

LASER COMMUNITY.

Of people and photons



Laser technology opens up new possibilities for steel in architecture.

#29

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EDITORIAL



A constantly evolving process

Does our cover page remind you of something? But you can't quite remember what? Let me enlighten you! The picture is inspired by Pink Floyd's 1973 album *The Dark Side of the Moon*, one of the most commercially successful albums of all time. There's something captivating, almost magical, about seeing that ray of light against the dark background. On Pink Floyd's eye-catching album cover, the ray of light passes through a prism and emerges on the other side as the colors of the spectrum. Of course, with a laser you don't get the effect of the light fanning out—but the result—*Light builds house*—is no less striking.

The laser has always helped us conceive of things in new ways and do things differently than before, giving us the freedom to come up with new designs. In the mid-1980s, for example, it revolutionized sheet metal cutting. Companies that were used to working with sheet metal cutters, nibblers or jets of water were suddenly able to use a laser to get the job done faster, more efficiently and with greater precision. And the laser could cut contours that were virtually impossible with conventional methods.

Laser-based additive manufacturing processes such as laser metal fusion have given us a particularly powerful injection of creative freedom. They have enabled us to produce parts with internal channels and cavities—things that we could only imagine, but not produce, without the power of the laser.

Of course, it was only a matter of time before architects began to take advantage of the freedom laser technology offers. Today, it has opened up so many possibilities in steel fabrication that they can let their imaginations run riot! As a result, we are now surrounded by buildings that couldn't have been built without lasers.

Personally, I never cease to be fascinated by the almost endless range of applications that laser technology can handle. It's a constantly evolving process, because we're always finding new niches for the laser to move into, whether it's processing semiconductors, cutting films for the display industry or forging a path in quantum technology.

And it's not just terrestrial applications, because lasers also have their sights set on space and the Moon. Lasers and satellites are a match made in heaven: lasers can be used to measure gravitational waves, Earth's gravity and atmospheric pollution, while retroreflectors on the moon allow lasers on Earth to measure time-of-flight and distance.

"See you on the dark side of the Moon," is a lyric from Pink Floyd's song *Brain Damage*. Chances are that they could probably find a laser and applications for laser technology there, too! Of course, strictly speaking, the Moon doesn't have a dark side, because the Sun illuminates it from all sides over the course of a month. But that's another story.

DR.-ING. CHRISTIAN SCHMITZ

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Unpacked

A man and his machine meet for the first time: over the next few years, Carl Hauser will be exploring the additive manufacturing of large aircraft parts at at TWI Ltd. For this article, our photographer was on hand to document the exciting unboxing of Hauser’s specially designed XXL version of a TruLaser Cell 7040. Read more on **page 10**.



Undefeated

It doesn’t seem long since the laser celebrated its 50th anniversary—in fact we’re still recovering from the hangover! So what could there possibly be left to say about the whole Schawlow-Townes-Maiman story? Well, there’s Gordon Gould for a start. We raise our glasses to the brave battler who missed out on glory at first, only to hit the jackpot later. Three cheers to Gould on **page 7**.



Undigged

Everyone loves a digger—and we thought we might finally have a chance to print a picture of one in our article on hard chrome plating. But it’s tough building a narrative bridge from EHLA as a replacement for hard chrome plating, to a wear-resistant hydraulic cylinder, and all the way to a digger arm. So we had to tearfully park our dream digger here, instead of on **page 22**.

AdobeStock/photollurg, Gemot Walter, Darren O'Brien

LASER COMMUNITY.



Carsten Behler, Hermann Köpf

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Owen Lystrup, Jan Michael Hosan, temp-64GTx/shutterstock

