated electrode foils. As they pass through a convection oven up to 100 meters in length, hot air is blown onto them. This consumes an enormous amount of energy, and drying efficiency is poor. Scientists from RWTH Aachen University have therefore turned to VCSEL heating systems. These mini infrared beam sources are able to dry the electrodes over a distance of just ten meters. The process is not only much quicker than a conventional drying oven but also uses around 40 percent less energy.

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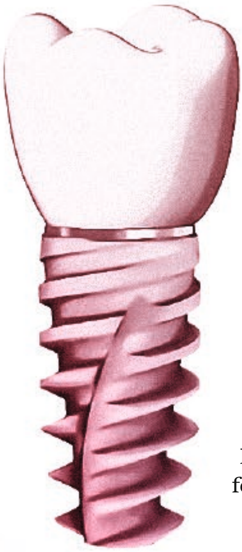
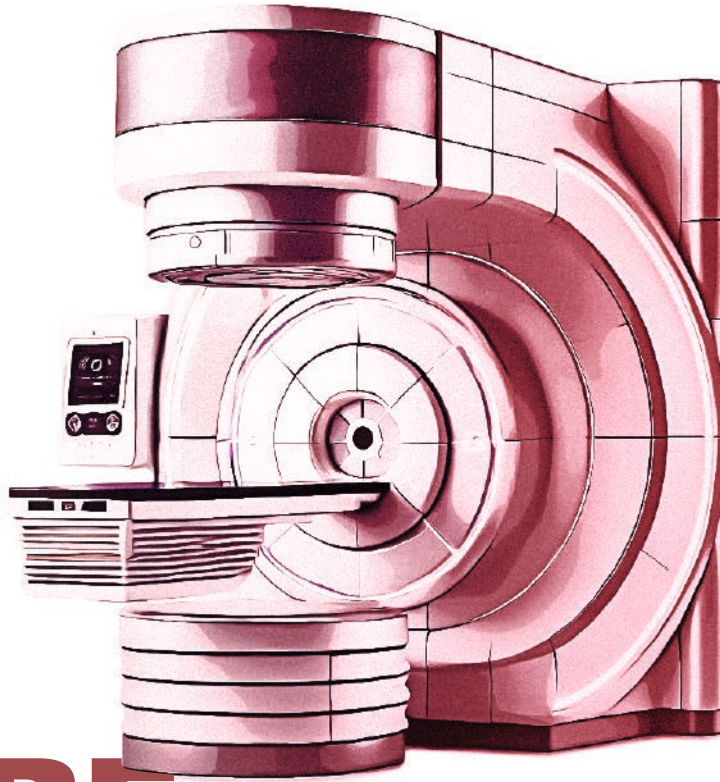


AN AFFORDABLE SMILE

Good teeth were once an unmistakable indicator of wealth. In many parts of the world where people are unable to afford high-quality restorative dentistry, this is sadly still the case. Yet huge advances in laser metal deposition—additive manufacturing with metal—are making implants more affordable for everyone. Easy to customize, they can then be cost-effectively produced in large volumes with a 3D printer. Meanwhile, in a blessing for nervous patients, laser technology is also helping to improve dental therapy. Access Laser, a company owned by TRUMPF, has now developed a CO_2 laser that provides pain-free treatment of caries without the need for an anesthetic injection.



Industrial lasers not only lead to improved medical equipment. They also mean that more people worldwide have access to good healthcare.

BETTER HEALTHCARE FOR ALL

CHEAP AND PORTABLE DIAGNOSTICS

Many diseases can be diagnosed via a simple blood test. This includes not only acute infections such as malaria but also chronic conditions such as diabetes and hereditary diseases such as sickle cell anemia. But not everyone has quick and easy access to a blood lab. Bahram Javidi, professor at the University of Connecticut, has therefore developed a rapid test device for regions with poor medical infrastructure. Although it features such high-tech methods as laser-assisted digital holographic microscopy, the device has been purposely built of the cheapest and most robust materials possible. A cell-phone or laptop battery suffices as a source of power.

ENHANCED CANCER THERAPY

Hard X-rays are an effective therapy against cancer cells, though the treatment places a big burden on patients. Electron beam therapy offers a gentler and, ultimately, more effective treatment, since an electron beam can be focused more accurately and therefore target cancer cells more precisely without impacting surrounding tissue. At present, however, electron beam devices are extremely large, extremely expensive and therefore extremely rare. Happily, this is now changing, thanks to the so-called laser bow-wave method, which accelerates the electrons in a different way. As a result, many more people will have access to a better and more gentle form of cancer therapy.

ENERGY TRANSITION

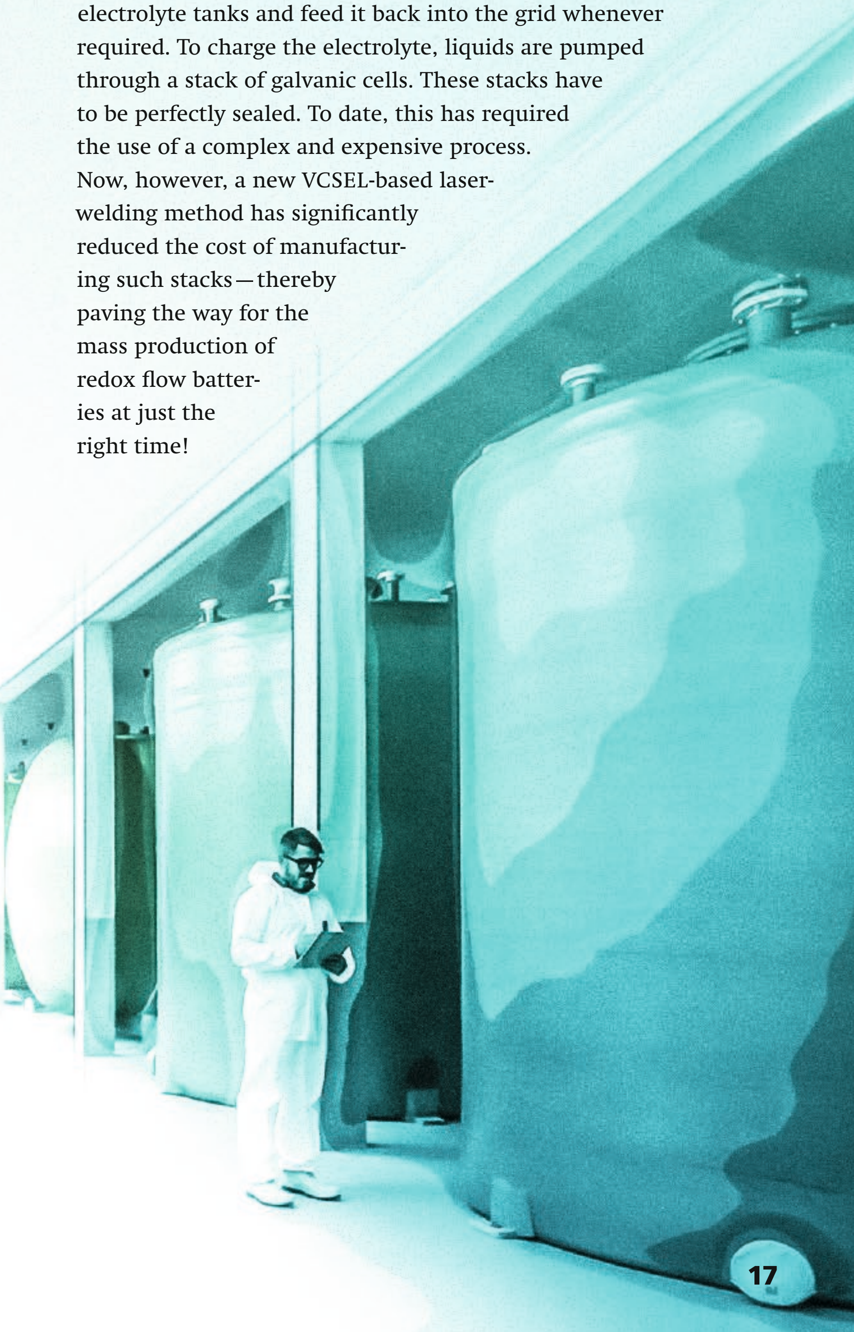
The energy transition means more than a mass installation of PV systems, wind farms and hydro plants—though that too! It's also about making the grid robust and flexible enough for these forms of power and making more effective use of alternative energy sources such as hydrogen.

