LASER COMMUNITY.
Of people and photons

THE PULSE OF LIFE

How lasers are helping medical devices to save lives.

#31

#31

DECEMBER 2020

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Gernot Walter

Our constant companion

The sad fact is that the coronavirus pandemic has not released its grip on the world as we move into winter 2020—and it continues to dominate our private and professional lives. Nothing is as it once was—and coronavirus is our constant companion. Unfortunately, there is currently little sign of improvement on the horizon. I do not wish to comment on how the events of recent months have impacted the economy and society, as *Laser Community* is simply not the right place to do so. So what should be done? I am searching for a few positive aspects amid the crisis.

As I do so, I of course turn my attention to the tool that many years ago became my calling: the laser. The laser is (probably) unable to rid the world of coronavirus, but it can certainly help. It can, for example, help to speed up virus testing by heating up the samples much more quickly, thus reducing turnaround times from several hours to just a few minutes. It can also help to dispel any suspicions of counterfeit vaccines by enabling analysis of the deviations in frequency between irradiated and reflected light. UV radiation can even be used to eliminate viruses and bacteria from many different surfaces in a matter of minutes. This is all great news, especially in an era where hygiene precautions are a central weapon in the fight against the pandemic.

We are therefore using the coronavirus pandemic as an opportunity to turn our attention to medical devices in this issue. After all, health care is also a fast-growing industry from the perspective of TRUMPF. Whether endoscopes, ophthalmic forceps, stents or pacemakers, medical devices can only be produced efficiently and to a high standard if manufacturers employ reliable and reproducible production processes. In other words, they need lasers. The power of laser technology can also be harnessed to print precision implants for the spinal column or skull, not to mention hip replacements and crowns. Additive manufacturing is opening up a multitude of new possibilities for the medical devices sector, with the laser as the tool of choice.

This issue is appearing in winter 2020—a period in which the pandemic is confronting us all with considerable challenges. I sincerely hope that the spectre of coronavirus will have been banished by the time we next meet here in summer 2021. *Stay healthy*.

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SCATTERINGS

News and nominees

"The photon aces of the EUV team have won the Deutscher Zukunftspreis!" As much as we wanted to write these words, we didn't know if they were true. This issue was being printed at the time of the awards ceremony. Turn to **page 7** for more details of the nomination.

Good and evil

In this issue, we will be encountering viruses on no less than three occasions—as subject matter, that is. Due to the pandemic, we only see viruses as villains. There are, however, useful ones too. Turn to pages **6, 14 and 23** for a clearer picture.

Mountains and cattle

How best to photograph high tech in a rural setting? Having pondered for a moment, HAIL-TEC boss Alexander Renz had a bright idea: "There's a meadow for Swabian cattle next to my office. What if I go out there?" Find out how the company is taking the bull by the horns on **page 8.**

Fotogloria / Tobias Gerber, Gernot Walter, TRUMPF

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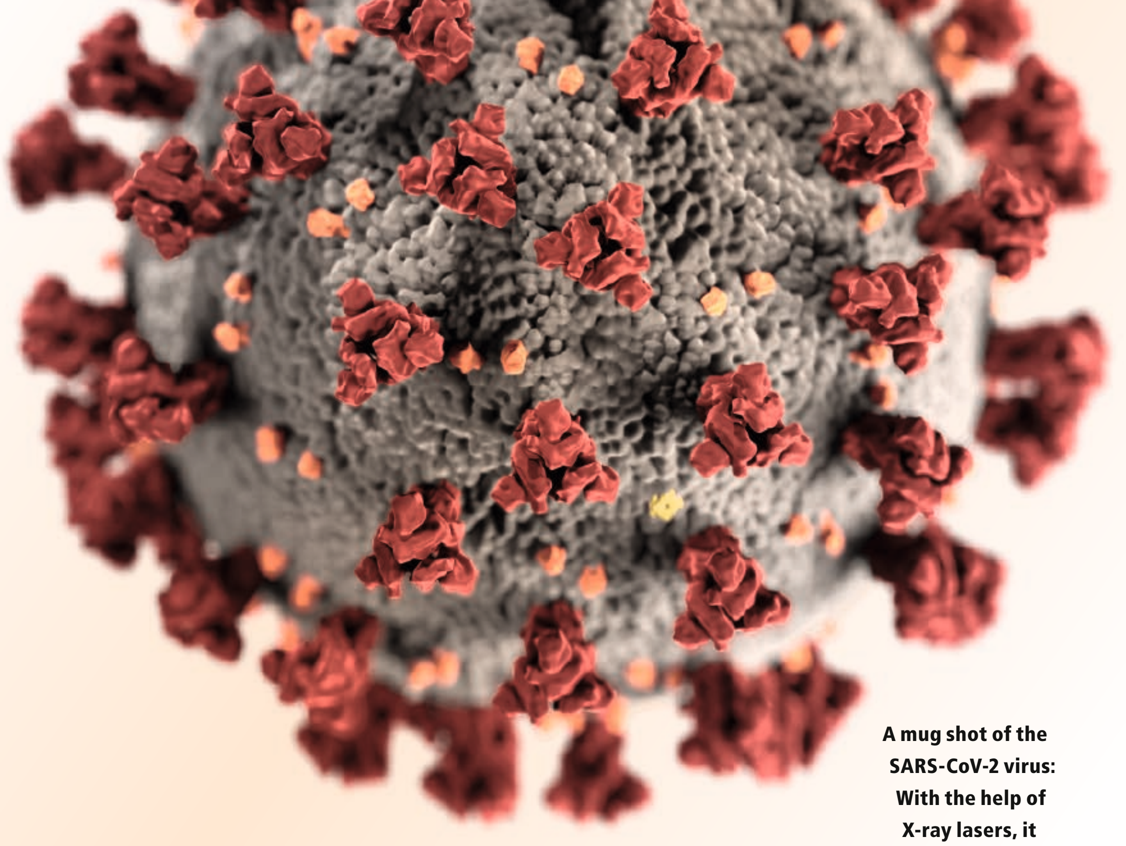
POWER



A mug shot of the SARS-CoV-2 virus: With the help of X-ray lasers, it should soon be possible to find out more about the enemy in order to combat it.

FACE TO FACE WITH THE ENEMY!

Giant lasers represent the most powerful weapons in the fight between humans and viruses.

Huge X-ray lasers—like here in Hamburg—help us to identify the weak points of viruses.

The battle between host and virus is fought with molecules. The now-infamous spikes of the coronavirus, for instance, are actually highly specialized proteins that enable the virus to latch onto specific molecules within cells. Other proteins seduce the cells into letting the virus in. In turn, the immune system responds with special molecules, i.e. antibodies.

In order to intervene in support of the immune system in this battle, which takes place at nanometer level, it is not enough to perform biochemical analysis of the processes involved. The three-dimensional molecular structure and the way it changes during the process play a vital role: what exactly happens at molecular level when the coronavirus unleashes its spikes in the microseconds before attacking? And how might this process be disrupted?

It is now becoming possible to observe these goings-on, with X-ray lasers shedding light on the matter. These lasers generate coherent X-rays with ultrashort pulses. The most powerful X-ray laser to date is located beneath the city of Hamburg—and emits pulses with a duration of less than 100 femtoseconds and wavelengths of less than a nanometer.

X-ray lasers gain photons from free electrons. In tunnels measuring several kilometers, these electrons are accelerated before being brought to an abrupt halt—and release energy in the form of photons.