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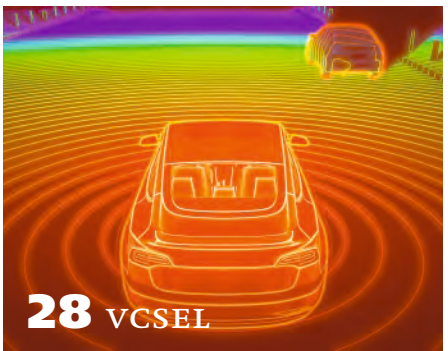
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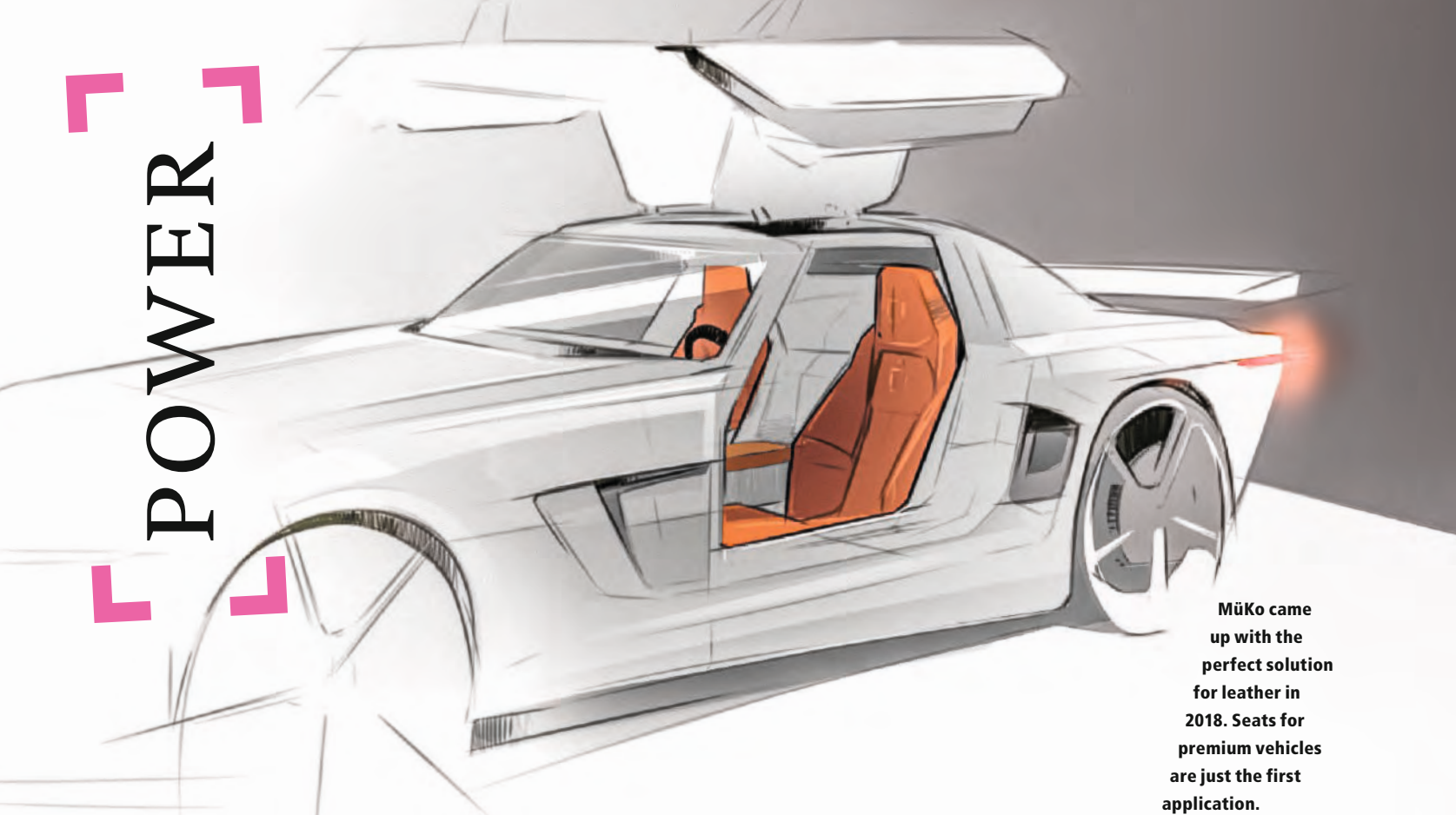
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In the train restroom



POWER

GLORY



MüKo came up with the perfect solution for leather in 2018. Seats for premium vehicles are just the first application.

MAKING LIGHT WORK OF LEATHER

Production-scale leather processing with laser cutting, marking and perforation all on the same machine.

The car interior is bathed in a soft light. The leather upholstery of the seats is subtly textured—and it's emitting a gentle, yet clearly perceptible, glow. This effect is produced by LEDs positioned behind thousands of tiny perforations in the leather, each measuring around just 0.05 millimeters.

As any expert will tell you, that degree of precision suggests a laser must have been involved. What's less obvious, however, is that all the steps required to process this organic material—cutting, marking and perforation—were performed on an all-in-one laser machine. And not as a one-off job, but in an industrial-scale process that can tackle even the largest pieces of leather at high speed.