POWERFUL FUEL CELLS

Big electrical vehicles such as trucks, buses and construction machines need an energy-storage device with a high power density to supply their motor with electricity—a fuel cell, for example, fed with hydrogen. PEM (proton-exchange membrane) fuel cells are a good option here. With this type of technology, a key challenge is to ensure that water and gas are transported efficiently within the cell throughout its service life. This is where ultrashort pulse lasers play a key role. They are used to create intricate structures and bore tiny holes within the cell. Thanks to this trick, PEM fuel cells can be made more powerful and efficient and also enjoy a longer service life.

BUFFER STORAGE FOR GRID STABILITY

Photovoltaics and wind deliver clean energy—but on an irregular basis. To ensure grid stability day and night, operators need buffer storage systems such as redox flow batteries. These can store vast amounts of energy in huge electrolyte tanks and feed it back into the grid whenever required. To charge the electrolyte, liquids are pumped through a stack of galvanic cells. These stacks have to be perfectly sealed. To date, this has required the use of a complex and expensive process. Now, however, a new VCSEL-based laser-welding method has significantly reduced the cost of manufacturing such stacks—thereby paving the way for the mass production of redox flow batteries at just the right time!



CHEAPER PHOTOVOLTAIC SYSTEMS

There is not enough silver in the world for all the photovoltaic modules that countries around the world are now planning to make. At present, heterojunction solar cells, a highly efficient form of this technology, use this costly metal in their conductors and contacts. Now, however, the German start-up PV2+—a spin-off from the Fraunhofer Institute for Solar Energy Systems ISE—has developed a way of replacing silver with copper. This involves a method that combines galvanic processes with laser texturing. At the same time, they have developed a new masking process that ensures no microplastics enter wastewater when the modules are recycled at the end of their service life.

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CHEMICAL-FREE PRODUCTION

It's an evergreen story within the laser community: yet another ghastly wet-chemical procedure, which is inconvenient and expensive, has now been replaced by a new laser process!

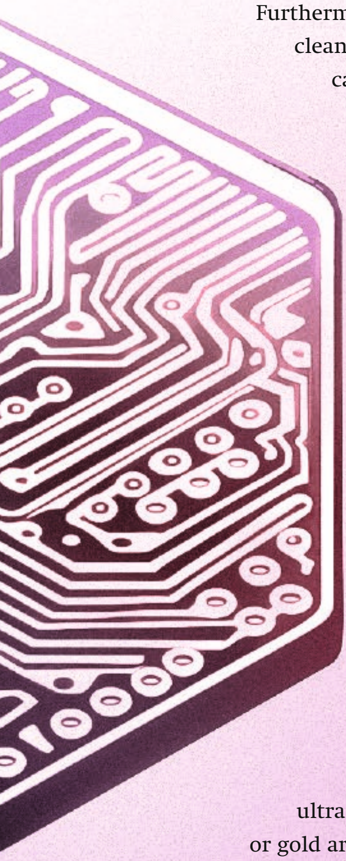
LASER CLEANING

Before gluing, before painting, before welding, before coating—everything must first be cleaned. This is because the components are likely to be smeared with oil, or are soiled, or have an oxide film. At this point, industry generally reaches for a cleaning agent, a chemical bath or—worse still—an acid pickling bath. A much cleaner method would be to use light: a laser beam to vaporize impurities or ablate an oxide film. Furthermore, if only a few contact surfaces require cleaning, and not the entire component, a laser can be targeted to take care of these areas alone. Try that with an acid bath! And with laser cleaning, there's no chemical waste to dispose of.

NONTOXIC SCREENS

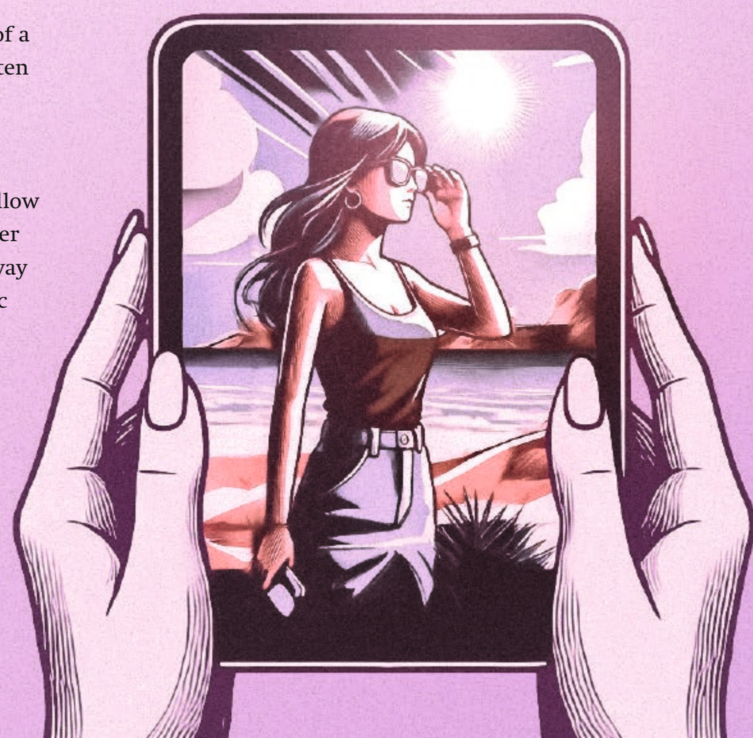
Whether smartphone, tablet or e-reader, the display must deliver a sharp picture—even in bright sunshine. In other words, screens must be nonreflective and, ideally, matte. In the past, this meant immersing the display glass in what is probably the nastiest and most hazardous chemical known to industry: hydrofluoric acid. Now, however, engineers at TRUMPF are developing a laser process that will obviate the need to use this substance. Peppering the display glass with ultrashort laser pulses creates exactly the same matte effect as that achieved when using hydrofluoric acid. With the process now producing perfect results, it is merely a question of scaling it up for industrial use.

For more details, turn to page 22.