In 2015, a team at the SLAC National Accelerator Laboratory in California managed to record molecular processes in a living E. coli bacterium. In 2017, a co-operation of British, German and US scientists analyzed the spatial structure of virus proteins in atomic detail. In 2019, a further team developed a process for producing stereophonic recordings of virus proteins more quickly. It is now even possible to film how proteins change their shape during biochemical processes.

The invention of the electron microscope has finally shed more light on viruses. In the future, X-ray microscopes will help us to analyze viruses and their proteins in atomic detail. If it's visible, it's vulnerable.

CDC/ Alissa Eckert, MS; Dan Higgins, MAM; Jan Hosan / Sechsnull.de

GLORY

CHIP, CHIP, HURRAY!

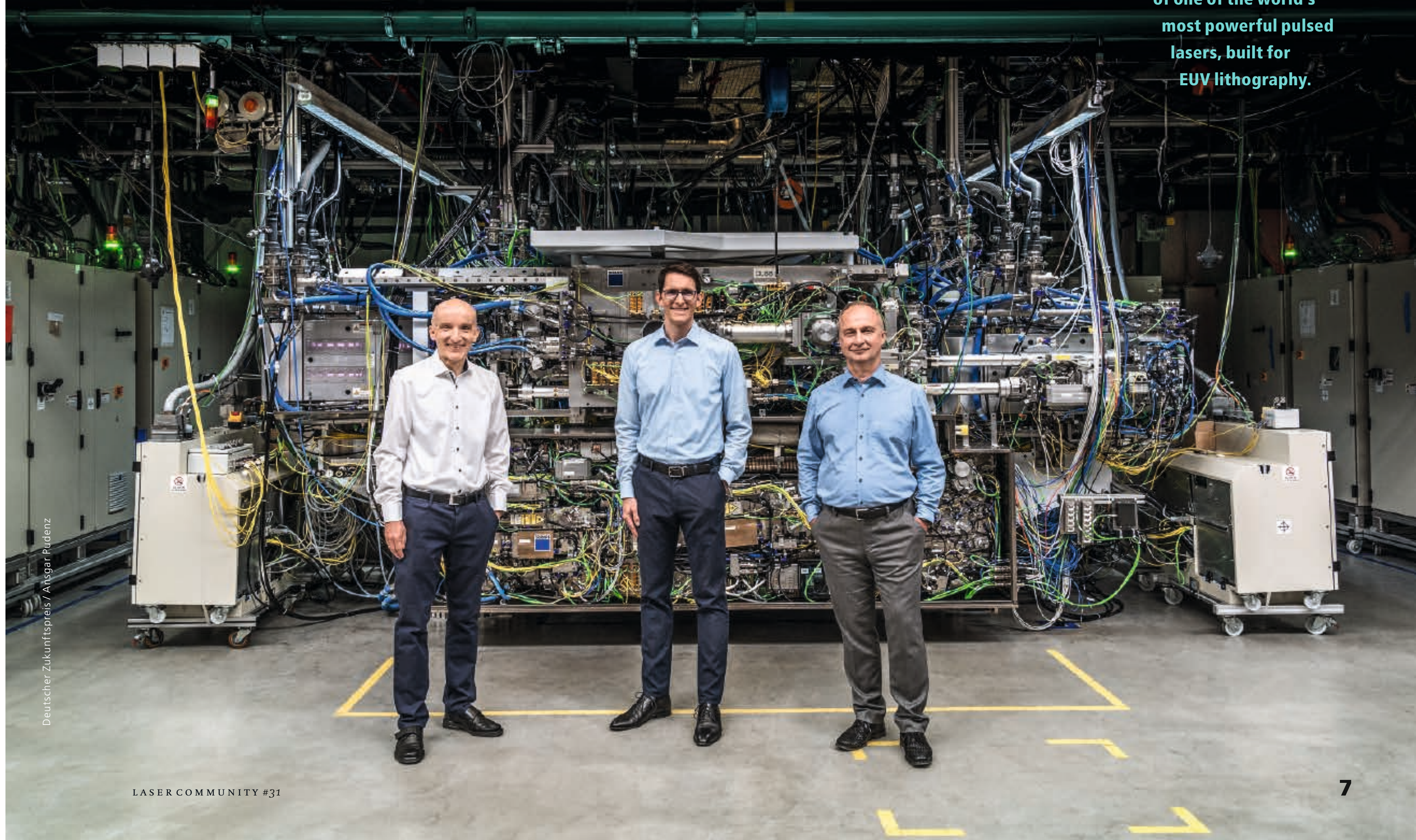
The EUV team has been nominated for the Deutscher Zukunftspreis.

Whether self-driving cars, artificial intelligence or smart energy grids, all promising future technologies have one thing in common: a need for increased processing capacity in an even smaller space, i.e. more powerful microchips. EUV lithography enables precisely that. All it needs are the most powerful pulsed lasers in the world, the most precise mirrors of all time, more than 2,000 patents and, of course, a team of engineers who are crazy enough to push back boundary after boundary for years on end.

News of what has been made physically possible due to a dazzling series of partnerships has even reached the very highest office of the Federal Republic of Germany. Federal President Frank-Walter Steinmeier has nominated three of the many thousands of people involved in this mammoth project for the prestigious Deutscher Zukunftspreis: Michael Kösters of TRUMPF, Peter Kürz of ZEISS and Sergyi Yulin of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. The Zukunftspreis award honors outstanding achievements in the fields of technology and natural science that have a direct impact on the economy and society.

The idea behind EUV lithography is to open up the gateway to a whole new dimension of microchip production. It generates extreme ultraviolet (EUV) light with a wavelength of 13.5 nanometers and thereby illuminates silicon wafers. This finally paves the way for circuit arrangements that are many times smaller than with previous technologies, thus enabling more processing power in a tiny space. In other words, these are the microchips of the next generation.

In broad terms, the EUV lithography machine comprises a high-vacuum chamber, a giant laser and a multitude of optical components inside. The world's only manufacturer of these components is the Dutch technology firm ASML. TRUMPF develops and produces the laser that generates EUV light. ZEISS is responsible for the high-precision optics that collect and focus this light. The system as a whole weighs approximately 180 metric tons, with the laser alone made up of more than 450,000 individual parts. Intel describes it as the "most technologically advanced tool of any kind that has ever been manufactured"—or words to that effect. The award would be richly deserved.



Nominated for the Deutscher Zukunftspreis: Peter Kürz, ZEISS, Michael Kösters, TRUMPF, and Sergiy Yulin, Fraunhofer IOF (from left to right). They are standing in front of one of the world's most powerful pulsed lasers, built for EUV lithography.

Deutscher Zukunftspreis / Ansgar Pudenz

“The laser attracts nerds out into the country-side.”

With the help of an ultrashort pulse laser, Hail-Tec offers top-class high tech. An entire line of business at the company is even built on this technology.

Mr. Renz, Hail-Tec is a job shop for stamping and punching tools of all kinds; this sounds like a tricky business model, as it’s all about individual components …
Absolutely not! If you are able to deliver outstanding parts quickly, then this kind of business model works perfectly.

So you’re always in a rush?
You could say that. Our customers in the stamping/punching industry work with tools made from cemented carbide or powder metallurgy steels, which they use, for example, to punch automotive components by the million. If there is a fault with the punch, i.e. the tool that punches the component out of the sheet metal, the entire production line grinds to a halt. The punch has to be replaced extremely quickly, which is where we come in.