The machine was built by the company MüKo, a special purpose machine maker based in Weinstadt, Germany. It was commissioned by an automaker that was keen to give its seats an extra 'wow' factor. The tricky thing in this case, however, is that burnt leather has an unpleasant smell.

So as well as harnessing top-notch laser precision, it was also essential to keep the heat input as low as possible. MüKo achieved that goal with an ultraviolet marking laser from TRUMPF's TruMark series, which uses a wavelength that is absorbed well by organic materials. What's special about this system is that the light energy applied to the leather breaks up its molecules instead of heating them. Rather than a thermal process that produces heat, it uses a photochemical process that does not generate heat. Although this doesn't entirely prevent the smell from developing, any residual odor is dealt with by a three-stage filter system and suction device positioned directly adjacent to the material.

MüKo quickly realized that its versatile, special purpose machine for car seats, which they christened Permacut, had the potential to set a new industry standard for processing leather. It turns out there are many leather products that could do with an extra 'wow' factor, from handbags and purses to belts and cowboy boots. Permacut isn't limited to leather; it can also handle other organic materials including paper and wood—and even glass. So it sounds like we have some exciting new designs to look forward to! ■

Timo Müller

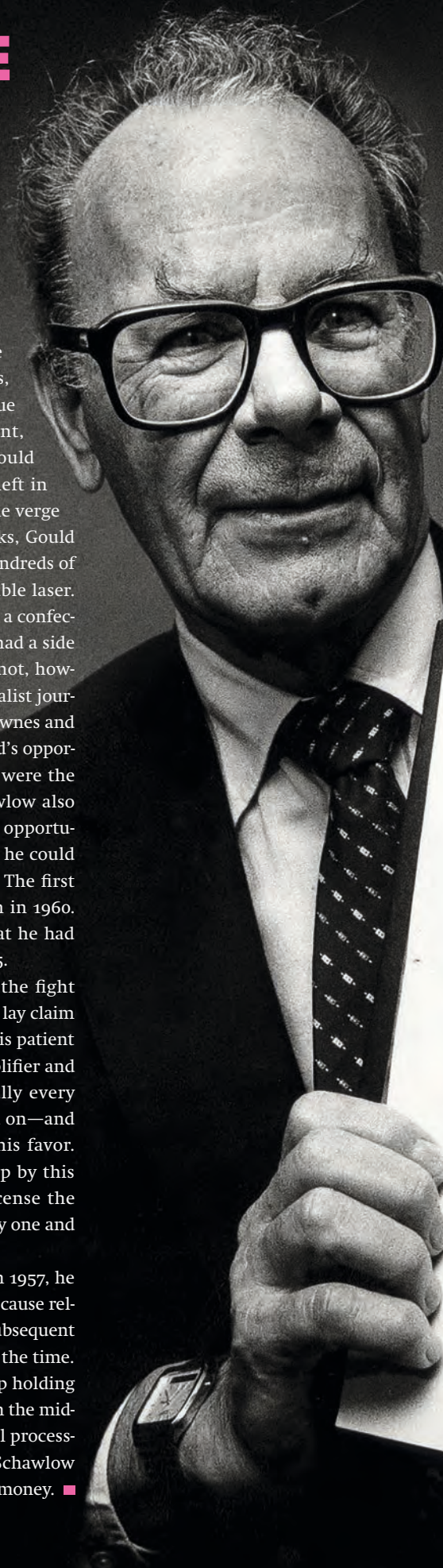
GOULD TOOK THE MONEY

Physicist Gordon Gould failed to file a patent for his laser concept in 1957. Thirty years later, that mistake made him a rich man.

