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Of people and photons

E-car for you

We've been promising our kids affordable electromobility. It's about time we delivered.

#26

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Gernot Walter

I'm ready for my first electric car

Perhaps it seems a bit obvious for me to kick off my editorial by writing nostalgically about my first car in an issue about electromobility. But doing the obvious is often the best path to take!

So, here we go: my first car was a second-hand Renault R4 with a 1.0-liter gasoline engine. I bought it in 1977, the year European car magazines voted the Rover 3500 as their car of the year—and the success of the Golf had turned VW into a market leader. People were happily driving around with their internal combustion engines, and electromobility was just a dreamy vision of the future.

Forty years later, sitting in planning meetings with my team, I realize that the future starts here! Our order books have seen a significant increase in focusing optics combined with high-powered lasers for highly productive systems in the realm of electromobility. We're also fielding more and more inquiries about green lasers for welding copper, as well as solutions for cutting carbon fiber reinforced plastics. What this suggests is that many established companies in the automotive and supplier industry—plus a few new market players—have realized which way things are heading. So they are now preparing their factory floors for the mass production of electric cars. And, based on all the new inquiries I mentioned above, we're also "doing the obvious thing" at TRUMPF by offering lasers and laser systems specially tailored to the requirements of electromobility.

The whole discussion about the future of mobility is very emotionally charged. We worry about carbon footprints and clean energy. People argue about potential bans on certain types of vehicles. But, if we put our personal feelings aside and look at things rationally, there's a fairly obvious conclusion: gasoline and diesel engines will be around longer than many predict today in politics and the press. Nevertheless, it's both important and right for us to be pushing ahead with electromobility and equipping industry with the tools they need to mass-produce electric cars. Because this is about our future—about jobs, lifestyles and clean air.

So, to balance out my nostalgic reminiscences at the start of this editorial, let me finish with a vision of the future. If, in a few years, I find myself looking for a new car, then the infrastructure for electric vehicles will be so well-developed in both urban and rural areas—and battery energy-management technology will be so mature—that I will buy an electric car without a second thought.

DR.-ING. CHRISTIAN SCHMITZ

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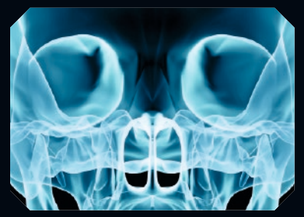
Lice-zapping laser

We were hoping to write an article about how a company is using lasers to delouse salmon, but no matter how many times we called, we heard only an answering machine. We're crossing our fingers that the Norwegian company Stingray is still very much afloat, because we think the idea sounds fantastic.
www.stingray.no

Burst bubble

When we called Kasper Fladmose in the Danish city of Odense and asked him to photograph a story about offshore wind turbines, he felt a surge of excitement at the idea of choppy water and fresh ocean air. It turned out to be a shoot in a welding technology lab, but it was fun and hyggelig all the same. **Page 10**

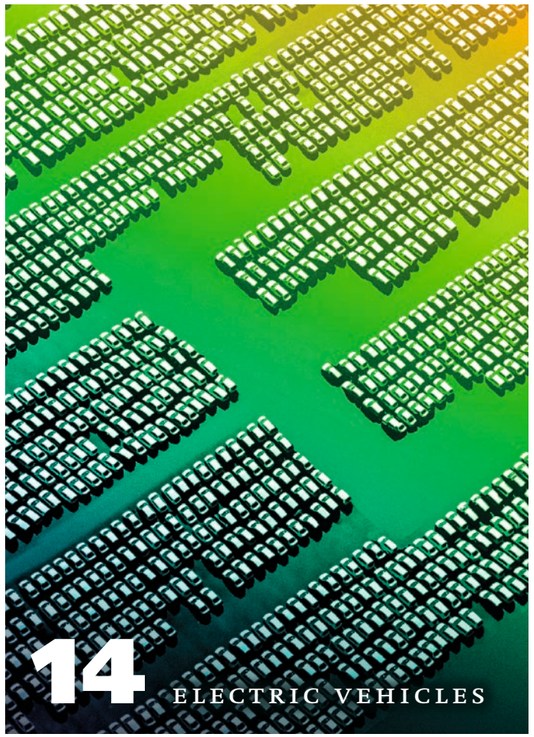


Family fright

When we asked X-ray researcher and associate professor William Graves to appear in this issue as half-head and half-skull, it's fair to say he had his doubts. But then he figured that at least he would have something to frighten his family with! See the scary results on **page 30.**

fotolia/azure; Kasper Fladmose; iStock/angelhell

LASER COMMUNITY.



Philipp Reinhard, Gernot Walter

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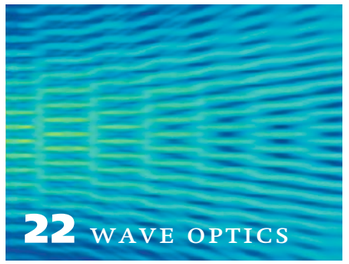
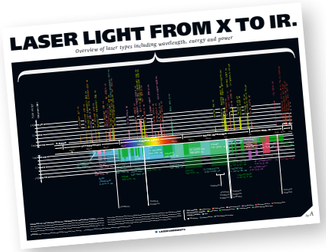




EXTRA: POSTER!

The most important lasers in the light spectrum

POWER

A laser system scans the pastures' surroundings and uses beams to scare eagles off.

SORRY EAGLES, NO HUNTING HERE!

A hungry eagle with its eye on a lamb circles over the pastures—but the lamb is protected by a laser-wielding scarecrow.

Scotland virtually wiped out its white-tailed sea eagles over 200 years ago. Not for the thrill of the hunt, but because the raptors were getting too greedy. Some of the eagles were no longer satisfied with fish from the sea, and had taken to swooping on lambs and carrying them off. The farmers showed no mercy, and the sea eagles suffered the consequences.

But now the birds of prey are back! In the 1970s, conservationists set up a colony of sea eagles on the west coast of Scotland. Since then, the population has been increasing steadily. That has rekindled the same thorny problem as before, however, with farmers losing young livestock.

The time had come for Scottish Natural Heritage (SNH) to come up with a solution. As the agency responsible for preserving Scotland's wildlife and landscapes, SNH's scope of responsibility includes white-tailed sea eagles. They decided to enlist the help of Bird Control Group, a company that specializes in finding species-appropriate ways of frightening birds away from places where they interfere with human activity, such as airports—or indeed pastures. Now SNH and the Bird Control Group are working together to protect Scotland's lambs without harming the eagles.

In fact, they already have a promising, life-saving solution in the pipeline: the Agrilaser Autonomic is a fully automated, laser-based protection system that can successfully repel eagles. Installed in the sheep pastures and operated by solar power, the low-wattage laser system uses an optical sensor to scan its surroundings up to 2,500 meters. That enables it to keep track of bird movements. If it detects an approaching eagle, the system directs a low-power laser beam toward the bird, triggering its survival instincts and causing it to flee. So, lamb is off the sea eagles' menu again—looks like it's back to fish! ■

iStock / fredericoriz

GLORY

NOZZLE SEEKS ETERNAL LIFE

Marcel Scalise from Benteler Laser Applications expects to get only two or three shifts out of a standard nozzle. This one lasted 273 shifts.

Cutting nozzles lead a short and tough life that is far from glamorous. They typically spend no more than 24 hours—and often fewer than 16 hours—in action from the moment the machine operator inserts the new nozzle to the moment they throw it away. During that time, a cutting nozzle will zoom over thousands of parts at a distance of just a few millimeters, scrape over bumps, and accumulate slag spatter until it is no longer capable of maintaining the shape of the gas flow—and is discarded.

It's the textbook definition of a wear part, as anyone who earns money from laser cutting will tell you. They'll also tell you that working distance and quality are closely intertwined: the closer you get, the higher the quality of the cut edges. But increase the distance and what you currently get is a steady rise in cutting gas pressure and consumption coupled with lower edge quality.