Which means?
Generally speaking, the customer brings us a blank, as each customer has their own preferred carbide. We then produce a new punch within 24 hours. The key point is that we use an ultrashort pulse laser. We first adopted the technology back in 2018 with a five-axis laser machining system from DMG Mori with a TRUMPF TruMicro laser. This has considerably sped up the process, as we now produce the component directly from the digital CAD model—without a negative.

And what makes the process so great?
With the femtosecond laser, we ablate the material in an extremely gentle manner, allowing us to achieve the desired geometries. As we use ultrashort laser pulses, very little heat enters the workpiece—and, where heat does enter, this only happens in a highly localized way. One atom evaporates before the neighboring atom can heat up, which is why we refer to “cold” laser processing. This prevents the build-up of tension in the metal and increases the longevity of the punch, which is of paramount importance for our customers.

How did these punches and stamping presses used to be made?
Usually, the customers made them in-house using sinker EDM, but this process harbors numerous drawbacks. Considerable heat comes into contact with the workpiece during sinker EDM; in turn, this causes minute micro tears, which soon result in material fatigue and thus diminish the longevity of the punch.

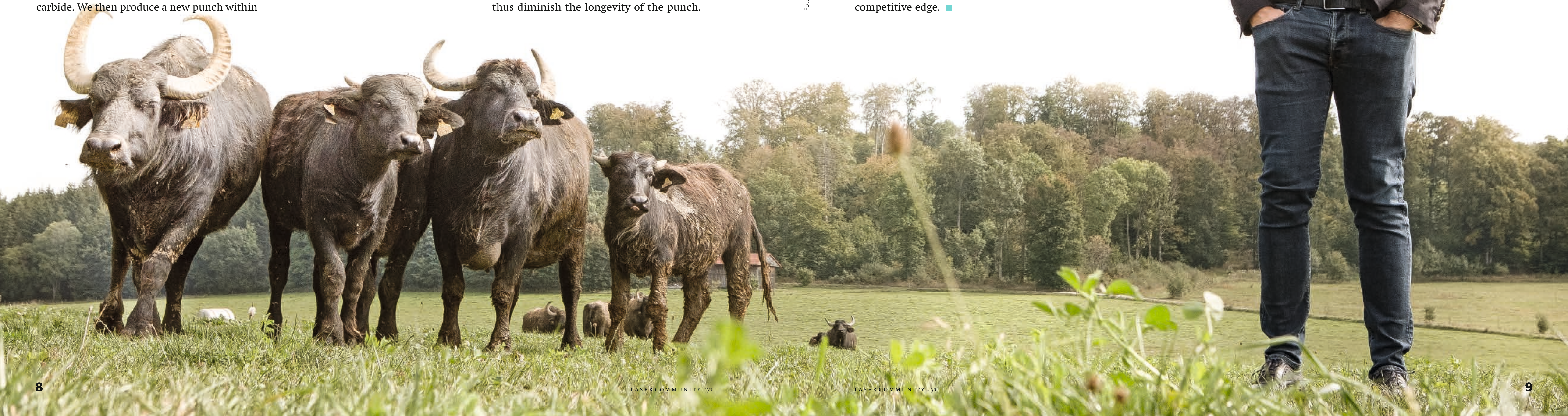
Fotogloria / Tobias Gerber

So the laser is much quicker …
… and much more precise! A tool electrode (i.e. the negative shape that is transferred onto the workpiece) is made for the purpose of sinker EDM. Since electrodes are milled, certain deviations are inevitable. Also, the tools are subject to wear and tear, which leads to inaccuracies in the workpiece. The laser, on the other hand, is always sharp and always precise. Thanks to the fine grain sizes of the carbide, we produce extremely high surface finish grades with a mean roughness of 0.1 microns and cavities with internal corner radii of up to 0.03 millimeters. Therefore, we simply eliminate the need for downstream polishing processes. Thanks to the fixed sets of parameters, the results are also completely reproducible.

This abundance of high tech gives rise to another question: you’re based here, in the heart of the Swabian Jura. Swabian buffalo are grazing outside your window. Idyllic as it is, are you able to find enough specialists here for so much high tech?
That is indeed a challenge. The region is sparsely populated—and there’s no public transportation. But new and exciting technologies—like our USP laser—are a great way of attracting technology nerds out into the countryside. Some of them are even willing to travel 40 kilometers to work. Even here, our ultrashort pulse laser gives us a competitive edge. ■

Out in the Swabian sticks, **Alexander Renz** has built up a genuine high-tech firm: the 22-strong team at Hail-Tec are able to supply customers with new punches—and produce ultra fine microstructures for 3D forms—within just 24 hours.

AHEAD

Fotogloria / Jan Hosan

Stricter emission standards were the best thing that could have happened to Isolite. Now all automotive manufacturers are looking to insulate their exhaust systems—and are beating a path to Isolite's door. The company is managing the surge in demand with 3D laser cutting on a huge scale—combined with a touch of genius.

BOOM TIMES

> *"Ever since the focus has been on better emissions figures, we have been absolutely inundated."*
>
> **Jonas Boettcher, Business Development Manager at Isolite**

There is a simple rule of thumb for exhaust aftertreatment: "the hotter it is, the cleaner it is." And that's why business is booming at Isolite—an SME headquartered in Ludwigsburg that employs some 500 people worldwide. The firm has tripled its revenue in just a few years. Its speciality: high-temperature insulation systems.

The company's actual expertise is concentrated within the layers of insulating materials that line the red- to white-hot components. Thin stainless steel shells compress the insulating materials to form a tightly sealed blanket that is precisely tailored to the shape of the components involved, which are found within machines and technical systems, turbines, engines and exhaust systems. To keep the insulation as lightweight as possible, the sheet metal shells are ultrathin.

"THE HOTTER IT IS, THE CLEANER IT IS" reiterates Jonas Boettcher, Business Development Manager at Isolite, who is holding one of the firm's stainless steel shells—made of thin sheet metal and measuring almost a meter in length—in his hands. "The exhaust temperature plays a crucial role when it comes to the performance of particle filters and catalytic converters. Once the automotive industry understood this, heat within the exhaust system became a blessing rather than a nuisance." This is why manufacturers now enclose almost every component—from the manifold to just before the exhaust pipe—in insulating material and stainless steel. "Ever since the focus has been on better emissions figures, we have been absolutely inundated," explains Boettcher.

A BEWILDERING ARRAY There is a specially shaped stainless steel shell for every insulation option. This is where the laser comes in. Speed is of the essence at all stages of the manufacturing process, which is why Isolite has built a veritable palace of 3D laser cutting systems: there are 20 double-cabin cells on one factory floor in Ludwigshafen alone, cutting up to 28,000 shells a day. Boettcher: "3D laser cutting is the only process that meets our three core requirements: mass production, flexibility and precision."

Flexibility is essential, as Isolite not only makes prototypes, but also medium-sized batches and large-scale production runs. The component forms are alternated frequently; Isolite produces some 2,000 varieties in order to meet customer requirements. What's more, the range is growing all the time. Some half-shells are six centimeters long, whereas others measure almost one-and-a-half meters. "We have two full-time programmers who program the 3D laser machines."

THE EXCITING PART Once the half-shells have been punched or deep-drawn, they are placed inside the laser cell, where the overhang is cut away. Precision is imperative here, as there is a tolerance of just half a millimeter. After all, the fiber mats have to fit precisely within the form, with the half-shells closing with pinpoint accuracy.