NON-ETCHED PRINTED CIRCUIT BOARDS

Printed circuit boards consist of a nonconductive substrate—often plastic or ceramic—and a conductive layer—usually copper or gold—on top. In order to create the traces—the conductive tracks that allow current to flow—sections of the upper layer of copper or gold are etched away with chemicals. This produces a toxic waste that is difficult to dispose of. Industry is therefore turning to a clean alternative: the laser. Here, ultrashort pulses of light ablate the copper or gold around the traces so precisely that the remaining material is not heated. This method also offers design flexibility and is completely free of corrosive chemicals.



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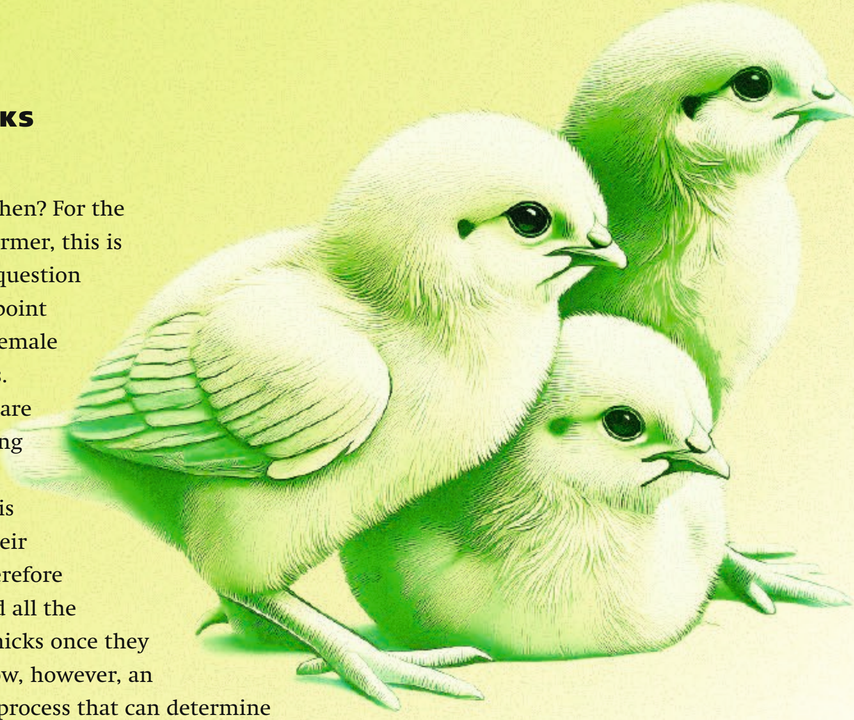
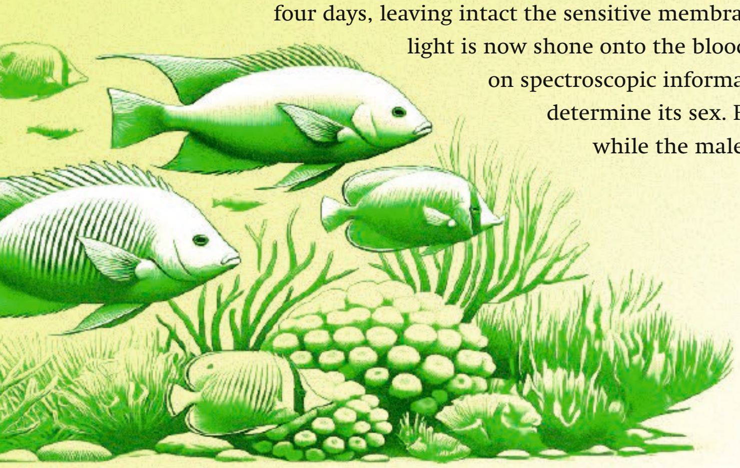
NATURE & ANIMAL WELFARE

SEXING CHICKS IN THE EGG



Rooster or hen? For the poultry farmer, this is a crucial question from a business point of view, as only female chickens lay eggs. Laying hens that are reared for breeding purposes are no good as meat. This also applies to their brothers. It is therefore common to shred all the “useless,” male chicks once they have hatched. Now, however, an automated laser process that can determine the sex of embryos in the egg has put an end to this cruel practice. Using a CO_2 laser, a small hole is carefully cut into the shell of an egg that has been incubated for four days, leaving intact the sensitive membrane beneath the shell. A beam of light is now shone onto the blood vessels of the embryonic chick. Based on spectroscopic information from the blood, the system is able to determine its sex. Female eggs are returned to the incubator, while the males are removed at this early-embryo stage.

Global warming poses a key threat to our ecosystems, yet there remain many other “classic” <u>conservation and animal welfare issues</u> to be resolved in areas such as agriculture, livestock rearing and marine pollution.

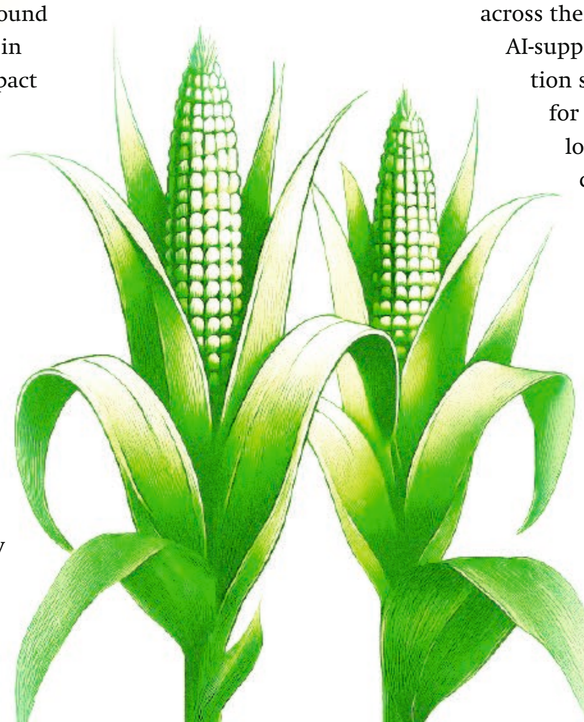


A FILTER FOR MICROPLASTICS

Microplastics are particles of plastic smaller than five millimeters, right down to the nanometer range. They are now to be found everywhere—from the deep sea to the Antarctic, in fish and even in the human bloodstream. The impact on living organisms and ecosystems has not yet been fully investigated, but initial findings are a cause for concern. In other words, there’s a lot to be said for, at the very least, filtering microplastics out of wastewater and reducing the overall burden. The problem is that microplastics are minuscule, so the holes in any such filter also have to be tiny. A collaboration between industry and science has now found a way of using an ultrashort pulse laser to drill millions of holes into a filter for use with a cyclonic separator. To make the process more economical, the laser beam is split, meaning that over 100 holes can be drilled at once. The filter catches any plastic particles larger than ten micrometers.