So the distance is kept to a minimum, and another cutting nozzle bites the dust every 16 to 24 hours. For a company like Benteler Laser Applications in Paderborn, Germany—which runs 18 high-performance 3D machines around the clock—that means you virtually never have all your machines up and running at the same time—all because of a brass part no bigger than a fingernail.

Marcel Scalise rolled his eyes resignedly when the TRUMPF representative solemnly placed the X-Blast nozzle on the table in front of him. But he confesses that his interest was piqued. He was highly skeptical that this new nozzle could really deliver better quality at a much greater working distance. But the operations manager knew that it would be a major coup if the new nozzle really did turn out to last several times longer than a conventional nozzle.

He decided to give it a shot; the nozzle pictured on the right shattered the previous record. It finally ceased to function after 2,184 hours—and not because it had run its course, but because a minor operating error threw it for a loop. ■

The deep notch on the right ended the nozzle's record-breaking stint at the helm. X-Blast nozzles are designed with fluid dynamics in mind, and their streamlined design keeps the flow of cutting gas focused, even from a distance.

The secret behind the record-breaking nozzle: trumpf.com/s/x-blast

Gernot Walter, Thorsten Doark

"NEXT YEAR YOU'LL BE ABLE TO BUY A SMARTPHONE WITH EUV CHIPS"

EUV lithography is well ahead in the race to make the next generation of semiconductor chips. Marco Pieters explains how ASML did it.

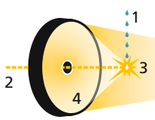
Today, EUV lithography is widely regarded as the enabler of future chip manufacturing. Have things always looked this bright?
Extreme ultraviolet lithography has been in development for over 20 years and it's been a tricky technology to master. ASML, its customers, suppliers and partner research institutes have all worked together to bridge the gap between understanding the fundamental physics of EUV lithography and engineering an industrialized EUV machine that is ready for high-volume chip manufacturing. The technology really turned the corner in 2016 when we demonstrated the productivity and performance requirements that our customers had laid out for us.

What are those requirements?
We have worked tirelessly on requirements like reliability, uptime and cleanliness but, when it comes down to it, the number one requirement is that the lithography system is able to produce 125 wafers per hour. That's the magic number for cost efficiency in chip manufacturing. One of the enablers for that productivity has been source power, where we've worked together with TRUMPF toward getting a stable 250 watts.

How did you manage to get that source power?
Specifically, with TRUMPF, we worked at lightning speed to develop a module that completely isolates the seed module from the four amplifying CO_2 lasers. Together, we got the whole thing ready from prototype to industrialized module in just nine months. As a result, the Seed Isolation Module significantly increases the stability of the laser beam in our highly complex system and contributes to the consistent EUV performance we need. TRUMPF sent the new module from Germany to our lab in San Diego just before Christmas last year. We were able to demonstrate the module's success both in the lab and in front of our customers. It's a Christmas present to be proud of for everyone involved!

Have you made any other improvements to your EUV system?
We have managed to steadily improve the availability and reliability of the system as a whole. We have a new-generation droplet generator with much shorter maintenance times. We've also incorporated a highly advanced temperature management system in the droplet chamber, combined with a sophisticated hydrogen flow system that prevents particles of tin from hitting the laser optics and impairing the system's performance. All in all, that is steadily increasing uptime to 90 percent.

When are we likely to see the first high-performance smartphones with chips made using EUV?
There are currently 22 EUV systems in chip factories around the world, and we have another 28 systems on order from six customers. These orders show that chipmakers are committed to taking EUV into production at the end of this year. In terms of smartphones, that means you could be buying one with an EUV-enabled chip as early as 2019. ■



HOW EUV LITHOGRAPHY WORKS:
The machine drops 50,000 tiny droplets (1) of tin per second through a vacuum chamber. A CO_2 laser pulse (2) hits each droplet and turns it into plasma (3). That produces EUV light, which is then reflected (4) onto the wafer.

Marco Pieters is Senior Director Service and Product Marketing EUV at lithography giant ASML.

Christ Clijsen

AHEAD

ASML Headquartered in the Netherlands, ASML is the world's largest manufacturer of photolithography systems for the semiconductor industry.

EUV lithography The semiconductor industry has spent many years searching for a suitable method of printing even smaller features on silicon wafers. Smaller features mean you can pack more power into the same-sized chip. Dutch lithography company ASML and its German partners Zeiss and TRUMPF worked together to harness extreme ultraviolet (EUV) light with a wavelength of 13.5 nanometers for use in semiconductor lithography. The lithography system is an engineering marvel and offers the world's top chipmakers a cost-effective technology to continue to shrink chips.

When European shipbuilders got into rough seas, highly productive laser hybrid welding showed them the way ahead.

Minden Pictures / Mitsuaki Iwago

The perfect storm

European offshore wind-turbine manufacturers are struggling to keep their heads above water in a highly competitive international market. A small Danish lab is hoping to come to their rescue by following in the footsteps of the shipbuilding industry: by relying on highly productive laser hybrid welding.

Now two defenders of the European wind turbine industry are hoping to repeat that feat: project managers Steen Erik Nielsen and technician Jørgen Thomsen from Force Technology / LWT.

Kasper Fladmose

Welds up to 25 millimeters deep: Force Technology/LWT engineers use a 32-kilowatt laser to demonstrate laser hybrid welding processes for the maritime and the offshore wind turbine industries.

Kasper Fladmose, Gernot Walter

When it comes to prophesying what will happen in the energy industry, there's one thing experts agree on: offshore wind power has a definite role to play in the broad macroeconomic future. What's more, that role is set to become increasingly important, as demand for clean energy is growing. On the face of it, that seems like good news for wind-turbine manufacturers. So why is there such a tangible feeling of uncertainty along Europe's coastlines? Essentially, the wind-turbine sector is facing the same dilemma as many other industries: its products are unquestionably superior in technical terms, but the prices are simply too high for many customers. The problem lies in the manufacturing costs. Assembling a wind turbine remains a predominantly manual, time-consuming job—and specialized welders command very high hourly wages. That's why the industry is desperately searching for automated methods. The problem is that wind-turbine components are enormous, have complex geometries and are made using materials whose thickness in millimeters starts in mid-range, double-digit territory. Faced with that kind of challenge, even automated systems end up being too complex and costly. European wind-power companies have so far balked at making such huge investments. But all that might soon change: a small company in the Danish town of Munkebo is hoping to allay manufacturers' fears by showing them how investments in automation can pay off in the long term.

CHANGE IN MINDSET The Lindø Welding Technology (LWT) institute is a subsidiary of Force Technology, a technology consulting company. A project manager at LWT, Steen Erik Nielsen is responsible for innovative welding technologies. He doesn't regard either himself or his colleagues as researchers: "We leave it to other people to tackle the basics," he says. "Our goal is to deliver tangible results to manufacturers." In the case of wind turbines, his approach is modeled on a very specific example: shipbuilding. Around 15 years ago, European shipyards were in the same situation as wind-turbine manufacturers find themselves in today: they were stuck using expensive, manual manufacturing methods, and global competitors were breathing down their necks. One by one, the European shipyards fell by the wayside; the last remaining shipbuilders frantically searched for something that could save them. They changed their mindset, welcomed the laser into their production halls—and have managed to stay afloat. "Laser hybrid welding played a crucial role in achieving that," says Nielsen. "We were able to show that it works and fits the bill of cost-effective automation. That helped us get it certified as an application method, and now laser hybrid welding is in widespread use throughout the shipbuilding industry." The idea now is that laser hybrid welding could also save the European wind-turbine industry.

Over the past five years, Nielsen and his colleagues have completed four projects funded by the Danish government that focused on various parts of the manufacturing process. "As far as laser power goes, we have plenty of resources to draw on," says Nielsen with a smile. LWT's cutting-edge 32-kilowatt laser system delivers enough power for materials of just about any thickness. In addition, it can produce welds up to 25 millimeters deep in a single pass. Two 200-micrometer fibers connect two 16-kilowatt TRUMPF disk lasers to a laser welding head, which is positioned on a robot arm together with the arc-welding system. "With this set-up we can demonstrate the hybrid process very realistically," says Nielsen. "The absence of technological limitations means we can focus entirely on process design."