"Our components are tricky. You can't just buy a laser cell and start cutting," points out Boettcher, who places the half-shell back on the pile.

In order to clamp such varied components, Isolite would ordinarily need a traditional multipoint clamping apparatus. This grips the sheet metal at various points using adjustable clamps. But as the sheet metal at Isolite is often barely thicker than 0.15 millimeters, the half-shells begin to vibrate. "As the overhang gradually falls away, the component springs back slightly. Over the course of the entire cut, more and more vibrations enter the workpiece." This even makes it hard for the precision-guided laser beam to observe the tolerance.

"You can either accept these inaccuracies—or you can try to compensate for the vibrations. But it would actually be better to avoid them in the first place." In order to cut in a vibration-free manner, however, the entire workpiece would have to lie on as extensive a surface as possible and pressed down. While this is no doubt economically viable for a few parts in large batches, how does it work with up to 2,000 variations?

Boettcher is tight-lipped on this point: "All I can say is that we have managed it. Isolite is now able to clamp and hold each workpiece in its entirety and thus cut at maximum speed and with the utmost precision." However, Boettcher is not willing to go into detail about how this has been achieved. ■

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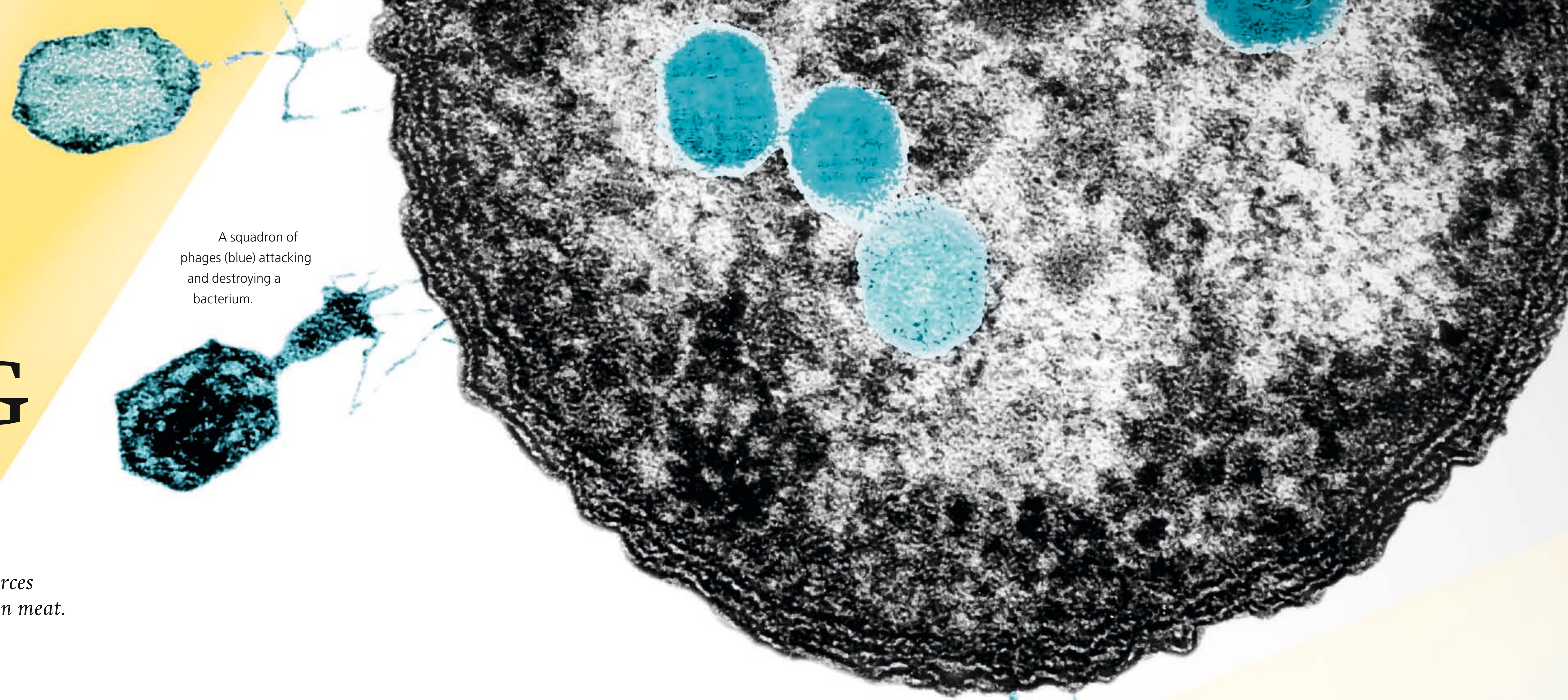
Top: **deep-drawn form for a stainless steel outer shell (left), the 3D laser-cut final form (center) and overhang following removal (right).**

Below: **twenty 3D laser-cutting cells operate in the Isolite "laser palace."**

Fotogloria / Jan Hosan



A squadron of phages (blue) attacking and destroying a bacterium.

KILLING GERMS

UV lasers and friendly viruses are joining forces to combat bacteria — and decontaminate chicken meat.

Fresh chicken meat is a paradise for bacteria, with campylobacter and salmonella especially dangerous for humans. Both spread extremely easily and often cause severe fever, headaches, diarrhoea and vomiting. Meat processing companies do everything in their power to eliminate infectious contamination at the abattoir. Depending on the country and its legislation, this could even mean washing the chicken in chlorine. To make poultry meat safer, further “hurdles” are sought, which can be opposed to pathogenic bacteria and which are also easy to implement. Therefore, our work at Laser Zentrum Hannover e.V. (LZH) and our partners’ work seek to develop a simple and reliable method of decontaminating poultry. Any method would need to be capable of being seamlessly incorporated within the production line.

The project presented here goes by the name of “Minimizing the microbial contamination of poultry, before and after cutting up, by means of structured surface decontamination with laser applications and bacteriophages” (ODLAB). As the project name indicates, we are seeking a twin-pronged solution. On the one hand, we aim to destroy the germs through the surface irradiation of a UV laser and, in addition, treat the meat in a targeted manner with bacteriophages. Bacteriophages—or “phages” for short (from an ancient Greek word meaning “to devour”)—are viruses that specifically attack and destroy only certain types of bacteria; they have no negative influence on human beings. Initially, we are pursuing each of the two approaches independently of each other. Subsequently, the aim will be to combine laser technology and phages in the best possible way.

LASERS VERSUS BACTERIA UV laser light destroys bacteria. The food industry has been researching this capability for some time. UVC radiation with wavelengths of around 260 nanometers is usually the light of choice, as its energy is readily absorbed by proteins and bacterial DNA. It inflicts such direct and devastating damage on the bacteria that they are unable to reproduce and largely die off.

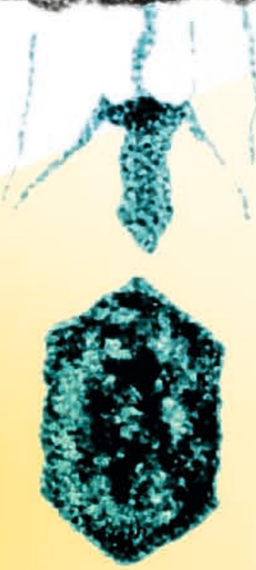
While this works extremely well in test tubes, we discovered that UVC radiation is much less effective for bacteria on meat surfaces, probably because it is difficult to reach the bacteria due to the nature of the surface (edges, channels, pores, water, fat, etc.). We are therefore examining longer wavelengths, which can reach deeper within the meat. We are now working with approx. 315 nanometers, which is at the borderline between UVA and UVB light and closer to the spectrum of visible light. Here, the active mechanism is different. Instead of smashing the molecules directly, the light stimulates the process of chemical combination with oxygen. This oxidation damages the molecules and therefore the bacteria.