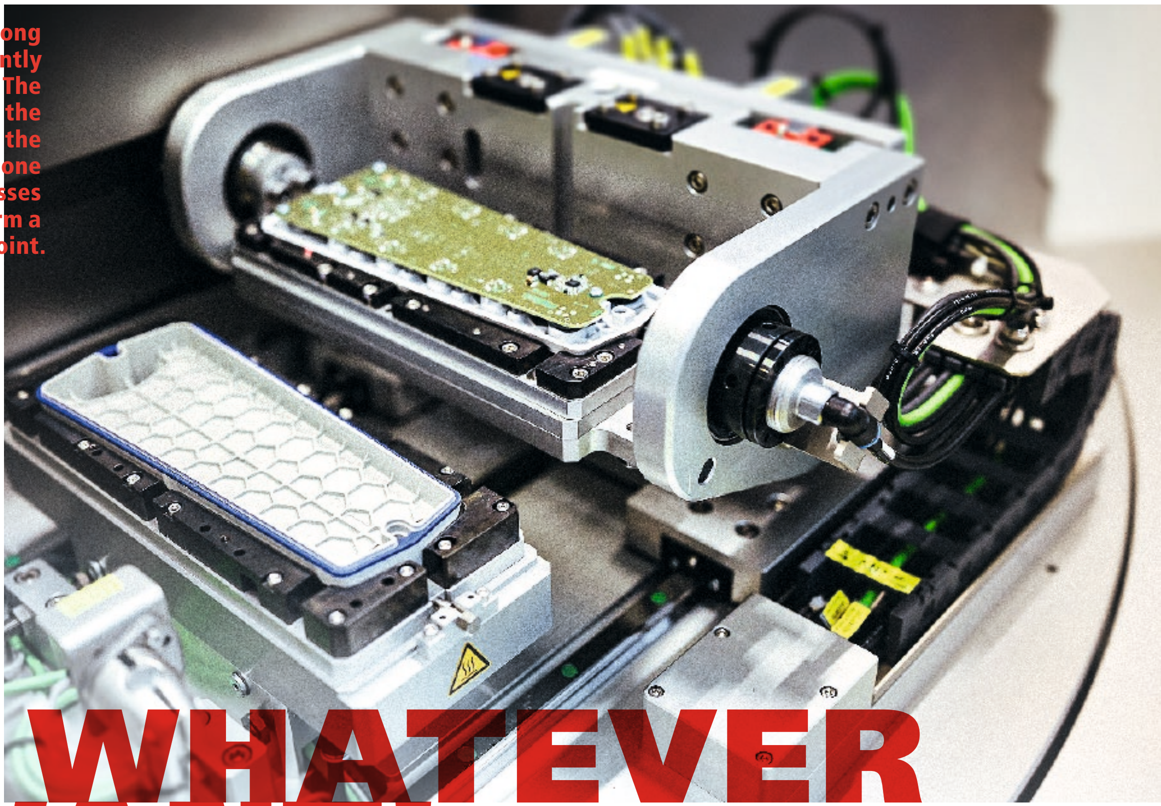
FARMING FREE OF HERBICIDES

The development of laser weeding is a bit like nuclear fusion: whenever you look, its practical application is as far away as ever. Yet that’s no reason to halt development. The idea is simply too good to abandon: high-yield crops without the need for toxic herbicides that harm insects, humans and other creatures. A European alliance of research centers, universities, companies and farming associations has now built a prototype laser-weeding system. A self-driving vehicle moves across the field. Onboard is an AI-supported image-recognition system, which scans for weeds and then locates their growth center, the so-called meristem. One ultraprecise pulse of energy from a fiber laser, and the weed goes up in smoke. The alliance is currently working on making the system—which has been named WeLaser—ready for market.



Die Magaziniker & AI

The laser sweeps along the joint and gently melts the plastic. The machine then mates the joining partner on the right — clack! — to the one on the left and presses them together to form a perfect joint.



WELD WHATEVER YOU WANT!

Gefasoft, an automation and software specialist from Regensburg in Bavaria, has finally worked out how to weld any type of plastic with a laser.

Known internally as the flyswatter — officially as A2A — it works in the following way: two plastic joining partners, each mounted in a clamping unit, are heated by a laser beam at fixed seam points. As soon as the material melts, the laser beam cuts out, and then — *clack!* — with a high-speed, high-precision movement, the machine mates the two halves and presses them together: a perfect weld seam that will hold forever. Stephan Englmaier is a laser applications engineer at Gefasoft. "That's one way of describing it," he says with a grin. "Calling it the flyswatter makes everything sound simple and fun, but this process will also take component design to a whole new level." Englmaier could well be right. After all, it removes most of the constraints that traditionally make it difficult to laser weld plastics. As such, it will give component designers a whole new freedom.

JOINT FREEDOM In recent years, lasers have become a real option for joining thermoplastics — plastics that become molten within a certain temperature range. However, there are considerable drawbacks. Known as laser transmission welding, this process only works if one of the joining partners is made of a plastic that is transparent to the specific wavelength of the laser being used. The laser beam then passes through this first joining partner and hits the second one, which is made of a plastic absorbent to that wavelength. The second joining partner heats up and melts. Pressing the two halves of the component together creates a firm joint.

Yet this type of joining process is less than ideal for many applications, not least when specific combinations of materials are required — as is often the case in the electronics, automotive and med tech industries. Increasingly, products from these sectors need to be composed of nontransparent plastics, either of the same or of a different kind. A host of other processes have therefore been devised to join such plastics. All of them function in principle, albeit with certain drawbacks. Typical problems here include the inexact application of heat or excessive strain on the joining partners. And if friction welding is used, this can generate unwanted particles. "One of our major industrial customers commissioned us to reduce particle formation in friction welding," says Englmaier.

LIGHT INSTEAD OF FRICTION Experts at Gefasoft set to work. Before long, the company's proficiency in laser technology had triggered the development of a totally new and innovative process. "Our initial idea was to preheat the joints with a laser so as to minimize particle formation during friction welding," Englmaier explains. "But then we thought: Why do we even need friction? Why don't we just combine the two processes and use the laser for joining as well?"

It seemed a great idea. So Gefasoft engineers began experimenting. To heat the plastic, they used a TruDiode 301 Laser from TRUMPF. "It's a very precise laser source, flexible and dynamic," says Englmaier. "And it's a real workhorse that our customers trust." The new process uses one or a number of laser sources. A sensor monitors the temperature of the seam points as they are heated. "The time required here depends on the material used. We have to work out individually the precise heat input and duration for each different application," Englmaier continues.

However, the biggest challenge for the team, which at times comprised up to 20 colleagues from across Gefasoft, was not how to

Stephan Englmaier (left) and his team thought a laser might improve friction welding. Then they realized that a laser can do the job all on its own.

"In the company, the A2A is known as the fly swatter."

Stephan Englmaier, laser applications engineer at Gefasoft

Stefan Hobmaier

heat the plastics. Rather, it was to develop a clamping system that mates the components so quickly that the heated seam points can bond before cooling. "That took a long time to get right," Englmaier admits. "It was a question of combining speed and precision, which isn't always possible. But that's what we needed: an extremely rapid and also extremely precise movement." After countless attempts, it all clicked. "We've now got a joining technology that does exactly what we require," he says happily. "That said, we can't reveal how it all looks and works because the A2A is patented."