A WIN-WIN SITUATION One of the biggest issues was butt joints. These are an important element in the construction of wind-turbine towers, which are typically composed of multiple rings. The rings are made from rolled sheet steel and are welded together horizontally with a butt joint. The individual elements themselves are also joined using butt joints; the material is somewhere between 40 and 70 millimeters thick. "Turbine makers have traditionally used submerged arc welding to do that," says Nielsen. "But to be sure the seam is tough enough, you need around ten welding passes. The laser hybrid welding process we've developed gets it done in just two!" In LWT's method, the machining head travels over the weld once on either side of the metal sheet, producing a high-quality weld seam with no distortion. "That speeds up processing fivefold, and in some cases even tenfold," says Nielsen enthusiastically.

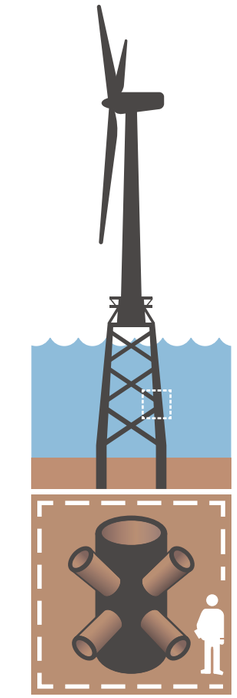
For a variety of reasons, some users prefer to weld on only one side of the sheet. "And we have a solution for them, too: root welding." The Danes first execute the root pass with gas metal arcwelding. Then they finish off the seam with one pass of the hybrid welding system. "Regardless which approach the manufacturer chooses: they still benefit from the time savings the laser offers," says Nielsen.

JACKET ON THE SEABED When it comes to making wind turbines, particular attention has to be paid to the components that will end up underwater. The wind turbine rests on a lattice structure known as a jacket, whose individual parts are extremely costly to produce—particularly the nodes. These are the components that interconnect the various tubes at the intersections of the lattice structure. It takes a welder between 30 and 50 passes to finish each part. "What would you say if I told you that, with our method, you need just a fraction of those passes?" says Nielsen.

A modern node consists of three to five individual parts, basically two to four smaller tubes that connect to a larger one. LWT examined every joint and began drawing up a plan for an automated process. "Although there are some minor variations in welding depth and joint geometry at each of the joints, our experiments quickly revealed that the root welding method would work well in this case, too," Nielsen explains. Gas metal arc welding is used for the first root pass on the inside, and then all it takes is a single pass of laser hybrid welding on the outside—and the node is finished. "Now the construction process for welding the full node takes just a few hours," says Nielsen happily. "With conventional methods, it would take somebody several days to do that!"

"If we convince one wind-turbine manufacturer, everyone else will then follow suit."

Steen Erik Nielsen, Project Manager Innovation in Welding Technology



The nodes are a crucial part of the underwater lattice structure that supports a wind turbine. It takes several days to make one of these by hand—but the method developed by Force Technology/LWT gets the job done in just a few hours.

EXCELLENT RESULTS—BUT WHAT NOW? So, does that mean that wind turbines made using laser hybrid welding will be sprouting up everywhere the next few years? Nielsen very much hopes so. The task of getting the method certified is almost finished, he says. "Now we just need someone bold enough to put it into practice," he says. "I imagine that we will convince at least one manufacturer to take the plunge—everyone else will then follow suit." ■

Contact: Force Technology / LWT,
Steen Erik Nielsen, Phone: +45 22 69 73 86, sen@force.dk

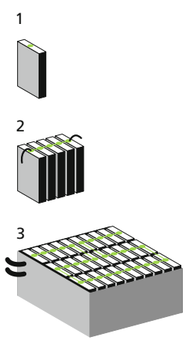
IT'S HEADING THIS WAY

We're well beyond the stage of just envisioning electric vehicles. Now we're looking at producing them by the million.

The honeymoon is over for electric carmakers. Or perhaps it never happened in the first place? After all, haven't the manufacturers of electric vehicles always had it tough?

The first people to build electric cars were seen as researchers, idealists—even pioneers. At first, they were laughed at or simply ignored. They struggled against skepticism over technical feasibility, range and their business model. And they always had to rely on buyers being willing to spend a few thousand more. The only thing they never had to worry about was volume production.

ELECTRIC CARMAKERS WERE IDEALISTIC PIONEERS. BUT NOW THEY HAVE TO START THINKING ABOUT MASS PRODUCTION.



An electric car battery basically consists of three elements: individual battery cells (1) are packed together to form battery modules (2). In the vehicle itself, multiple modules are combined to create a battery pack (3).

To build electric vehicles, or EVs, you needed patience, incredibly optimistic investors, nerves of steel and a market. What you didn't need was a solution to orders like "I'll take 100,000 of those parts, please. Every month." Budgets were tight, but with such low-volume production nobody had to rack their brains about whether method X would save half a cent at each step of the process as compared to method Y.

CHINA LEADS AND THE REST FOLLOW But now the honeymoon is over. Electric cars are set to become mainstream. Washington, DC and most governments in Europe have given them their backing and started plowing money into this vision of the future. Yet in some ways it hardly matters what the Europeans and Americans are doing, because EV trends will ultimately be set by the world's largest automobile market, China. And here the die has already been cast: in a country with 30 million new car registrations every year, the government has decreed that, starting in 2019, carmakers will have to make ten percent of their sales from electric vehicles. Even subdued forecasts suggest that half of all new cars worldwide will be electrified as early as 2025—in other words all-electric or hybrid models, with or without charging sockets. Today's parents driving their newborn babies home from the hospital in internal combustion engine cars will almost certainly be taking them to school in an electric car seven years from now. For a long time, the question was whether electromobility could even be achieved in practical terms—but now the question is how to produce millions of EVs in an affordable manner.

RAPID CHANGE OFFERS OPPORTUNITIES So the time has come to develop methods of mass production. The good news is that this accelerated upheaval in drive technology offers real opportunities to newcomers. The question is still open as to where EV value creation will lie in the future, and who will be in the right place to profit from it. It's perfectly possible, for example, that today's big automakers will limit themselves to designing the body and interior of their vehicles in ten years' time while simply buying in the batteries and electric motors.

However things pan out, what matters now is being smart enough to develop highly efficient manufacturing methods for EV-specific components. Over the past 30 years, automakers have clearly shown that the laser is a material processing tool they can use to execute flexible, high-precision steps on the factory floor in next to no time. And many of the key car components—body, interior, lightweight components, brakes, etc.—aren't going anywhere. Even in 2025, electric cars will still need doors, and the carmakers already know how to make them efficiently. But now three new fronts are opening up: batteries, electric drives and high-power electronic systems. EV sales are currently running at about two million a year, and forecasts suggest that will rise to 40 million in just a few years' time. To keep up, many industry players will once again have to rely on laser material processing.

BATTERY TIMES THREE What we loosely refer to as a battery is, in fact, a fairly complex entity. There are actually three components that hold the key to the efficient manufacturing of energy storage devices for electromobility: battery cells, battery modules and battery packs.

Lithium-ion battery cells are built up in layers: copper foil and coated aluminum layered together with the electrode foils of lithium metal oxide (cathode) and graphite (anode). Each of the different foils is approximately 100 microns thick, and the easiest way to cut them is with a short-pulse laser. After adding the liquid electrolyte, the next step is to seal the cell with a cap and fit a pressure-relief valve. It is essential that the welds completely seal the cell, but it is equally important that they do not penetrate too deep since this would render the cell useless. So, once again, battery-cell manufacturers turn to the delicate and reliable touch of the laser. Today's market for battery cells is largely divided up between volume manufacturers in China, South Korea and Japan. In contrast, the market for battery modules is still open—so far, no standards have been set for the rest of the process.