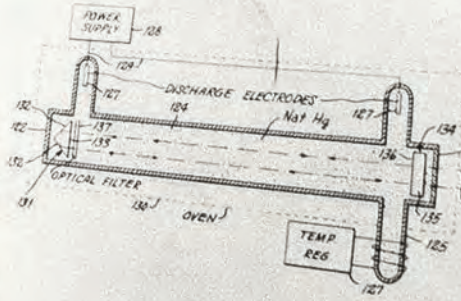
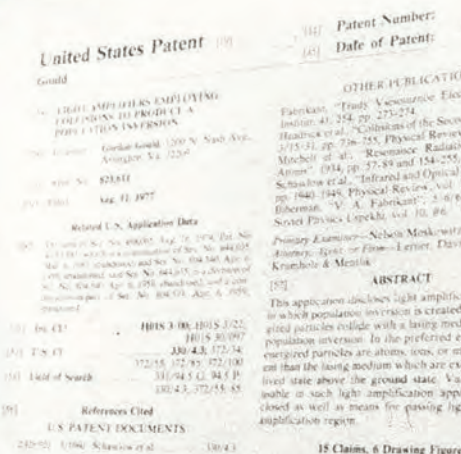
When Gordon Gould put down the phone one day in October 1957, he knew he had no time to lose. He had just spoken to Charles Townes, the inventor of the maser and Gould's colleague at Columbia University's physics department, who had called to find out what progress Gould had made on the thallium lamp. Gould was left in no doubt that, just like him, Townes was on the verge of inventing the laser. Over the next few weeks, Gould frantically scribbled in his notebook, filling hundreds of pages with information on how to make a viable laser. On November 16, 1957 he took the notebook to a confectionery store owner—a friend of his who also had a side job as a notary—and had it notarized. He did not, however, prepare a paper for publication in a specialist journal. This turned out to be a mistake, because Townes and Arthur Schawlow did exactly that in 1958. Gould's opportunity for glory was gone. And so, it seemed, were the financial rewards, because Townes and Schawlow also filed a patent for the laser. Gould missed that opportunity, too, because he mistakenly believed that he could only do so once he had built a working laser. The first person to achieve that was Theodore Maiman in 1960. Gould went to court, determined to prove that he had invented the laser, but he lost the case in 1965.

Vowing not to give up, Gould continued the fight from a different angle: instead of attempting to lay claim to the laser in its entirety, he decided to limit his patent applications to the optically pumped laser amplifier and a variety of applications that covered virtually every aspect of laser material processing. He battled on—and in 1977 and 1979 the court finally ruled in his favor. Numerous laser manufacturers had sprung up by this time, but they refused to pay royalties to license the technology. Gould dragged them to court one by one and finally won an enforcement victory in 1987.

If Gould had patented his idea for a laser in 1957, he wouldn't have found it very profitable. That's because relatively few lasers were built and sold over the subsequent 17 years, which was the term of a U.S. patent at the time. But the way things worked out, Gould ended up holding his patents through the 1980s and 1990s, right in the middle of the first boom in industrial laser material processing—and that made him a rich man. Townes, Schawlow and Maiman took the fame. But Gould took the money. ■



Gordon Gould won a 30-year legal battle.



“We’re keeping our quantum trick secret!”

Q.ant CEO
Michael Förtsch is
working on 21st-
century quantum
technology.

QUANTA

A quantum is a small particle such as an electron or a photon. It changes state—its energy level or spin, for example—not gradually, but only by leaping from one state to another.

Q.ANT

Q.ant is a Stuttgart-based start-up that emerged from TRUMPF in 2018. It develops extremely small, diode laser-based light sources for quantum technology.

Michael Förtsch from Q.ANT insists that quantum technology will define the 21st century. His company is already getting the ball rolling.

Mr Förtsch, when will I be able to write WhatsApp messages using thought waves?

I would say that’s still some way off! But the good news is that we’ve already taken the first steps.

By that you mean your light sources for quantum technology?

Exactly. They’re set to be a real game changer.

In what sense?

In the future, we will be able to control physical quanta, such as photons, to a degree that was previously impossible. That’s essential for making any kind of beneficial use of quantum phenomena.

Let’s start at the beginning: what is quantum technology?

Quanta are everywhere, but the way they behave is something the human mind struggles to grasp. For example, in quantum mechanics it’s possible for something to exist simultaneously in two mutually exclusive states or occupy two different positions at the same time. I know that sounds ridiculously confusing! It’s best to simply accept how tough that is to imagine and focus on the possibilities it offers. Quantum technology can help us make use of the kind of quantum phenomena that we are simply not conscious of in our daily lives. Of course, applications based on quantum technology are not really anything new. Just think of semiconductor-based circuits in microprocessors, for example, or indeed lasers. But right now we’re crossing the threshold of 21st-century quantum technology.

What does that mean exactly?

It all comes down to control—our ability to control individual quanta. They carry specific information encoded within them, for example on their intrinsic angular momentum, or ‘spin’. In order to read this information and use it for calculations and other purposes, we have to make it visible, in other words amplify



The idea is to make light sources even smaller in the future. Much smaller.

it to some degree. To do that, we use photons. But not just any old photons! Depending on what you are trying to measure, these ‘amplifier photons’ require certain properties, for example a precisely defined wavelength or polarization. So that means I need a way of telling my light source to give me photons with this precisely defined wavelength or very specific polarization.

And your light sources can do that?