NEW FREEDOMS As the name suggests, A2A ("Absorbent to Absorbent") is able to join plastics, whether of the same or of a different kind, that are not transparent to a laser—and to do so with a weld seam that is media-tight and pressure-tight. No other joining partners or additives are required. Moreover, this new process can accommodate tight tolerances and compensate for irregularities such as component warping. And thanks to the precisely controlled input of heat via laser, it can be used for complex components in combination with sensitive inserts such as printed circuit boards. "It is also suitable for joining intricately shaped components that might block a laser beam and cause shadowing," Englmaier adds. Similarly, multiple components can be stacked on top of one another to form a complete product—i.e., modules to create a battery unit. "For QA purposes, our clamping system features real-time monitoring of the entire process, including measurement of force and travel," he explains. "And in many cases, the joint is tested for tightness once welding is complete."

NEW DESIGN POTENTIAL So customers are now lining up to add this innovative process to their production operation? Englmaier laughs. "A2A is without doubt a game-changer," he explains. "But it requires a total rethink in terms of component design. As in the early days of additive manufacturing, we will first have to explain just what you can achieve with this new freedom." But once this has been done, new design ideas will take hold, and customers will most definitely be knocking on the door. ■

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A smartphone
in bright
sunshine?
No problem
with a matte
display!

Summer, sun, *smartphone*

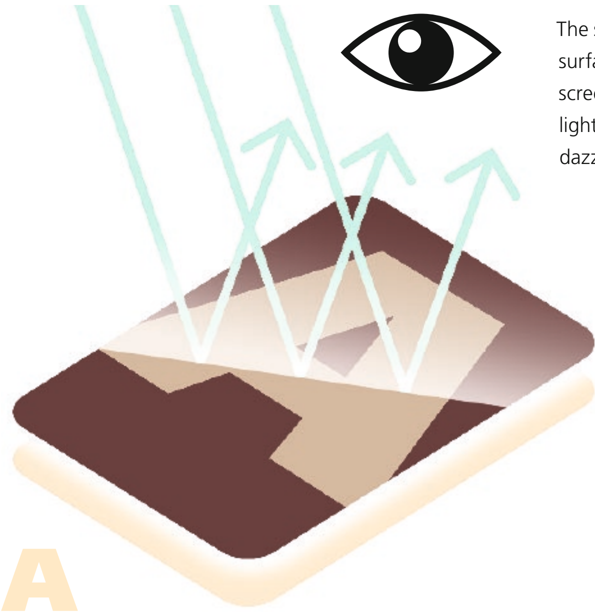
Demand for displays is huge—best of all, those with a matte anti-glare screen. Yet their production is hazardous for workers and the environment alike. Thankfully, help is on its way.

Author **Jonas Mayer** works at TRUMPF as an application developer in the advanced development division.

We're so keen on our screens that most of us can't tear our eyes away from them even on vacation. When untreated, however, they tend to display an annoying glare, since the smooth glass reflects any incident sunlight. The simple solution is to give the surface a matte finish. To achieve this effect, the glass display is roughened to create an uneven texture. Viewed under a microscope, the screen now looks like a miniature landscape of valleys and hills. This now scatters incident light in many different directions, instead of reflecting it directly back into your eyes. Yet it is vital to ensure that this texturing is not too coarse. If so, the image on the screen will appear blurred. On the other hand, the depressions on the surface must not be too deep either. Otherwise, this will split the light from the display into red, green and blue pixels, creating a rainbow of weird color effects. But when the screen is textured to exactly the right degree, any incident light from above is scattered in such a way that users can see display content clearly.

EXTREMELY CORROSIVE If glare can be eliminated, why do most displays still reflect sunlight? That's because the mass production of matte screens is costly—not least because of environmental and worker-safety concerns. The first step of the process is relatively harmless: the surface of the glass is sandblasted. Grains of sand hit the surface, leaving a random pattern of tiny craters. This makes the surface less reflective but not yet truly matte. Moreover, the texture is still too coarse for comfortable reading of content. A second step is therefore required: here, an acid bath widens the tiny depressions left by the grains of sand and smooths their sharp edges. And it's here that things get hazardous. Only a few acids can etch large quantities of screen glass fast enough to satisfy the demands of modern mass production. This means the use of hydrofluoric acid, one of the world's most aggressive and dangerous chemicals. Even a few drops on the skin will quickly burn their way into underlying tissue, destroying nerve systems and depleting the calcium in bones. In other words, we now have a matte display, but we also have an extremely high outlay to prevent pollution and ensure worker safety. Stringent standards must be met when recycling the large volumes of acidic waste from production. On no account must this be allowed to enter the environment. No wonder then that manufacturers are asking whether there isn't another way.

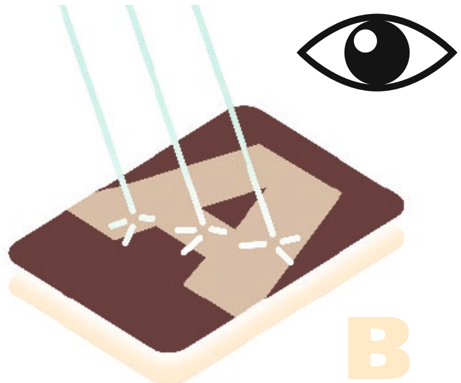
PERFECTLY IRREGULAR
"Yes, with a laser!" would be the obvious answer. A laser can etch glass and other surfaces. So why not use light instead of sand and acid? One reason is that there are difficulties in getting a laser to work at random. A USP laser will sweep across the surface of the glass, firing ultrashort pulses of light with a frequency in the microsecond range. The energy from each pulse vaporizes the glass, leaving behind a series of



The smooth glass surface of an untreated screen reflects ambient light, leaving the user dazzled by glare.

Wanted:

NONREFLECTIVE DISPLAYS



A screen surface textured with small depressions scatters incident light in many directions. Display contents remain clearly visible.

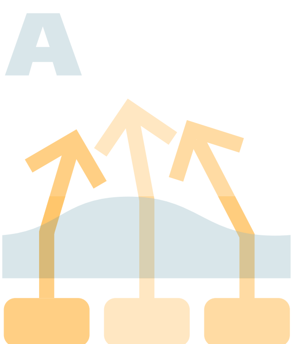
smooth, flat and transparent craters. Although the pattern of this texturing—the depth of, and gap between, each depression—can be defined with micrometer precision, all the standard techniques for laser processing large surfaces have one thing in common: they create a regular pattern. And that's the problem: a uniform texture in the glass surface causes refraction patterns. This is known as a moiré effect—also seen on TV screens when someone is wearing checked clothing. A screen textured with a laser is no longer reflective, but it still plays funny tricks with text and images on the display.

In other words, the challenge is to take a tool that operates in a uniform manner and make it produce a pattern that is every bit as random as that produced by sandblasting. It's precisely the kind of problem that TRUMPF's advanced engineering team loves to get its teeth into. Before long, the team had devised a beam-shaping technique that enabled them to create a perfectly irregular pattern with a perfectly uniform tool. By firing a stochastically random array of pulses at the glass surface, the laser now creates a miniature and completely irregular landscape of craters.

IT TAKES SEVERAL MILLION INDIVIDUAL LASER PULSES TO PROCESS AN AREA THE SIZE OF A BEER MAT.