It is intended that the technology will be subsequently used for comparatively large areas, which is why we are utilizing a TruMicro high-performance nanosecond laser. This UV laser was developed for processing large surfaces in the semiconductor and display industry. TRUMPF has modified the laser slightly for our requirements, as the working environment in a slaughterhouse is much harsher than in the semiconductor industry.

DR. MERVE WOLLWEBER leads the Food and Farming group at Laser Zentrum Hannover e.V. She develops laser processing technologies for applications in agriculture, food and environmental technology, and biomedicine.

VIRUSES VERSUS BACTERIA On its own, however, the UV laser cannot reach all bacteria. We believe that the juices in the meat shield some bacteria against the radiation. The viral attacks with phages are designed to break these pockets of resistance. Whereas laser irradiation indiscriminately attacks all bacteria within the meat, phages work in a highly targeted way, with specific phages only attacking specific bacteria. We therefore deploy phages from the Myoviridae family and highly specific Campylobacter phages in order to specifically combat our main enemies: campylobacter and salmonella. After we place the bacteria-destroying viruses on the meat, they spread out, come into contact with campylobacter and salmonella, and inject the bacteria with their own genetic material. The bacteria then keep producing phages until they burst. The phages have no difficulty in reaching the deep pockets that are beyond the laser.

With the UV laser, we have a kind of blunt instrument that sweeps away high numbers of germs over a large area. To continue with the metaphor, it sweeps the surface. While this is enough for most germs, it doesn’t quite do the trick for campylobacter and salmonella. For these two bacteria, we have highly specialized cleaning squads—in the form of phages—that pick off any remaining germs.



OPEN QUESTIONS We are currently in the concept development phase. This means that we also need to consider the cost-effectiveness and therefore the speed of the process. Adapting it to the harsh conditions will also be a challenge, as the components will, for instance, need to be exceptionally robust and easy to clean. It is still unclear whether the laser will rotate around the meat or whether the meat will rotate in front of the laser. Another interesting question is the order in which we attack the bacteria. Do we start with the laser and then the phages? Or the other way around? And if we start with the phages, how do we calibrate the laser so that it doesn’t disrupt the phages?

For this purpose, we are collaborating with the German Institute of Food Technology (DIL), which is developing and evaluating a concept for phage application. Together, we are examining the effect of laser and phage treatment on the quality of the meat. We are planning to unveil a demonstration model in 2023 that will operate in a real abattoir environment. ■

Campylobacter (above) and salmonella (below) colonize fresh chicken meat in large numbers. A problem for the food industry.

OPERATION LASER

The legal requirements: brutal. Quality: life-saving. The innovation level: high. That's why the medical devices sector is increasingly manufacturing with lasers.

Adobe Stock / edwardolive

No dazzling light allowed: laser-textured surface finishes are able to prevent surgical instruments from reflecting light. Just one of many applications in laser technology.

MANUFACTURERS OF MEDICAL DEVICES HAVE BEEN BENEFITING FROM CONTINUOUS INCREASES IN DEMAND FOR DECADES. BUT THE COMPETITIVE AND REGULATORY PRESSURE IS HUGE. IT'S TIME FOR MORE EFFICIENT PRODUCTION PROCESSES AND SMART NETWORKING.

As sectors go, the medical devices industry is a pretty safe bet. Globally, it can look back on continuously robust and virtually uninterrupted growth. So it's no wonder that more and more firms around the world are getting on board. This leads to cost pressure and drives the spirit of innovation, which was already a powerful force in the sector. At the same time, national and supranational institutions are always happy to pass new legislation; alongside pharma and aviation, the medical devices sector is one of the most tightly regulated industries in the world. On the one hand, this eases the competitive pressure described above, as many potential market players fail to overcome the high barriers to entry; on the other hand, however, established firms are also repeatedly forced to think about how they can make their products in a compliant manner.

A SECOND HONEYMOON Ultimately, the medical devices sector is undergoing the same transformation processes as all other manufacturing industries. And here, too, digitalized production processes are playing an ever greater role: Smart Factory concepts, sensors to record condition/quality data, AI-based analysis of large data sets—in other words, everything that falls under the banner of Industry 4.0.

All these trends in the field of medical devices—i.e. fierce competition, regulatory pressure, a high degree of innovation and digitalization—lead to one thing above all else on the factory floor: more laser technology.

Medical devices and laser technology have been going hand in hand for some 25 years: many welding tasks (e.g. on pacemakers) and many cutting applications (e.g. on stents) have, for a long time, only been economically viable if performed using laser technology. But the second honeymoon period has now begun. The advantages of laser processing are increasingly coming to the fore due to industry trends, with the advances in laser technology itself also making a big impact. Take the area of marking, for example: the Unique Device Identification (UDI) requirements from the United States finally became mandatory in the European Union in 2020. Ever since, marking using ultrashort pulse lasers has been the only option for many products *(see page 21)*. Within the industry, the laser is virtually indispensable as a cutting and welding tool on account of its combination of high-quality, high-productivity processing and maximum flexibility *(see page 20)*.

THE RISE OF THE OLD PIONEER The greatest leaps of innovation in medical devices will, however, come courtesy of laser-based 3D printing. Here, industry experts anticipate a veritable revolution in the way the sector thinks and manufactures. The medical devices sector was already a pioneer of 3D printing. Most recently, the focus was on harnessing the boundless possibilities of 3D printing for customized products such as dental prostheses and bone grafts. Thanks to their experience with this technology, engineers can now explore new avenues: what are the benefits of 3D printing in terms of mass production *(see page 19)*?

Laser manufacturers also have their finger on the pulse of the medical devices industry. TRUMPF has, for many years, been developing new laser applications and digital product concepts that are targeted specifically at the sector. From the outset, these laser systems are designed and prepared in such a way that they can effortlessly comply with the complex requirements in terms of equipment and measurement validation.

The TRUMPF laboratory has recently produced a laser process that brings together two components that traditionally don't mix: glass and metal. Potentially, this will make it possible to bond glass and metal without additives and, for instance, eliminate the need for adhesives. This is music to the ears of those in the medical devices sector and could, for example, be applied to the production of endoscopes with camera and light for minimally invasive procedures. Laser-induced textures also have the potential to be of assistance in operating theaters. Surgical instruments with antireflective finishes are less dazzling for surgeons, which makes their work easier. Not only does the love affair between medical devices and lasers endure, but it is now stronger than ever. ■

PLENUM, SÃO PAULO, BRAZIL
"At first glance, it would seem that 3D printing and mass production don't go together. The technology is often thought to be too slow. As a manufacturer of bone substitute materials and implants, however, we see a crucial advantage: 3D printing is the only way to create specific surface textures that optimize the integration of the implant within the body, accelerate the healing process and reduce post-operative complications. In our case, we are talking about dental implants or, to be more precise, the screw that is inserted within the jaw and on which the actual dental prosthesis is mounted. These screws are available in different diameters: from narrow three millimeters up to six millimeters. We print the implants from titanium alloy powder, which has been produced in facilities certified for medical applications. The complex, bionic and detailed surface textures are not fully visible to the naked eye. As the idea for the technology application is so new, the approvals process of the Brazilian health authority has required a very detailed documentation. Our partner TRUMPF also felt the pressure but was ultimately able to fulfill all our requirements regarding the machine documentation and qualification process. We were granted approval in 2019. We are now ready for the next steps: the approval of other health authorities (e.g. FDA in the United States). Our main goal is to tap into the export market. We firmly believe that high-quality products will prevail. And our quality originates from 3D printers."