TACKLING A DILEMMA WITH WOBBLING Normally, between 9 and 12 cells are grouped together to form a battery module. For the battery module to work as a unit, the battery cell terminals must be interconnected. This is achieved using thin metal strips, generally made from 0.3-millimeter sheets of copper or aluminum. Known as leads, or tabs, these strips carry electric current into or out of the cells and are lap-welded.

That may sound simple, but it puts workers in a tricky situation: if they accidentally extend a weld into a cell that is packed with chemicals, or heat it to more than 80 degrees Celsius, the battery burns out and has to be scrapped. That's why it's so important to weld the seam with a carefully judged penetration depth, as close as possible to the minimum needed for a stable, lasting connection. Of course the weld seam's main purpose is not to hold the parts together, but to ensure an efficient flow of current. That, in turn, requires low resistance and a sufficiently large contact area: basically the bigger, the better. Scanner-based laser welding solves this dilemma with "wobbling." The scanner system automatically positions the small laser spot in the correct place and oscillates the beam over the metal strip. This creates a very fine, very long seam which produces a large contact area.

The second compelling feature of scanner welding is the tremendous speed the laser can achieve by working at a distance. No cumbersome steps are required to move the tool to the welding point—it simply executes numerous welds a minute as it flies by. The result is precisely the combination of short cycle times and high quality that automakers relish.

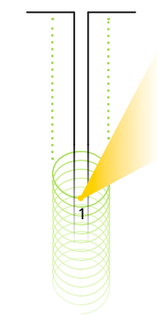
Connecting the busbar contacts poses a problem similar to that of the cell tabs. The busbar connects up all the battery cells in a module and collects all the current. The contact welding process often requires the joining of dissimilar materials—in this case, the highly reflective materials aluminum and copper. Disc lasers can easily deal with the sustained back reflections and, once again, scanner-based welding with a disk laser and wobbling prove to be the ideal solution.

IT'S STILL FAR FROM CLEAR WHO WILL MAKE THE MOST MONEY FROM ELECTROMOBILITY.

The battery pack is what ends up being installed in the vehicle. To achieve the ideal center of gravity for the vehicle, all the battery modules are packed into a shallow compartment on the underbody of the vehicle, just a few centimeters above the asphalt. The pack must be completely sealed to avoid any chemicals dripping onto the ground and to prevent water from the road spraying into the compartment. And, just like a gas tank, it needs to remain intact not just under normal driving conditions, but also in the event of a crash.

The manufacturers weld together the five-sided, tightly sealed compartments from steel components, aluminum and other sheet metals using a highly productive disc-laser welding technique. Once the compartment is finished, they glue the lid onto it. The laser plays a role here, too, cleaning and structuring the surface to prepare it for gluing. Even when companies start producing battery packs in higher volumes, the laser will still have its place on the factory floor. Even though standard battery compartments will probably be formed by deep drawing, lasers will still be used to weld parts for model variants and special short-run series, such as convertibles with a lowered chassis that need a flatter battery compartment than standard models.

MAKING ELECTRIC MOTORS FASTER As the industry seeks ways to accommodate volume production, companies are also starting to reconsider some of the traditional, yet sluggish, manufacturing methods currently used for electric motors. One example is the coil. Normally, the stators in electric motors are provided with a winding of copper wire. Each individual slot in the stator is wrapped in a winding that goes in and out, in and out, almost like knitting! That takes time—and it's tough to automate. →



Wobbling is a technique that involves oscillating a scanner-guided beam (1) in a spiral motion. This effect can be exploited to create fine welds with a large contact area for battery modules and busbars, without requiring any filler material.

MORE THAN JUST CARS

The trend toward using electric traction drives in mobility extends far beyond the automobile. The core technology of the battery and motor—and the way they are manufactured—are essentially identical whether you are dealing with a pedelec or an electric ferry.

Gernot Walter

TRUCKS
Much of a truck's fuel consumption and wear occurs when it's braking and accelerating. That's when an electric motor can step in, leaving the more economical diesel engine to handle longer periods of freeway driving. Meanwhile, the first all-electric trucks are already being tested on the road. And the old idea of powering trucks with overhead electric lines is currently being tested on stretches of Swedish and German freeways.

DELIVERY VEHICLES
Postal and parcel-delivery companies all over the world are switching to EVs, because internal combustion engines ultimately perform worse when vehicles have to constantly stop to make deliveries. Deutsche Post even produces its own all-electric delivery van. Tradespeople and florists, for instance, are also increasingly switching to electric delivery vehicles.

SHIPS
The world's first car and passenger ferry powered solely by batteries is already in operation in Norway. The crossing is short, so the battery doesn't have to hold its charge for long. The ferry recharges the battery for the next trip while passengers are embarking and disembarking. Newer cruise ships use electric motors, constantly charging their batteries with a highly efficient diesel engine.

MUNICIPAL VEHICLES
In many parts of the world, municipal authorities have already opted to electrify their fleets for street sweeping, garbage collecting, and spreading sand, salt or grit. Landscape gardeners also use their electric vans for work on site, plugging in tools such as electric chainsaws.

AGRICULTURAL MACHINERY
The first all-electric tractors from U.S. manufacturer John Deere are already quietly carving out furrows in the soil. Once again, this sidesteps the problem of power-hungry acceleration, paving the way for zero-emission agriculture.

PEDELECS AND ELECTRIC BIKES
Bicycles with electric pedal assist have been gaining in popularity for years, making cycling an enjoyable option in hilly areas, too.

INDUSTRIAL VEHICLES
Heavy-duty EVs are used primarily in places where companies want to avoid exhaust emissions, such as electric mine vehicles, forklift trucks with lithium-ion batteries on the factory floor and even electric snowcats on ski slopes.

ELECTRIC SCOOTERS
Millions of electric scooters are already sold each year in East and Southeast Asian markets. Here, too, governments see them as a means of reducing noise and pollution in city centers—and are offering major incentives to make them cheaper to buy.

BUSES
More and more cities are clamoring for zero-emission public transport, and therefore buying battery-powered city buses from companies like Chinese automaker BYD and Polish company Solaris. The first all-electric long-distance buses have also entered the market. Russia has been operating public buses with overhead electric lines for decades.

AIRCRAFT
Electrically powered one- and two-seater aircraft are already on the market. In addition, Airbus is confident that its small ten-seater aircraft will soon crack the thousand-kilometer range. Meanwhile, Rolls-Royce and Siemens expect the first 90-seat airliner with a hybrid electric drive to take off in 2020.

RAIL
Electrically powered streetcars and trains may seem like old hat, but rail-vehicle manufacturers are also set to benefit from the numerous innovations in e-mobility.

The auto industry considers this process to have reached the limits of its productivity and is banking on a new technique known as hairpins. This involves using a compressed-air pistol to fire a rectangular copper wire similar to a hairpin straight into each slot. This method is several times faster—just one shot per slot—and it completely fills the space with copper, which increases the motor's efficiency. The protruding parts of the hairpin on both sides are then pressed onto each other using a mask, or are jammed or twisted together. The problem is that the hairpins are sometimes slightly out of alignment with each other after this process, with unsightly gaps in certain places. That's when scanner welding comes back into play: a camera in the laser optics determines the orientation of the objects within the space and finds the ideal welding point within just a few fractions of a second. The beam focus oscillates and, in little more than a minute, all 200 of the welds required for each motor are finished—and the laser is ready to weld the connections for the next motor.

The second benefit of using high-precision scanner laser welding for hairpins is that it reduces the overhang of the weld seam to almost zero. The slots and hairpins can move closer together, and that means the motor takes up less space.

At this point the copper hairpins go under the laser for the second time, having already had their insulating enamel removed by a pulsed nanosecond laser earlier in the process, either directly on the coil or before winding. Mechanical methods to remove the enamel—such as planing and milling—can no longer keep pace with the required level of productivity.