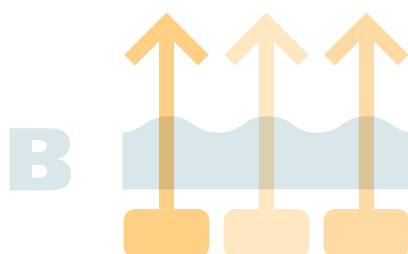
Challenge 2:

BLURRING

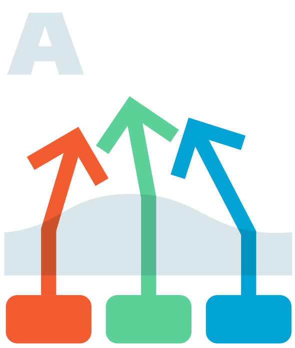


If the texture is too coarse, it scatters light from the display diodes and the image is blurred.

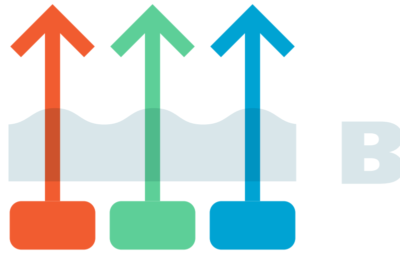
With a finely textured screen, the light from the display Is rendered in razor-sharp images.



Challenge 1: GLITTER



A too coarsely textured screen refracts the red, green and blue light from the display. This breaks the image up into colorful pixels.



With a more finely textured screen, the pixels merge to form a clear image.

MASS PRODUCTION Problem solved? Not quite. It takes several million individual laser pulses to process an area the size of a beer mat. In the lab, with a medium-power ultrashort pulse laser, this takes several days—not yet fast enough for mass production. The process can, however, be scaled up by means of a beam splitter. This divides the laser beam into hundreds of partial beams that simultaneously texture the glass surface in a random manner. So is there still a problem? Or can we all look forward to having cheap anti-glare screens?

MICRO GOES MACRO There is still one problem. Using a beam splitter to scale up the process splits not only the light but also the energy of the laser beam. While the process now covers a larger area, it also becomes much slower and even underpowered. One solution here would be more energy. Thankfully, recent times have brought a rapid development in the average power of ultrashort pulse lasers. Only a few years ago, the average power of a USP laser was ten watts. Today, however, colleagues in another area of TRUMPF are working on a one-kilowatt USP laser and are already looking ahead to one of several kilowatts. In other words, a suitable process is in place, it can be scaled up, and extra power is on the way. The future therefore looks good for the production of anti-glare screens. Soon, the industry will be able to stop using hydrofluoric acid and clean up its act. ■

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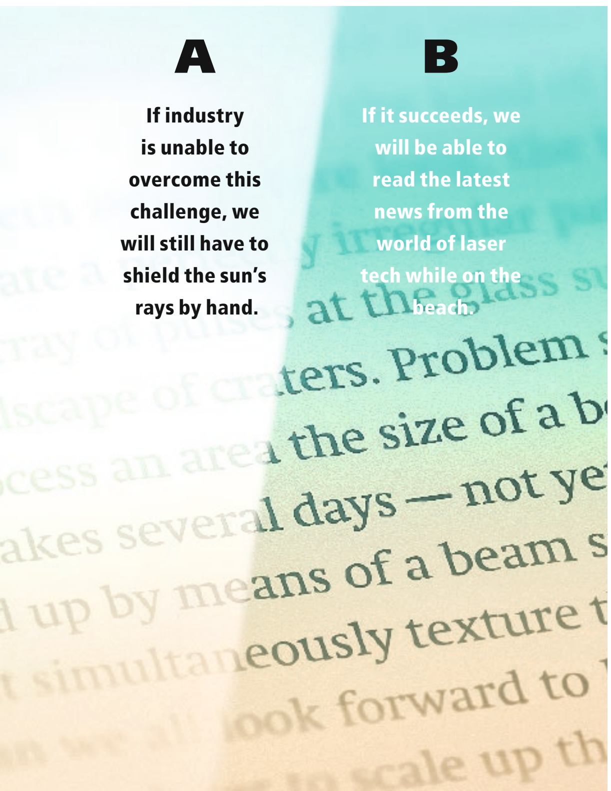
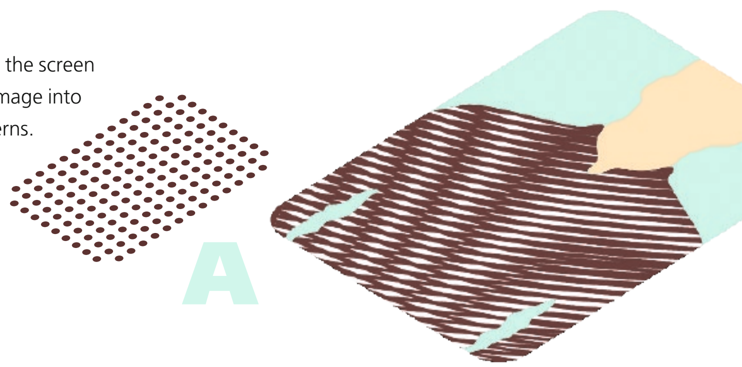
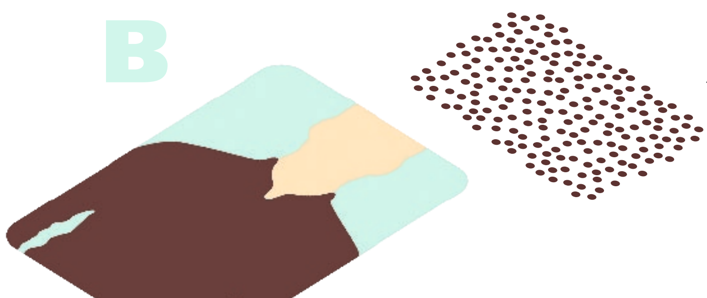
Gernot Walter, Christoph Kahlscheuer



Challenge 3 MOIRÉ EFFECT

A uniform texture on the screen surface distorts the image into so-called moiré patterns.





A screen textured with random depressions renders a razor-sharp image.

Nicole Franco

“Mexico’s economy is undergoing a rapid transformation. This will provide a huge boost for laser manufacturing,” says Christian Félix Martínez, a specialist in laser metal deposition (LMD) at the CIDESI center for engineering and industrial research.

Mr. Martínez, what's the position of laser manufacturing right now in Mexico?
Not great, unfortunately.