Absolutely. And not after 20 attempts in some kind of controlled lab setting, but on a reliable, industry-ready basis.

How did you reach this stage?

We fire the beam of a tiny diode laser through an arrangement of optical elements that form it into exactly the type of beam we need. And then we perform what we call the ‘quantum trick’, but I hope you understand that’s something we want to keep secret! One of the keys to our light sources is to make them with as few optical components as possible, because we hope to make them even smaller in the future. Right now, they are slightly bigger than a paper clip. But our goal is to shrink them even further, because that’s one of the keys to success in many applications. That presents us with some major challenges in terms of design and connection technology, but we’re confident that we have greater strengths in those areas than anyone else.

What applications will your light sources be suitable for?

The range of potential applications is almost endless. Our task is to equip the quantum engineers of this world with the technology they will need in the future. Our light sources will play a part in all sorts of areas, from novel sensor systems for medicine and autonomous driving to new types of data encryption, new microscopes and pieces of equipment that we can’t even imagine yet!

Including an interface to control things with our thoughts?

Well, we’re just the enabler. But yes, even that is conceivable. Quantum technology will enable us to read human brain waves with an extremely high resolution. But to create a thought interface we would still have to learn to interpret them.

So we need to be patient?

For now, yes. But it’s good to have something to look forward to! ■



It's not yet possible to produce an entire aircraft using a laser. But Carl Hauser (right) from TWI has taken the bold step of extending AM processes to larger components—and is starting to think in terms of meters.



REACHING FOR THE SKY

The aerospace industry pioneered the use of laser additive manufacturing (AM) processes—yet it has balked at adopting this technology for larger components. The UK-based organization TWI Ltd. hopes to change that.

The future looks bright for the aviation sector, with the International Air Transport Association (IATA) predicting that global passenger numbers will double over the next 20 years. The increase in demand for aircraft therefore looks set to continue. What's equally clear is that the race for orders will only be won by aircraft manufacturers that supply airlines with efficient, fuel-saving aircraft models. This has prompted the industry to embark on a feverish hunt for ways to reduce component weight, transfer new designs into production and manufacture aircraft more economically, all with an eye to gaining a crucial competitive edge. The UK is one of the biggest players in this sector. Britain has the third biggest aviation industry in the world—and the government innovation agency Innovate UK is keen to ensure it maintains this dominant position. To this end, it is support-

ing a raft of measures designed to put new manufacturing methods to the test. One of these is the Open Architecture Additive Manufacturing (OAAM) project, which aims to convince companies to invest in additive manufacturing technologies. The best place to find out more about this project is Rotherham in South Yorkshire, not far from Sheffield, the former heart of Britain's steel industry. This is where TWI runs a research center. The globally renowned institute specializes in welding and joining technologies and is the lead partner on the OAAM project, which also involves various universities as well as companies including Airbus. Carl Hauser can hardly wait to get started on the project. The scientist manages a team of 16 researchers who specialize in laser manufacturing processes, and he is very clear about the benefits of producing parts using 3D printing: "Lasers can create geometries that you could never get with a milling

machine. What’s more, 3D printing caters to a wide range of materials and only uses the amount of material that is absolutely necessary.” The difference can be striking: a typical material removal process might require 40 kilograms of raw material to produce a component that weighs no more than one kilo. With aircraft manufacturers dependent on expensive materials such as aluminum and titanium, the cost of raw materials can be substantial.

Obviously AM processes are nothing new in the aerospace sector. In fact, this was one of the first industries to start reaping the benefits of 3D printing. Processes such as nozzle-based laser metal deposition, or LMD, have been a popular choice for many years. A good example is 3D printed turbine components. Yet these parts have typically tended to be on the small side. The OAAM project aims to make the leap to larger components, scaling up from multi-centimeter to multi-meter sizes. The team believes the LMD process could be used to manufacture major aircraft components, including, for example, engine casings.

FINDING THE RIGHT MACHINE Hauser is convinced lasers can get the job done—but finding the right machine poses a bigger challenge: “Right now, there are quite simply no suitable systems that offer a reliable means of producing larger components.” Fortunately, Hauser already has a potential solution in his sights. He and his team will soon be ready to run the first tests on a TruLaser Cell 7040. “We’ve been using a TRUMPF machine for 15 years, but now we need something bigger to meet the goals

of the OAAM project,” he says. German company TRUMPF won the public tender process to supply the new machine, and its engineers immediately set to work on tailoring the new system to TWI’s requirements. In particular, this involved extending the capacity of the Z-axis, doubling the default configuration to obtain a traverse range of 1,500 millimeters. “This machine is the only one of its kind in the world—the maximum would normally be 750-1000 millimeters,” Hauser says. He is excited to see what the machine can do once the team has finished setting it up and running some preliminary tests. The TruLaser Cell also offers laser cutting and welding, giving manufacturers the option of combining several processes in one.