MOBILE POWER ELECTRONICS For the first time, power electronics such as chargers, transformers, rectifiers and battery-management systems are making massive inroads into the realm of cars and their charging infrastructure. While the electronics in cars powered by fossil fuels had to make do with a 48-volt battery, electric cars will soon be using voltages as high as 800 volts. Once again, the companies that manufacture these kinds of power electronics are faced with the dilemma of how to mass-produce these components—and how to make them as small as possible. That's because every millimeter counts for carmakers when it comes to battery-pack size and installation space, and engineers may decide that even the millimeter-sized contact pins are too big. What's more, weld spatter can become a serious problem for contact connectors: a large spatter droplet could easily consign the virtually finished component to the scrap heap. Even worse, spatter could end up stuck to the component, initially harmless, but then suddenly come loose later on when the car is in motion—causing a short circuit and bringing the car to a standstill. The problem is that space is tight when it comes to welding electronic components, so there is simply no space for devices designed to intercept spatter. That's why engineers opt for a disk laser. Combined with special technology that simultaneously overlays two welding foci, a disk laser can create virtually spatter-free welds even in small, cramped environments. The laser welds directly in the groove, which keeps the contact pins below three millimeters. More valuable millimeters shaved off the size of the components—and every little bit helps!

E-CAR FOR EVERYONE MEANS MORE LASER-BASED SERIES PRODUCTION PROCESSES.

THINKING ELECTRIC A whole army of professors, think tanks, companies and elected officials are pondering the future of mobility; they often come to very different conclusions. But one thing they have in common is the belief that all the most promising solutions for personal transportation are electric, from car sharing to autonomous driving. Most industry trendspotters have simply forgotten about sputtering, fossil-fuel cars—a sure sign that their era is coming to a close. At the same time, however, personal mobility is more in demand than ever before in human history. The next five years will reveal the big winners and losers in the transition to mass-produced electric motors. It already seems clear, though, that the idea of electric cars for everyone will ultimately mean more volume and series production processes that rely on lasers. ■

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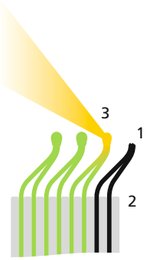

Hairpin-like windings instead of coil windings in an electrical motor: Hairpin-like windings (1) made from rectangular copper wire inserted in a stator (2). The protruding ends are pressed together and laser welded with a scanner system (3).

Gernot Walter

INSTALLATION SPACE IS KEY FOR TODAY'S ELECTRIC MOTORS AND POWER ELECTRONICS—EVERY MILLIMETER COUNTS.

LATEST → RESEARCH

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

MACHINING OF 3D MICRO-STRUCTURES BY FEMTOSECOND PULSED LASER ABLATION

High-precision material machining with femtosecond laser pulses offers new opportunities in all sorts of areas, for example in surface processing. As part of his doctoral dissertation at the University of Wisconsin-Madison, Yinggang Huang (32) applied the technique of ablation with a femtosecond laser to create three different microstructures that would be difficult to produce using other methods. These micro-structures have considerable potential for microfluidics, photovoltaics and imaging.

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LASER MACHINING THE SURFACE OF A SHIP'S HULL PREVENTS BIOFOULING

Biofouling—damage to a ship's hull caused by the accumulation of organisms such as bacteria, microbes and larvae—is a serious problem in the shipping industry. Because of a ban on applying toxic antifouling paints to ship hulls in the name of protecting marine organisms, there is a clear need for alternatives. In her master's thesis at Lamar University in Texas, Swagatika Patra (25) collaborated with her research partner Raghabendra Rout to investigate how the surface topography of a ship's hull can be modified with a picosecond laser to prevent biofouling.

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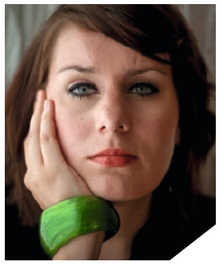
HEATING AND EXCITATION OF METAL NANORODS

Nanorods absorb light in the infrared region and are efficient nano heat sources. They are already used in fields such as cancer treatment and optical data storage. Their shape is not stable, however. Metal nanorods typically deform toward a more sphere-like shape, which is far from ideal in applications such as cancer treatment. As part of her PhD at Utrecht University in the Netherlands, Wiebke Albrecht (31) excited metal nanorods on a single-particle level with femtosecond laser pulses, and compared the nanoparticles before and after excitation. The results should help scientists understand the deformation behavior of nanorods and optimize them for use in specific applications.



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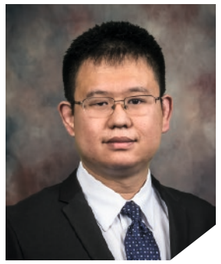
LASER CLADDING OF ALLOYS USING A HIGH-POWER DIRECT DIODE LASER

Erosion and corrosion are the most common causes of component failure in the oil and gas industry, hydropower plants and mining facilities. One effective and efficient way to mitigate these issues is to apply protective coatings to component surfaces. For his doctoral dissertation at the Research Center for Advanced Manufacturing at Southern Methodist University in Dallas, Zhe Zhang (29) used a high-power direct diode laser to produce two types of protective coating based on the martensitic stainless steel AISI 420. These two coatings could extend component life significantly.



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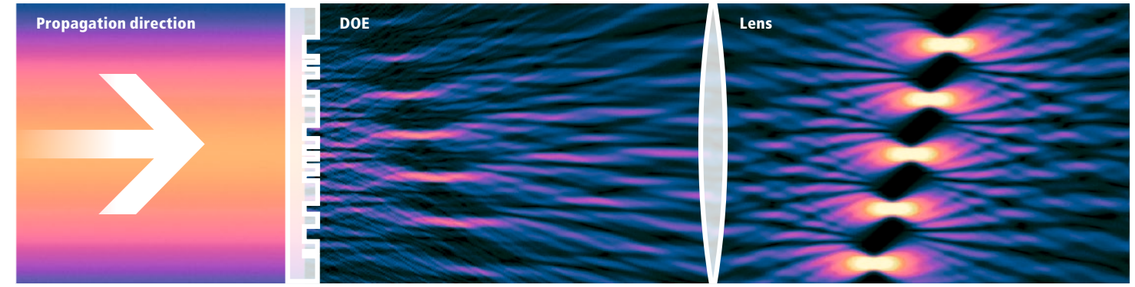

Simulated effect of a diffractive optical element (DOE): in this example, the system generates six volume-distributed focus zones on the workpiece from a single beam using targeted aberration of the laser light. The different colors show the intensity distribution.

The transition from geometrical optics to wave optics opens up a new dimension in laser material processing. A thousandfold increase in productivity is realistic.

Power of the wave

I still remember a bearded physics teacher drawing a ray of light and a mirror on the board and saying: "The angle of incidence is equal to the angle of reflection." Later on, we would discover that the whole light thing was a lot more complicated, but this seventh-grade perspective on optics has proved to be sufficient for laser material processing for decades: light is a ray, and a focus is a point at which converging rays unite. Frankly, that wasn't such a bad thing. In most applications—and for the purpose of designing optics—geometrical, or ray, optics gives you plenty of information, at least for the rectilinear propagation of light in a medium, reflection, refraction, shadow formation, and the path light follows in optical devices, such as focusing optics. If you are interested only in focusing light energy on a particular spot, then ray optics is a useful model.

CROSSING THE THRESHOLD But there's a lot more you can do with light, so it's worth taking things a few more steps. Even in well-established laser machining processes such as cutting steel with conventional optics, engineers often strive to optimize the focal point, which essentially means acknowledging that the focus is not actually a spot, but rather a spatial distribution of intensities. In order to calculate and optimize these intensity distributions, we need to picture light as a wave; we thus enter the domain of wave optics. Here, a focus is not a point, but rather an intensity distribution that extends in the x, y and z directions. That opens up a wealth of additional information about the focus. And, more importantly, it means it can finally be manipulated. In a big way!