Really, what's the problem?
I see localized demand, but that's only to be expected. I'm working every day with companies to develop and implement optimized process strategies for AM — additive manufacturing — and LMD. But, in general, there are still big reservations and even some suspicion. A lot of Mexican production engineers don't really trust the technology. That's because they don't know too much about it and are therefore not familiar with any good examples of this type of manufacturing. Talk to people in Mexico about 3D printing, and they immediately think of prototyping with polymers and other plastics. →

ALL THE SIGNS POINT TO A BOOM”

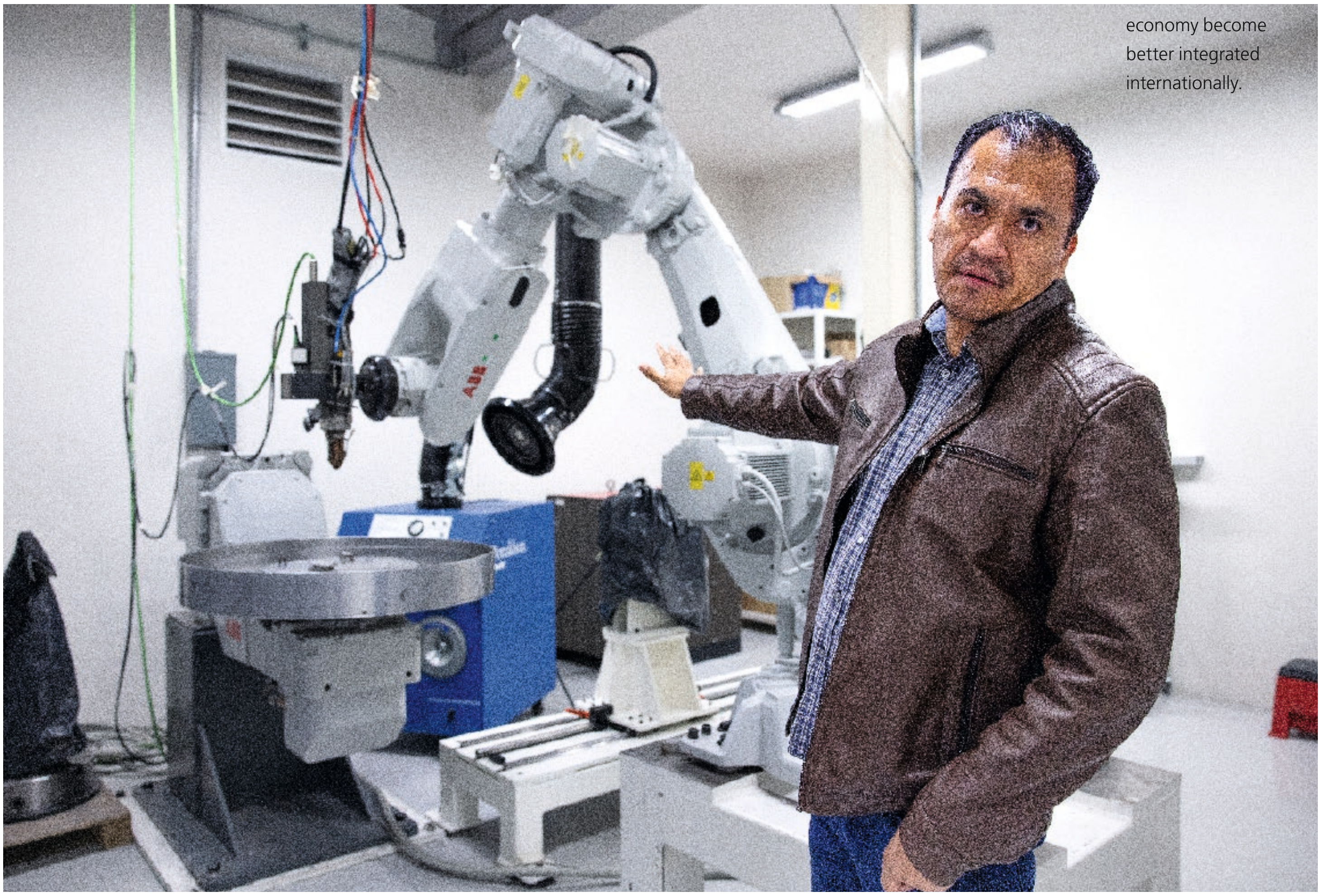
But LMD, with metal, is still not particularly common, unfortunately. In fact, it's not even well known. And when it comes to the repair industry, which is an important part of the Mexican economy, there are concrete reasons for this hesitancy.

What's the problem with LMD and the repair industry?
Wages are low in Mexico, and cheap labor fosters a more traditional way of thinking. Manual MIG and MAG welding are still the go-to methods here, despite the fact that automated AM processes such as cladding and LMD are widespread elsewhere and deliver higher quality. At the end of the day, it's also down to training: there's not a lot of people in Mexico who have the expertise in the methods of laser manufacturing. And many companies are put off by the investment costs for new machines and personnel. They prefer to stick with what they know.

So the outlook is poor for laser manufacturing in Mexico?
Not at all. Quite the reverse!

You're going to have to explain that!
Mexican industry is approaching a new dawn. A lot of U.S. companies and international corporations—with political encouragement—are looking to reduce their dependency on supply chains coming out of China. This will drive huge investment in Mexico—and, with it, the introduction of modern laser-manufacturing methods in areas such as the automotive industry, on the back of e-mobility, and even chip manufacture. As far as AM and LMD are concerned—and that's what I'm most familiar with—it's great to see that aerospace companies such as Safran and Airbus Helicopters are boosting their presence here. The aerospace industry loves AM processes such as 3D printing and LMD. Together with medical technology, which is another growth area here, it means we now have two powerful sectors that are well disposed toward 3D manufacturing. They will lead the way in Mexico. And more and more sectors will follow. That's because the traditional strong

CIDESI (Centro di Ingeniería y Desarollo Industrial) is a research and development institute headquartered in the industrial city of Santiago de Querétaro, about an hour's drive north of Mexico City. Its task is to perform industrial research for Mexican companies and to help the economy become better integrated internationally.



Christian Félix Martínez, an engineer by training, has been a lecturer at CIDESI since 2018. His area of specialization is additive manufacturing and laser metal deposition. He and fellow institute members are among the world's top authors of scientific papers in this field. Here he shows a cladding sample.

"My top business tip: set up a metal powder factory in Mexico!"

suits of AM and LMD—weight reduction, for example, and greater components complexity but without additional production costs—appeal to a lot of industries. All the signs point to a boom.

But what about the lack of skilled labor, a problem you already mentioned. Is that still an issue?
No! We're now getting on top of this too. For example, at CIDESI, my own institute, we've been training students to U.S. and European levels in laser technology, process technology and product design for AM since 2019. Our labs are really well equipped with the best technology the world has to offer. Young people here are eager to learn about a cutting-edge technology with a future. I have to tell you, I love my job! And we're not the only institute doing this. There are others like us in Mexico.

What's your actual role at CIDESI?
Apart from training students, my work focuses on industry-related development, mainly in the areas of AM and LMD. There are ten of us in my department, all senior staff. A typical task I recently completed for a plastics company was to optimize the process parameters for AM and analyze samples for metallurgical and other properties – things like tensile force, surface hardness, metal fatigue, porosity, longevity. I then use this data to make suggestions about how to improve production methods, the choice of material and so on, and I also help implement these proposals.

You also do research. What are you working on there?
I investigate the relationship between process, structure and performance in additive manufacturing. My research areas include the development of new materials with optimized properties and metamaterials for energetic or thermal efficiency. My approach is to generate knowledge and apply it in technological developments. To be successful, it is important to know people with in-depth knowledge of different metals.

If you had to give your students a business tip, what would it be?
Set up a factory for high-grade metal powder.

Why metal powder?
Right now, all the metal powder used in AM and LMD still has to be imported into Mexico. There's a massive 30 percent in duty levied on these imports. That alone would make home-produced metal powder of an equivalent quality 30 percent cheaper than rival imports.