INNOVATION AND APPROVAL

Alberto Blay, CEO of Plenum, and his printed implant screw.

Mass-produced items made using 3D printers: functional surface finishes for dental implants.

Fotogloria / Claus Lehmann

VARIETY AND PRODUCTIVITY

Laser tube cutting and laser welding handle more than 15,000 different products.

KARL STORZ SE & CO. KG, TUTTLINGEN, GERMANY
"We are a system supplier. In other words, we could provide you with a turnkey operating theater complete with lighting, light sources, operating tables, generators for electrosurgery, endoscopes, manual instruments and other equipment. We don't produce each and every component ourselves, but we have a very high vertical range of manufacture. More than 15,000 products—which, in turn, are split into different component groups—are made in-house in batches of all sizes. Therefore, flexibility and short retooling times represent a key factor for our production system—and have been central reasons for using laser material processing for 25 years. The ongoing development of the laser systems reflects our need for increased productivity and reliability. Take tube cutting for endoscopes: the laser machines allow us to switch quickly to a new product, without changing tools. The new systems are not only much faster, but the quality is also better: burr-free cuts reduce the need for finishing, whereas the low heat input also enables us to make thin-walled tubing without warping. When it comes to welding, we use modern lasers with low heat input. As a result, we are able to master delicate joints, which once again saves us plenty of finishing work. We produce quickly and—thanks to the outstanding level of efficiency—consume relatively little energy. Wherever I look, I can't see any alternative process that could replace laser technology at our company."

Kamilla König-Urban, Head of the Manufacturing Technologies Department at Karl Storz, with 7 of 15,000 products.

Fotogloria / Tobias Gerber

RICHARD WOLF GMBH, KNITTLINGEN, GERMANY "As we are a manufacturer of endoscopes for human medicine, the coming into effect of the EU Medical Devices Regulation in May 2020 was an important date for us. Owing to this Regulation, Unique Device Identification (UDI) codes—which still have to be machine-readable following disinfection for the umpteenth time—are now also mandatory within the European Union. We have been using laser marking for the past 20 years. In preparation for UDI-compliant marking, we switched to the innovative technology of marking using ultrashort pulse lasers. We are impressed with the quality, as ultrashort pulse lasers facilitate black marking. Basically, this means minute textures on the surface of the steel that swallow light. The markings are clean, mat and—above all—durable. When it comes to quality, we regard black marking as the gold standard. The heat input is so low that there is no notable warping of the workpiece. The ultrashort pulse laser allows us to access all areas, with curved surfaces and small diameters posing no problem whatsoever. The marking systems from TRUMPF are fitted with cameras that immediately perform a threefold check on the freshly engraved code: is the code there and in the right place? Is the result up to standard? Is the engraved content correct? This gives us considerable peace of mind. We have also fitted some of our marking stations with a direct interface to our SAP system. This means that the laser can retrieve the marking content itself from the server, write it back to all relevant databases and store it for documentation purposes. This makes our work much easier and reduces stress levels."

Markus Lienhart, Industrial Engineering at Richard Wolf, and the perfect data matrix code.

Fotogloria / Tobias Gerber

UDI-compliant marking using ultrashort pulse lasers. And the corresponding digital documentation is updated automatically.

SECURITY AND DOCUMENTATION

i4.0

FINALLY! A STANDARD!

A true Smart Factory can only run smoothly if there is a reliable tracking system for parts, tools and transportation vehicles. Finally, there is now an industrial standard for tracking systems.

Imagine that you have just bought a Wi-Fi router from company X; you set it up—and your tablet is simply unable to get a signal. You call company X and ask them what to do. The company service representative asks: “Did you buy your tablet from us? No? Unfortunately, there’s nothing we can do.” That would be absurd. In industry, however, this is sadly common practice—for example in relation to tracking systems. Here, the manufacturers of different devices speak different languages. But there is now finally a single industrial data transfer standard: omlox.

TRUMPF has developed this tracking standard in partnership with approximately 60 other industrial companies from Europe, Asia and North America. It is based on ultra wideband (UWB) transmission. With omlox, users can track all their workpieces, driverless transportation systems, drones, incoming/outgoing deliveries and tools to the nearest centimeter and in real time—irrespective of provider. It doesn’t matter which company supplies the transmitters, the data transmission infrastructure, the production software or the individual machinery/components—because omlox makes them all talk to each other. Although omlox uses the lowest-interference ultra wideband protocol, it also incorporates all other common locational signals, such as GPS, RFID, Bluetooth, SLAM and 5G. Small-scale localization tasks—“order X is about to reach the laser machine, please load the following program”—are handled just as efficiently as large-scale tracking requests: “the current location of the truck with the spare parts is ...” The potential applications are as numerous as the individual tasks and requirements at industrial companies across all sectors. There is now one standard for everyone.

Here at TRUMPF, we made a conscious decision to initiate the open standard omlox and therefore to give our customers complete independence from all manufacturers—including ourselves. Ultimately, we believe that all industrial companies benefit when Smart Factory concepts gradually gain traction across the board. The problem of tracking has now been solved. ▫

Céline Daibenzeiher is the project manager responsible for the omlox tracking standard at TRUMPF New Business Technology.

TRUMPF

LASER VS. PANDEMIC

Science and research are joining forces in the fight against the novel coronavirus. As they do so, they are harnessing the power of light. Two examples from the beginning and end of a pandemic.

QUICKER

The gold nanoparticle (A) absorbs the laser energy (B) and heats up and the viral DNA (C).

SPEEDIER TESTS The PCR test remains the gold standard when it comes to the question of “What virus do I have?” However, it takes a few hours to produce a result, as the samples have to be repeatedly heated and cooled to facilitate the individual stages of the reaction. Gold and lasers may be able to change this: a new method combines the DNA in the sample with gold nanoparticles. These absorb laser light and transmit the heat to the DNA molecules. As a result, the molecules can be heated in a targeted manner—and in fractions of a second—using laser pulses. The turnaround time is reduced to approximately 15 minutes. ▫

In laser light (A), vaccine (B) shows its specific spectrum (C). If it matches that stored in QR code (D), the substance is genuine.

SAFER

SAFE VACCINATIONS Is the vaccine the real deal? In cases where a counterfeit substance is suspected, getting an answer often takes more time and equipment than are available on-site. Raman spectroscopy represents a promising potential solution in this area. It measures the differences in frequency between irradiated and reflected laser light. This Raman spectrum is highly distinctive in the case of certain substances. The idea is to use statistical methods to reduce the Raman spectrum of a vaccine down to a “fingerprint.” Small quantities of the vaccine can be quickly analyzed and compared with the fingerprint. ▫

Gernot Walter

The prospects of the company Christian Maier hinge on a thin coating. Time to make the firm's competitive edge unassailable.

OFF TO THE LAB →

A proliferation of knowledge thanks to LMD welding: at the materials lab, the team work on new powder mixtures day in, day out.