A THOUSAND TIMES MORE EFFICIENT Targeted aberration of the laser beam enables us to tailor the focus to the requirements of a particular application. In glass cutting, for example, we can extend the focus along the direction of propagation in order to simultaneously change the structure of the material throughout the entire volume of the glass. Another option is to use diffractive optical elements (DOEs) to accelerate light. This method causes the focus to bend at a certain angle, so it looks like the letter C, for example. Laser beams with a C-shaped focus can then be used during cutting to give display glass the curved edges it needs without any reworking. Other DOEs split the focus and distribute it freely in space within a given volume. In TRUMPF's advanced engineering department, we have already split a laser beam into 133 foci and freely distributed them in a different form within a volume of one cubic millimeter. This has enabled us to tap into new opportunities and efficiencies in the microprocessing realm. On this basis, it is perfectly conceivable that we could distribute them in other volumes, too, with the number of foci ascending to the hundreds of thousands. Metalworking applications could benefit from rectangular functions (flat-top distribution), which generate homogeneous intensity over a certain width, while the intensity outside the rectangle is simply zero. Instead of producing surface structures pulse by pulse, a focus with flat-top distribution can ablate the material in a single shot. The efficiency gains are huge: depending on the laser you're using, diffractive beam splitting can divide each focal point of the beam into between 50 and 1,000 foci without any loss of power, thereby increasing the processing throughput by a factor of 50 or 1,000, respectively.

HIGH COMPUTING EFFORT As we can see, wave optics offers all sorts of new opportunities. But it's not just about shifting how we think about things; it also involves a lot of hard work! That's because switching from ray optics to wave optics means leaving behind a mathematically simple model and switching to a much more complex one. This transition affects not only mathematical modeling, but also computer simulations and the analysis of lab results. In the TRUMPF advanced engineering department, we have performed pioneering work in all these fields. As a result, we can describe light in terms of wave optics along its complete path from the beam source to the workpiece. This also involves not only modeling the coherence of light waves from the light source, but also considering issues such as resonator modes in order to understand the field distribution within the focusing optics. It is not uncommon to be dealing with a billion pieces of information for a single laser beam within this kind of four-dimensional matrix (three spatial dimensions and one time dimension). That requires correspondingly high computing and simulation capacities. What's more, the wave-optics model is different for each laser. For example, there is a huge difference between cw, short-pulse, disk and fiber lasers in terms of their wave optics.

GATEWAY TO A NEW WORLD Wave optics are currently ushering us through the gateway to a new world of laser material processing. In the coming years, we will be operating with applications and achieving efficiency gains that will almost seem like witchcraft to users of geometrical optics! Yet the next threshold is already in sight. If we think of ray optics as a crutch, and wave optics as a pair of running shoes, then quantum electrodynamic (QED) optics may well seem like a racing car 30 years from now. But, for the moment, QED optics is difficult to calculate for macroscopic applications and yields far too much information, which we are incapable of using for optics design. Of course, that was also true of wave optics until recently. ■

DR. DANIEL FLAMM works in the TRUMPF advanced engineering department. This group of young researchers investigates fundamental aspects of laser optics. Among other areas, they are currently examining the potential of wave optics for laser material processing.

TRUMPF

BRUSHING UP ON 3D PRINTING

Two different additive methods to make one simple steel pin? That may sound excessive, but Klaus Eimann from Procter & Gamble realized it was the perfect way to solve one of the trickiest problems in manufacturing electric toothbrushes.

Klaus Eimann, Head of Additive Manufacturing, has been working with his tenacious team of experts to bring new technologies on board. Now they have acquired the expertise they need to play a pioneering role in the industry.

Philipp Reinhard

The challenge lay in this injection mold for the brush holder. The part poking out is the steel pin made using LMF and LMD.

"We had to completely rethink, experiment a lot and keep on persuading."

Klaus Eimann, Head of Additive Manufacturing

n 1890, Englishman Dr. George Scott patented a design for the first electric toothbrush. His success was limited since most people considered the device to be too expensive and bothersome to use. Nothing much changed until 1960, when Oral-B launched an electric toothbrush, called the Mayadent, aimed at a broader public. Today, Oral-B is part of the U.S. conglomerate Procter & Gamble—and just about every drugstore sells electric toothbrushes. The company makes some 100,000 toothbrushes a day at its plant in Marktheidenfeld, Germany. To keep up this pace, its production engineers have to find high-tech solutions for even the smallest and simplest-looking parts.

IN AT THE DEEP END Additive manufacturing is one of the key weapons in Procter & Gamble's arsenal of methods for speeding up production. When TRUMPF launched its first laser-based 3D printing machine TrumaForm in 2003, Procter & Gamble was one of the few companies to see which way things were heading. Klaus Eimann heads up laser machining and additive manufacturing in Marktheidenfeld: "We've been using both powder-bed-based laser metal fusion (LMF) and laser metal deposition (LMD) in our mold-making and maintenance processes since 2006." That's when the team of specialists started focusing on maximizing the potential benefits of additive manufacturing methods. "The new technology has always been an exciting challenge, and things don't always work out the first time around! In the early stages we had to completely rethink the design process. We were experimenting with all sorts of things and working hard to persuade our colleagues it was the way forward. But we believed in what we were doing, and eventually our stubbornness paid off. We gained a real knowledge advantage—and now that's helping us play a pioneering role in our industry."

EVERY LITTLE BIT HELPS The task of optimizing the Oral-B toothbrush manufacturing process is just one area that has benefited from the Marktheidenfeld toolmakers' expertise in LMF and LMD. Their focus was on a steel pin around eight centimeters long that is integrated in an injection mold. This mold forms the plastic section that subsequently holds the brush. "The problem was that the steel pin took a relatively long time to cool down," says Eimann. "The moment the plastic touched the steel, you could never be sure enough heat would be dissipated. That ended up deforming the molded plastic, which meant lots of parts had to be scrapped." Giving the mold more time to cool down wasn't an option since the rapid cycle times were non-negotiable. In fact, today's high volumes require the manufacturing process to go even faster than before. "So our job was to redesign the steel pin to make it cool down faster."

Two additive methods are used to produce the metal pin in the mold: the 3D-printed steel body features cooling channels (1) and contains a fast-cooling copper pin (2) which is built up in layers using LMD and joined to the steel body (3).

Philipp Reinhard

Cycle time is key in high-volume production. Engineers managed to shave seven seconds off the cycle time for Oral-B toothbrushes by using LMF and LMD.

CLEVER COMBINATION To begin with, the tool specialists focused on the benefits offered by LMF: namely, the ability to produce intricate designs with internally complex forms. Using powder-bed 3D printing, they built up the steel pin layer by layer, and managed to incorporate a highly efficient spiral cooling channel inside it—even though the part has a diameter of just 12 millimeters. "There's no way we could have done that with conventional manufacturing methods," says Eimann. Their tests showed that they could achieve a tenfold increase in the steel pin's thermal conductivity of 27 watts per meter-kelvin (W/mk) by pumping cooling water through the spiral channels. "That was certainly good, but we still needed it to be better."

So the experts came up with an additional solution that involved using a material with higher thermal conductivity: copper. Their calculations showed that they could cool down the steel pin within the required timeframe if they could somehow combine it with a section of copper pin at the top. However, this material is neither stable nor robust enough to cope with the heat that the mold is exposed to during injection molding. Incorporating an actively cooled area in a molded pin just three millimeters in diameter is impossible, but the engineers didn't want to give up on copper. Might it be possible to use the fast-cooling copper while somehow keeping it stable enough, they wondered?

The breakthrough came when they brought the second additive method—laser metal deposition, or LMD—into the equation. First, they inserted the copper pin inside the 3D-printed steel cast pin. Then the experts created a stable and seamless bond by encasing both pins in tool steel using laser metal deposition. The result was a piece without obvious joints that looks like it has been cast from a single mold. Now the new cast pin has efficient spiral cooling channels and a copper core that quickly and evenly dissipates the heat of the injection molding process from the plastic. The production team that makes the brushes is pleased with the results. "Our expertise and many years of experience with LMF and LMD guided us to an unusual but efficient solution. We managed to reduce the cycle time by seven seconds and keep scrap rates down to just a few parts per thousand." ■

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Dumb parts in a smart factory

IN A SMART FACTORY, A WORKPIECE CAN BE AS DUMB AS YOU LIKE. ALL IT TAKES IS A DATA MATRIX CODE—AND THE MACHINE WILL KNOW EXACTLY WHAT TO DO.