It would practically sell itself!
Exactly. ■

Nicole Franco

Netherlands

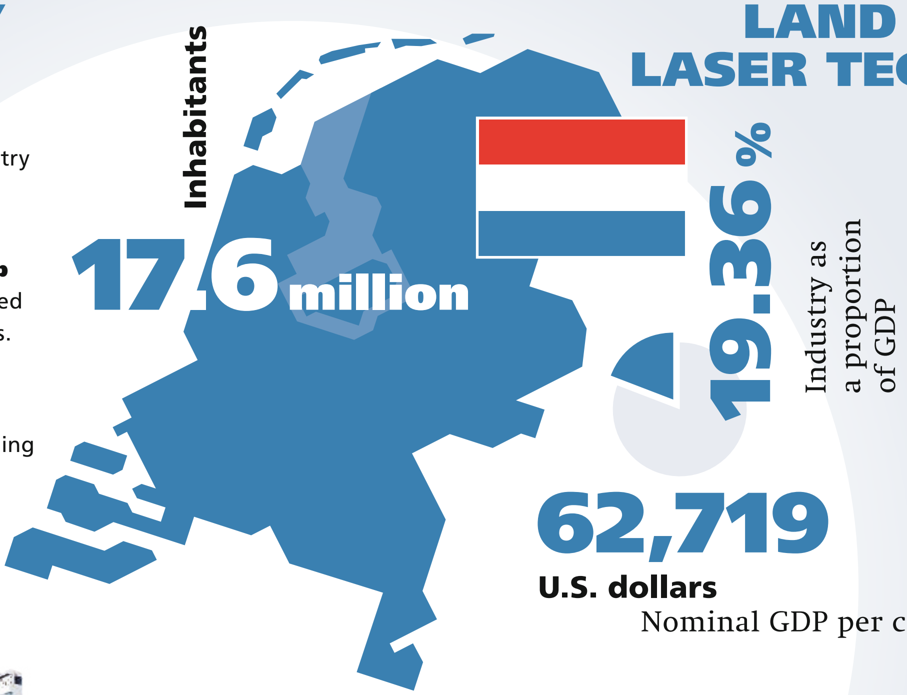
OVERVIEW OF THE ECONOMY

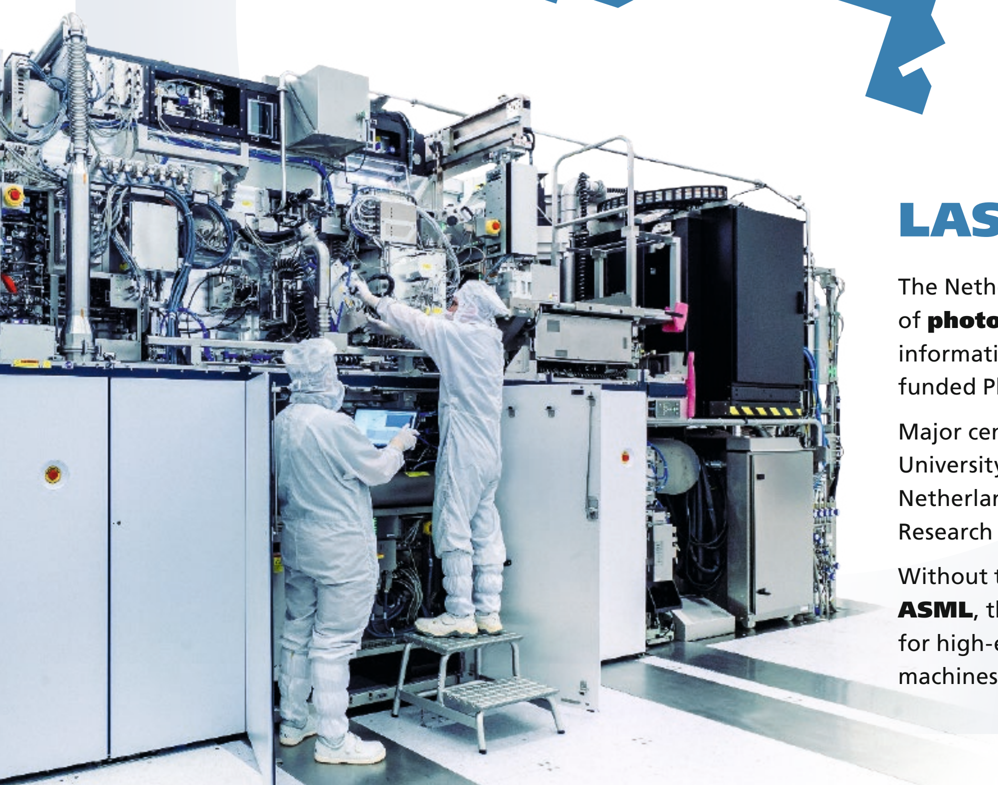
The mechanical engineering sector performs well in **future-oriented markets** such as digitalization, Industry 4.0 and smart farming.

Traditionally a trading nation, the Netherlands still acts as a **transit hub for goods:** around half of all imported wares are destined for other countries.

The country is fully embracing **renewable hydrogen,** with four gigawatts of generating capacity coming on stream by 2030. This green power will be produced by wind farms in the North Sea.

WELCOME TO THE NETHERLANDS, LAND OF LASER TECH!





LASER LAND

The Netherlands is a pioneer in the development of **photonic chips**, which use light to transmit information. A key driver here is the government-funded Photon Delta Foundation.

Major centers of **laser research** are Eindhoven University of Technology and various institutes of the Netherlands Organisation for Applied Scientific Research (TNO).

Without the EUV machines built by Dutch company **ASML**, there would be no high-performance chips for high-end smartphones. The lasers for these machines are supplied by TRUMPF.

ASML, Adobe Stock/matho

Victrola Record Players/Unspash

WHERE'S THE LASER?

In the joy of music.

A chorus to sing along to, a beat that transports us to another world, a violin solo that plucks the heart strings. Yet there are some people who have lost the magic of music, or have never known it, because their hearing is impaired. MED-EL from Tyrol in Austria makes cochlear implants: an audio processor behind the ear transmits sound information to an implant, which then sends this as electrical impulses straight to the auditory nerve. A laser is used to create the legible markings on such medical products, as required by legislation. That's because these customized devices are made of components that are small and light enough to ensure easy wearing and everyday use. *Let the music play!* ■

[ON A ROLL!]

33×1

The existence of so-called dark matter has been indirectly demonstrated, and theoretical physics would be meaningless without it. In other words, it must be out there somewhere! But what is it? And how can it be detected? Researchers at DESY, the large-scale accelerator facility in Hamburg, have now set about solving this puzzle. Using a 250-meter-long vacuum tube, light from a laser is amplified to the extreme and then fired through a field of 12 superconducting magnets before hitting a wall that absorbs photons. Installed behind this wall is a highly sensitive detector. Were it to detect even a single photon, there could—according to the theory—be only one explanation: the photon converted into dark matter before impact, passed through the wall and then turned back into a photon beyond it. The probability of this happening is a mere $1{:}10^{14}$—equivalent to rolling 33 dice and all of them coming up one! But should it succeed, it would mark a huge breakthrough for modern physics.

Gernot Walter