Fotogloria / Tobias Gerber

The entire renown of Heidenheim-based firm Christian Maier—which is led by Florian Maier in the fourth generation of the family—hinges on these complex components. "You will find our components in the systems of every industry, from A to Z. One of our areas of focus is PET bottle production, with which we serve two thirds of the global market." Rotary joints are critical components in virtually all applications. If there is a leak or loose fitting here, the entire production line often grinds to a halt. Therefore, we promise all our customers that our solutions will remain completely leak-proof and offer reliable quality with good regular maintenance over many years. This promise is underpinned by two factors: precision craftsmanship and a thin layer of material.

SEALING THE DEAL! Rotary joints connect two movable parts of a system. In essence, they comprise a housing that rotates around a shaft. The shaft has one or more longitudinal holes. These align with ring-shaped grooves in the wall of the housing. If the shaft is inserted within the housing, it doesn't matter how forcefully it rotates against it: gases, water, oils or, for instance, hot PET can always flow from one system component to another through the system of holes and grooves. The surface coating ensures that nothing spatters or drips between shaft and housing—despite their precise alignment. "It seals, prevents wear and tear between the shaft and the cylinder wall, and protects the metal against whatever flows through the joint," explains Maier. He then stops for a moment before continuing: "The precision of the parts is important. But the surface coating will really decide who remains in pole position."

METAL VERSUS CERAMIC Funnily enough, coatings were not one of the company's areas of expertise. Ceramic solutions have a long track record: "We could, of course, have adopted this approach," explains Maier. "But ceramic does not offer sufficient potential."LMD welding is different. During LMD welding, a laser beam fuses metal powder together with the surface of the workpiece to create a firm layer. This layer can be tailored to future requirements by adjusting the composition of the powder, the welding depth and other parameters. "At first, however, the process seemed too slow, the finish too coarse and the minimum thickness too high," recalls Maier.

High-speed LMD welding (EHLA), which was unveiled in 2018, was a game-changer. Maier dispatched two curious employees to the TRUMPF test laboratory to gather experience with it. The result: the coating is smooth and completely form-fitting, with the connection to the substrate stronger than ever. Another advantage over the previous process is the low heat input, which means that even fragile components can be coated without any warping.

TIME FOR A LABORATORY Even as Maier was signing the purchase agreement for a TruLaser Cell 3000, he was thinking of the next step: the need for a materials laboratory. After all, "if we can develop our own powder formulas, we can produce alloys that will be very hard for others to imitate." Maier put together a four-strong team of experts to develop materials and powder mixtures for LMD welding. "Our in-house expertise has mushroomed—and we have filed several patents in this field," reports Maier, bursting with pride. The laser cell coats some 2,000 customer components a month and, for the rest of the time, is used by the laboratory team. And it's not just paying off in terms of the existing core business.

The materials laboratory has also made a name for itself and is already receiving metal powder development orders from other companies. "A whole new line of business," says a delighted Maier. And that's not all: thanks to LMD welding, Maier is now also offering repairs for the first time. "To sum up: our customer base and our range of opportunities have grown considerably." ■

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“Nanoparticles at the push of a button”

Professor Stephan Barcikowski is able to produce nanoparticles by laser. Here, he explains how laser material processing is disrupting the chemical industry and why there will soon be fully automatic “coffee machines” for nanoparticles.

Professor Barcikowski, why does industry need nanoparticles?
Nanoparticles have applications in many different industries—and play a particularly significant role in the chemical industry. Here, they make a variety of products possible or economically viable in the first place and are used, for instance, in fuel cells, exhaust gas catalysis and 3D printing. Nanoparticles act as catalysts—as highly reactive coatings that trigger or accelerate chemical reactions.

Why are nanoparticles able to do this?
The greater the relative surface area of a material, the more it reacts—and nanoparticles have a huge surface area. Let me explain what I mean: if you cut a ball into ten pieces, you will have increased its surface area a hundredfold—i.e. it is enlarged exponentially with every cut. Eventually, you would end up with nanoparticles. Whenever the chemical industry needs platinum for catalysis, it buys it in the form of nanoparticles, because only a small amount of platinum is then required for a large platinum surface area.

Let’s talk about your manufacturing process. Am I right in thinking that you can produce industrial-grade gold nanoparticles with nothing more than a piece of gold, a glass of water and a laser?
To put it more generally, “a glass of liquid” and, to be more precise, a “pulsed laser”—but, yes, that’s all you need to make gold nanoparticles.

I’m assuming it’s a bit more complicated than that.
Not really. Whether cutting, welding or drilling, all laser processes produce nanoparticles, which then evaporate as smoke. Some 15 years ago, during a research project on laser texturing, we used an airbrush nozzle to eject the smoke from a home improvement store in order to protect the electrical systems and the workpiece. We then noticed that the spray water changed color. This was due to the nanoparticles. Our idea was that we could extract the nanoparticles from the process and use them. This gradually led us to our current process. We place the target material—e.g. gold, platinum or silver—in liquid and guide an ultrashort pulse laser over it. Minute particles of the surface material evaporate within nanoseconds and accumulate within the liquid.

Why in liquid? Why not capture the nanoparticles from smoke?
Because nanoparticles are easier to capture—and handle—in liquid; here, we refer to “colloids.” Nanoparticles are highly reactive and immediately begin to clump together in air. In water, however, the pressure is greater—and this holds our particles in place within a lentil-like microbubble following laser treatment; within this microbubble, the particles cool at an incredible rate of 1,012 kelvins per second. The bubble eventually bursts, scattering the nanoparticles throughout the liquid, where they then float around at room temperature—without

Professor Stephan Barcikowski with five liters of nanogold—the result of 30 minutes of laser ablation. Nanoparticles often have a different color to their more voluminous source material. Gold, for instance, turns red.

Carsten Behler, Gernot Walter

clumping together. This all happens within the space of microseconds. The second reason is more interesting: the properties of nanoparticles produced in water using lasers are even more special. For kinetic reasons, for instance, they have even more defects.

eliminating nitrogen oxide within diesel catalytic converters. What's more, our particles were much more stable, both in diesel and in the fuel cell. To be honest, we don't yet know where this stability comes from, but we are working on it. It's certainly a key factor for industry.

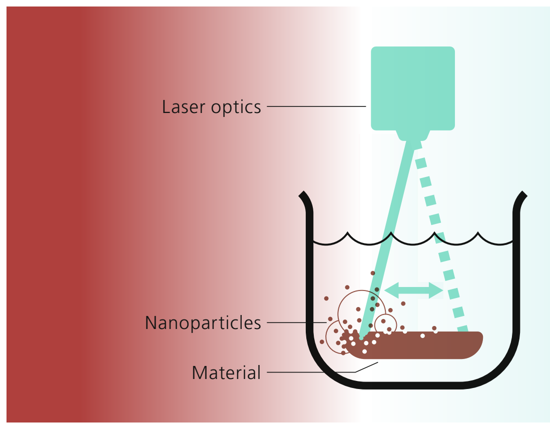
"The laser-based process is perfect in terms of systematically producing ranges of different alloys with different mixing ratios."

And that's a good thing?
Absolutely! We want our nanoparticles to have as many defects as possible. The smaller you make a solid body, the more angular it will be. In the industry, we use the term "faceted." The several thousand atoms in the particles separated by laser really want to arrange themselves in ideal facets, i.e. facets that fit cleanly together. But because they cool down so quickly and therefore solidify, they don't manage it in time, meaning that the facets stay rough—like a cliff face. This is what we mean by "defects." They activate the surface. And as I mentioned above, more surface area translates into more reactivity.