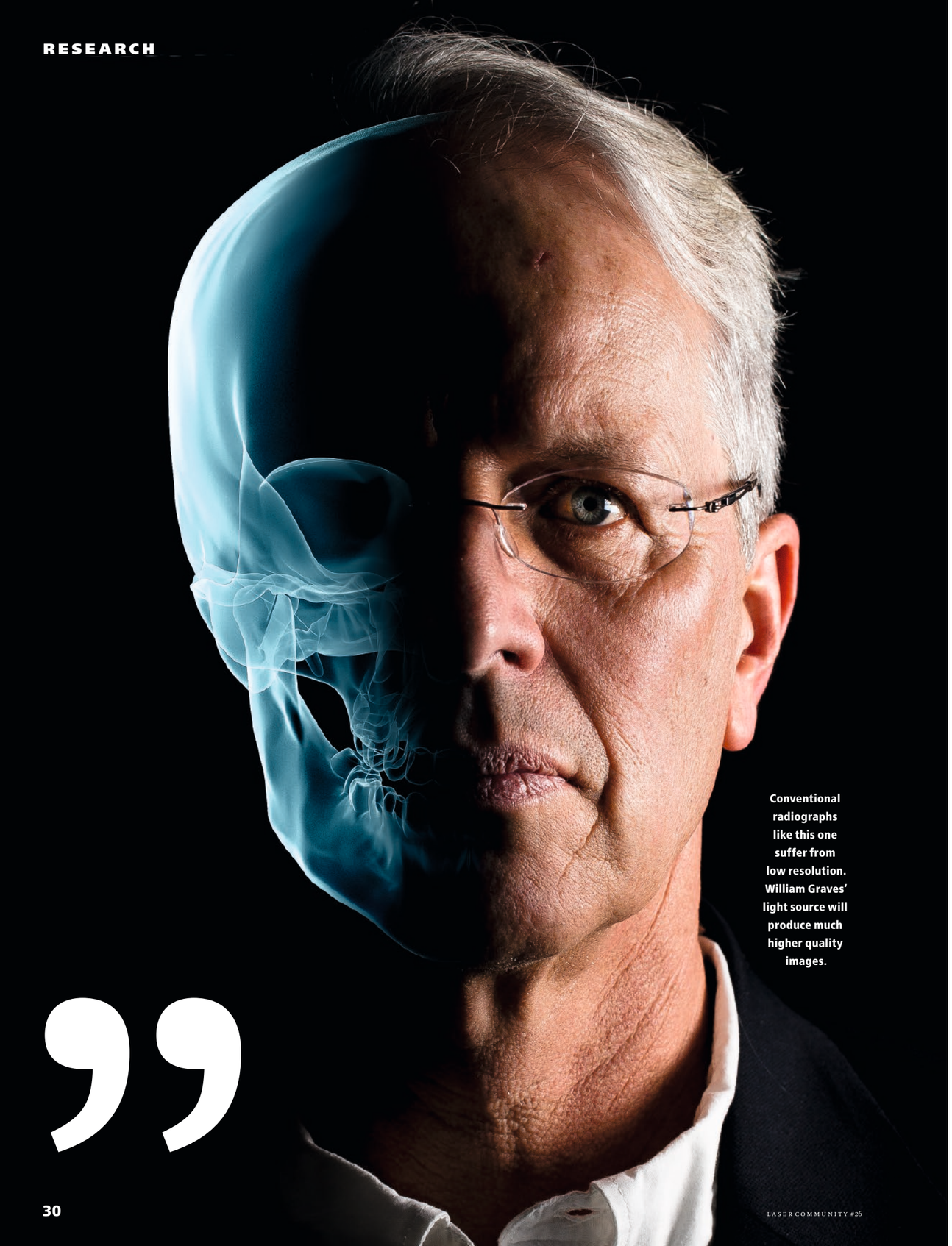
The goal of a smart factory is to get machines acting and reacting in harmony with the wealth of information flowing through the manufacturing environment. To achieve this, the machines need to be equipped with hardware and software interfaces, automated workflows and sensor systems. This may be challenging, but it is perfectly feasible. Nevertheless, things get trickier when you bring workpieces into the equation, because how are they supposed to communicate with the machines? How do they say: "I'm Workpiece X. Please process me using Program Y!"

The first reflex is to say: "Let's give the workpiece a tiny brain in the form of an RFID chip that transmits and receives information." But that presents all kinds of problems. RFID chips are foreign objects that you somehow have to mount on the workpiece. They might fall off, and they're not robust enough to cope with all sorts of standard production processes such as annealing, hardening, burnishing and acid baths. So a better, more practical idea is to give the workpieces their very own laser-marked Data Matrix code right from the outset. That means the workpieces can leave all the thinking to the smart factory around them. By scanning the code, the machines get exactly the information they need to execute their part of the process. Once a machine has finished with the workpiece, a marking laser applies a new code and the process continues. Any conceivable information can be accommodated in the space of just a few square millimeters. From the operations completed so far to traceability details, order numbers and quality control aspects: all the information is durably and permanently marked on the surface. Plus, if you are working in a laser machining environment, then 2D cutting machines can apply the marking themselves.

In all other environments, you can simply use a marking laser. The latest TRUMPF marking lasers are as quick and easy to add to a machine as a light, and once they are installed you can sit back and let them do their job. For a long time now, we've been offering our marking-laser hardware as a self-contained and extremely compact system consisting of easy-to-install components: PC, electronics, beam source and optics. And our marking-system software is compatible with a wide range of interfaces. Users don't need to know anything at all about laser technology. The marking laser does everything you need in the background, keeping factories smart and letting workpieces be as dumb as they like. And this is just one of the many ways we help foster the smart factory vision. ■

Dr. Florian Kanal works at TRUMPF as a product manager for micro and marking lasers.

TRUMPF, Gernot Walter



Conventional radiographs like this one suffer from low resolution. William Graves' light source will produce much higher quality images.

Marc Mintz; iStock/angelhell

"The X-ray revolution will be here in five years."

Extremely high-resolution X-ray images are incredibly complex and expensive to produce, so they are seldom used. Professor William Graves hopes to change all that with some ingenious laser technology.

You're working on an X-ray light source that costs several million dollars and is the size of a living room. Who would want something like that?
Everyone.
Everyone?
Well, perhaps not everyone! But certainly anyone who wants to peer inside objects, animals or people without actually opening them up.

But can't we already do that? What's so special about your X-ray light source?
It fills a huge gap in the market. On the one hand, we have the standard X-ray machines you see in hospitals and doctors' offices. But their resolution and brightness have barely improved since Wilhelm Conrad Röntgen's time, which was about a hundred years ago. On the other hand, you have researchers who have succeeded in creating much better X-ray light sources for scientific use called X-ray free electron-lasers, or XFELs. Their brightness is about a billion times greater than the machines doctors use. Scientists can use the beams to illuminate processes at the molecular and atomic level, so there's no doubt that XFELs are pretty amazing.

Do I detect a "but"...?
Well, the problem is that XFELs cost over a billion dollars to purchase and 100 million dollars annually to operate, essentially because they work only as part of particle accelerators that are kilometers in length. So where does that leave us? Basically, with a really good but incredibly expensive technology that is accessible to only a few people at one end of the scale, and a virtually obsolete technology for widespread use in doctors' offices at the other. The gap I'm referring to lies somewhere in the middle.

How do you propose to plug that gap?
By building a high-quality X-ray light source that matches the quality of an XFEL. The difference is that it will be just ten meters long and cost just a few million dollars. We call it a compact X-ray light source. It's aimed at researchers working at universities and in industrial labs, and of course doctors in major hospitals. It's set to have a significant impact on medicine and research.

What new things will your X-ray light source be capable of?
First, it makes high-quality X-ray sources available to a much wider group of people. That's what will lead to new applications, new knowledge and other developments. Our X-ray sources will enable extraordinarily high-resolution medical imaging, allowing us to create videos and images of things inside the body, such as different types of soft tissue. That will help doctors spot things such as tumors and arterial blockages—and even allow them to determine whether those tumors and blockages are dangerous or not. We'll also be able to overcome a constraint that has long saddled medical imaging: high-quality X-rays have virtually no negative impact on the body, so people will be able to get as many X-rays as they need. And second, it overcomes a severe shortcoming of the big X-ray facilities, which is lack of phase coherence, so that it can improve even their performance by a factor of 100.

WILLIAM GRAVES is an Associate Professor in the Physics Department and the Biodesign Center for Applied Structural Discovery at Arizona State University. Soon he will be constructing a revolutionary X-ray light source in a new building that is currently being erected on the ASU campus.

Are there any other potential applications?
How much time do you have? (smiles) There are myriad possible uses in research and development. Scientists working in pharmaceutical research, for example, will suddenly have access to a simple method of studying the molecular structure of different proteins. The same will apply to materials research at universities and corporate labs. Engineers in the semiconductor industry are currently working blind when they develop semiconductor architectures, but high-quality X-ray sources will finally enable them to see again. Galleries and auction houses will be able to use X-ray spectroscopy to examine paintings and verify they are the genuine article. In fact, this technique has already been used in Australia on an impressionist masterpiece by Edgar Degas to reveal a second painting of his hidden underneath. Archaeologists will benefit too, because it will enable them to determine the material composition of artifacts and improve their methods of dating them. As you can see, there are lots and lots of potential applications; all sorts of small, hidden things will suddenly become visible.

What's the technology behind it?
X-rays are produced when high-speed electrons are suddenly decelerated. In a particle accelerator, or synchrotron, researchers slow down an electron beam by deflecting it into an undulator using strong magnets and forcing it along a wave-like path. An undulator consists of two rows of magnets with alternating poles across the beam path. As electrons pass through the gap between the two rows, the undulator "wiggles" them from side to side, causing them to emit X-rays. But this process works only if the electrons are already traveling at an extremely high energy when they enter the undulator—and that's why you need particle accelerators that are kilometers long. We take a different approach. Our electrons can be lower energy, because we simply wiggle them faster using laser pulses in place of undulator magnets.

You might have to explain that.
Laser pulses are electromagnetic waves, so they also have a magnetic field. That's what we use. A standard magnet component in an undulator is about three centimeters long. So you need three centimeters just to make an electron wiggle once. But with picosecond laser pulses we can get the same wiggle effect over a distance of just one micrometer, which is thirty thousand times shorter. That makes the wiggling motion thirty thousand times faster, so all we need in the end is a very straightforward and not particularly powerful particle accelerator just one meter long. We focus the electrons with magnets that take up another nine meters, and what comes out the other end are photons with a wavelength in the X-ray range—just like you get from an XFEL.

What capabilities must the laser have to make all that work?
The laser is the key to the whole system. Since the pulses are meant to be imitating a fixed undulator field, we need a laser source that is incredibly stable in all kinds of different ways. The repetition rate has to be constant and at least one kilohertz. The laser must always deliver exactly the same amount of energy in each individual pulse, and we can't have the pulses straying from their path—we need maximum target accuracy. Plus, of course, the timing of the pulses has to be just right. TRUMPF Scientific Lasers in Munich was the only company that showed us they were capable of meeting those demanding stability requirements. They developed this new laser in close consultation with us over a two-year period. It took a bit longer than we had hoped, but the results are superb, and we're delighted to have TRUMPF as a partner.

"All sorts of small, hidden things will suddenly become visible."

Marc Mintz

When will people be able to order the X-ray machine?
Right now we're putting the system together at our institute with the help of various companies and hospitals. It's always difficult to predict when the test phase will come to an end and we'll be ready to market the product. But I think our compact XFEL will be available for anyone to buy within five years or less.

Where does your enthusiasm for X-rays come from?
I'm obviously interested in X-rays, but my motivation actually stems from something quite different. When I was 20, I didn't really know what I wanted to do with my life. I had a real thing for singular, high-spec cars, so I spent ten years tinkering around with Ferraris during the day and taking physics courses in the evening. I soon realized that I really liked elaborate machines with complex mechanisms! Then I got a new job through friends and started working as a technician at a particle accelerator—a job that involved even more complex mechanisms. My passion for the physics of beams led me rapidly to a PhD so that I could spend even more time working on complex machines. That's essentially what the compact X-ray light source is, too: a singular series of complex mechanisms. You could even call it my own personal Ferrari! ■

Here comes the sun

HOW THE LASER CAN SOLVE OUR ENERGY PROBLEMS — AND WHY WE CAN LOOK FORWARD TO WARP DRIVES OFFERING FASTER-THAN-LIGHT TRAVEL.

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

"Please tell me this doesn't run on gas! Gas explodes, you know!" I had almost forgotten that scene from "I, Robot"—the US blockbuster made nearly 15 years ago. The movie is set in the year 2035, when artificial intelligence has become a reality and all cars are electric. In this scene, Del Spooner (played by Will Smith) digs out an old gasoline-engine motorcycle—to the absolute horror of his companion Susan Calvin.

However over-the-top her reaction may seem, the movie's message is clear: nobody in 2035 wants vehicles that run on gas. Even the thought of it seems absurd. The future clearly belongs to electromobility. I think that's great, though at the same time I worry about the CO_2 footprint. After all, I find myself wondering, where will we get the clean power to charge all those electric cars?

As I tend to do in these cases, I find the answer in science fiction: nuclear fusion, the power of the sun! In the CBS series "Star Trek: Discovery," the gargantuan Imperial Palace starship roams the galaxies in a parallel universe. And it is, of course, fusion-powered. That basically means it uses the controlled fusion of deuterium and tritium in a thermonuclear reaction, tapping into a practically inexhaustible source of energy to keep the ISS Charon permanently powered up.

You might argue, of course, that outside the realms of science fiction we're still a long way from achieving controlled nuclear fusion—and you'd be right. But I can't help thinking about what Jules Verne wrote in "Journey to the Center of the Earth" in 1864: "Anything one person can imagine, other people can make real." And that's exactly what is happening at the National Ignition Facility in Livermore, California, where researchers are working on the world's most powerful laser. Scientists hope the laser facility, with a surface area as large as a World Cup field, will ignite an artificial sun by delivering a few megajoules of energy, creating a fusion reactor that could supply enough clean energy for all those electric cars.

So have no fear! The clean energy source to power our electric vehicles is on its way. And by the way, Mr. Verne, I can also vividly imagine time travel, teleportation and warp drives that distort space-time and accelerate starships to speeds faster than light ... ■

Could an artificial star ignited by a laser be the solution to our search for cleaner energy? What do you think? Let me know by email: athanassios.kaliudis@de.trumpf.com

Gernot Walter

WHERE'S THE LASER?

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In two bodies colliding:

Anyone who plays American football has to be willing to take some bruises. After all, tackling the ball carrier by knocking them to the ground is a standard tactic in this beloved national sport. Yet most cases of concussion and broken bones suffered by professional players in the National Football League don't actually occur during games, but instead during tackling practice. That's why the Rogers Group from Michigan decided to develop a padded, life-size dummy that weaves its way across the field and is perfect for tackling. The sports-gear specialists used a laser cutting system from TRUMPF to cut the dummy's skeleton to the right size. Since then, players have seen both their tackling skills and injury rates during practice improve. And even after 30 rough tackles, the dummy remains unbruised. ■

120 MILLION EYES

... could soon be saved from blindness by ophthalmologists. Researchers at Simon Fraser University in Canada have developed a laser-based retinal imaging scanner that can detect diseases such as glaucoma before they cause damage or sight loss. A harmless laser beam is fired at the patient's eye and bounces off their retina, delivering an ultra-high-resolution 3D profile of the entire retina to the sensors, including individual photo-receptors, fine capillaries and blood vessels. If the ophthal-mologist detects even the slightest change, they can mmediately start treatment before the patient experiences any loss of vision.

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