Up to now, the chemical industry has made its own nanoparticles. Why would they want yours?
Because mine are better. As I say, laser-generated nanoparticles are more reactive, i.e. more effective, on account of their defects. They also last longer, thus increasing the service life of a product. Just recently, two comparative studies on diesel catalytic converters and electric catalytic converters in fuel cells demonstrated that our nanoparticles perform better than traditional wet chemistry-based equivalents when it comes to

Is your laser-based process suitable for the mass production of nanoparticles?
That depends. We're not yet thinking in terms of tons, but certainly in kilograms. For many applications, it's not just about sheer volume. Instead, it is much more important to produce the particles in a simple and precise manner. Our laser-based process is, for instance, establishing itself in the field of large-scale industrial research. This is the first time that laser material processing is making an impact in the chemical industry—a market so huge that it's hard to get your head around.

Research is always good, but is it already possible to earn money with your laser nanoparticles?
Yes. There are multiple approaches. In the last three years, we have boosted the productivity of the manufacturing process by a factor of 100. We believe that a further factor of 10 to 100 is realistic—and already have a few specific ideas. The process starts becoming economically viable at a rate of about half a gram of nanoparticles per hour. We are already at several grams per hour. These can then be mixed with the usual small mass fraction to create kilo packs of catalyst powder, which can be easily stored. But there are also other powders that we enhance using our nanoparticles.



Nanoparticles comprise some thousand atoms/molecules or less. Owing to their special chemical properties, they are employed in various sectors, such as in medicine and in the chemical industry.

Gernot Walter

Stephan Barcikowski is Professor of Technical Chemistry at the University of Duisburg-Essen and researches the production and application of laser-generated nanoparticles. He and his team member Bilal Gökce are nominated for the 2020 Berthold Leibinger Innovationspreis in recognition of their pioneering achievements. Due to the coronavirus pandemic, the awarding of the prize has been postponed to 2021.

Carsten Behler

Care to share?
Powder for 3D printing. We are currently working with a big-name steel manufacturer in this area. The aim is to round off metal 3D printing powder with a dash of nanoparticles and thus enhance the printing process. One laser process drives another.

What other benefits does the laser-based process offer?
Wet chemistry is clearly well ahead of us when it comes to volume. But there are certain things that we can do better. For many applications, industry requires nanoparticles made from alloys, rather than pure metals. This is where laser technology comes into its own. The laser-based process is perfect in terms of systematically producing ranges of different alloys with different mixing ratios; it could hardly be any faster. What's more, the alloy nanoparticles come in the highest grade of purity, as we do not use any stabilizers or precursors (like those in wet chemistry that are present on the surface). As such, there is no need for laborious cleaning.

What can we expect next from your laboratory?
To put it in simple terms, a fully automatic "coffee machine" for nanoparticles. Two of my team members have already built a prototype and are setting up a company for it. The principle is simple: the laser machine is positioned on a desk; inside, it contains a replaceable cartridge with target materials. You press a button—"platinum," "gold," "silver" or whatever—and out come the desired nanoparticles. You don't even have to know anything about nanoparticles to produce them. What's more, the device is safe and reliable. All you need are an electricity supply and a bottle of water.

Nanoparticles for all?
Precisely. There is, after all, a considerable market for small quantities—and the process of ordering such day-to-day amounts is extremely annoying and unreliable. The fully automatic machine is just one example of the manifold possibilities of the laser-based process in liquids.

So would you recommend to an entrepreneur that they get involved in nanoparticle production?

Yes, why not? Nanoparticles are the future. ■

Gimme the news, holo doc!

WHY HARD ROCK AND LASERS ARE THE BEST MEDICINE FOR HEARTACHE—AND ALL KINDS OF OTHER ACHES AND PAINS.

"Damn laser!"—who would say a thing like that!? Chris Turk in the second series of US comedy drama *Scrubs*, which ran in the noughties. The young surgeon is annoyed because his superior has forced him to ask Chief of Medicine Bob Kelso for a new argon laser. A bitter pill to swallow, as Kelso is universally regarded as the devil incarnate: a man who often belittles his staff for no other reason than his own enjoyment—and who is vehemently opposed to spending money on new medical equipment. So it's understandable that Turk bad-mouths the laser.

It's a shame, because argon lasers do great work for medics, especially in the field of dermatology, where they are used to remove pigment spots and treat vascular skin disorders.

I am sure that the doc from the sci-fi series *Star Trek: Voyager* (from the late 1990s)—simply known as "the Doctor"—would have soon persuaded Turk of the virtues of laser technology. After all, he is pretty much a laser himself or, to be more precise, a hologram. Actually, the holo doc was programmed to assist the flesh-and-blood doctors on board the USS Voyager. But with the spaceship stranded on the far side of the galaxy—and the entire medical team dead—the holo doc is the only crew member with medical experience. He diligently performs his duties as the ship's doctor and, as the series progresses, he picks up human traits and forms his own character. AI and lasers—what a beautiful love story! And for us laser fans, what could be more exciting than the thought of being cured by a laser doctor if we got a case of "warp speed sickness" in the farthest corner of the galaxy? Amazing!

And because there is always one song or another playing in my head, I am reminded of the rock musician Robert Palmer. In 1979, he sang the words *"I need you, to soothe my head […] Doctor Doctor, gimme the news / I got a bad case of lovin' you."* Might lasers even be able to ease heartache?

This would probably be of great interest to Bob Kelso. Ultimately, Chris Turk got his argon laser. And how? He catches Kelso being unfaithful—and uses this knowledge as a means of coercion. As a result, Kelso decides that it's better to approve the money for the laser. He probably also has the words of *Doctor, Doctor* by Palmer ringing in his ears: *"No pill's gonna cure my ill"*—something that no one wants to hear their loved ones say. ■

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

Would you like to be treated by a hologram? Let me know by email: athanassios.kaliudis@trumpf.com

Gernot Walter

WHERE'S THE LASER?

Beneath the cat. Anyone who has ever laid flooring above an underfloor heating system will never want to see the maze of pipes ever again. Repair? Replacement? No thanks! And that is why the hot water pipes beneath our feet are built with stubborn durability in mind, with an aluminum pipe—plus a layer of adhesive—encircling a plastic inner pipe. In turn, the aluminum is also lined with adhesive and encased in a plastic coating. When it comes to seal-welding the aluminum pipes, the Hesse-based firm Templet uses a special version of the TruLaser Cell. It welds quickly and reliably—with a continuous weld seam and without overlapping. Good news for homeowners: there is no need to dig up the bathroom tiles and parquet flooring for a few decades yet. ■

AdobeStock / grafikplusfoto

42 000

satellites

are being sent into space by Elon Musk's aerospace company SpaceX. In this image, you can see some of them launching. In future, they will extend high-speed mobile Internet to the most far-flung corners of the earth—with transmission speeds of 10 gigabits per second. The project is called "Starlink." The idea is to use laser light to send the data from satellite to satellite so that it orbits the earth. And although the data packages travel thousands of kilometers more than they would on the ground, they reach their destination more quickly. Because here in the vacuum of space, light travels at 300,000 kilometers per second. In terrestrial cables, it only reaches speeds of about 200,000 km/s.

Photo by SpaceX on Unsplash