Hauser, however, is primarily interested in LMD. He has been working with AM technologies for 23 years, ever since he started his doctoral study on laser powder bed fusion. “I’m confident that LMD technology will play a key role in the future. All we need to do now is scale up AM production to cater to larger components.”

THE CHALLENGE OF OXIDATION The team needs more than just a bigger machine, however. Using AM to create parts requires a stable and reliable process—and that’s the second sticking point: “A stable protective atmosphere is crucial when you’re working with sensitive materials such as titanium and aluminum, because you have to protect them against oxidation,” Hauser explains. LMD applications therefore use shielding gases such as argon to keep oxygen away from the parts being built. Modern



TWI is working with its partners on the OOAM project to identify larger components that can be produced with a high degree of precision using LMD. Engine housings are one example that shows particular promise.

chamber designs offer a simple and versatile solution for smaller parts, but what about larger ones? “That’s where things get a lot more complicated,” says Hauser. Using full chamber shielding for the entire system would be far too costly and time consuming. Some alternatives could be trailing shrouds with diffusers to supply an enlarged area of controlled laminar flow of inert gas, and/or novel gas mixtures. “The next step is to join forces with our industry partners to work out what additional components we need to solve this problem,” says Hauser. Ultimately, the goal is to enable aircraft manufacturers to integrate LMD technology in their everyday production processes.

WHERE DO THE LIMITS LIE? If Hauser and his team succeed, aircraft manufacturers will be able to start thinking in entirely new dimensions and create geometries with new kinds of materials that were previously inaccessible. “Today’s manufacturing processes limit engineers’ creativity, but the laser has the power to break down those boundaries,” says Hauser enthusiastically. But doesn’t the LMD process also come with certain limitations, at least in regard to component size? “The truth is we just don’t know. But I’m confident we can apply it to far bigger components than we previously thought.” The OAAM project is set to run for another two years. Who knows what new options it might eventually open up for the aviation industry?

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“LMD technology will play a key role in the future. All we need to do now is scale up AM production to cater to larger components.”

Carl Hauser
TWI, laser engineer

TRUMPF engineers tailored the TruLaser Cell 7040 to TWI’s requirements. The next two years will show just how much potential the LMD process still has to offer.



WHAT ON EARTH WOULD JEAN PROUVÉ SAY, if he saw this steel truss? The French architect and designer, who was also a skilled blacksmith, ran his own metalworking company in the mid-1920s, where he developed economical methods of designing and constructing facades, window and door frames, roof elements and similar components. Up until his death in 1984, he poured his creative energy into efforts to blend industrial manufacturing technology with architecture—and he ultimately succeeded in turning the concept of industrial architecture on its head. While other industrial architects were busy setting the stage for industrial production with their factories and workshops, he focused primarily on what industrial manufacturing methods could offer architecture.

But let's return for a moment to that steel truss. If Prouvé were to take a tour of the TRUMPF Smart Factory that opened in Chicago in 2017, his heart would probably skip a beat. The 45x55-meter cantilevered roof in this fully connected factory is supported by eleven steel trusses welded from individual pieces of steel (on right, fig. A). All the pieces were cut using the factory's own machines. As a result, visitors—and not just imaginary ones like Prouvé—can appreciate this roof as a great example of what the smart factory's machines can do and experience first-hand just how much laser machines can offer the world of architecture. So what might Prouvé have asked fellow architect Frank Barkow from the architects' firm Barkow Leibinger, which designed the TRUMPF Smart Factory? His first question would probably have been how the building could possibly have had a budget high enough to include such extraordinary structures. He would have been amazed to discover that it wasn't nearly as high as he might have expected—all because TRUMPF laser machines were on hand to cut and weld the steel trusses and make the whole roof construction financially viable.

SHARP EDGES More and more architects are realizing that they can put their ideas into practice without breaking the budget by making use of laser technology. Property developers have fewer worries about exceeding the agreed costs, and passersby get to enjoy ever more aesthetic buildings. The current trend in architecture is to give the same weighting to form as to function, especially in airports, shopping centers and hotel lobbies. Specifically, that means that support structures should not only hold everything up but also look as attractive as possible. In architectural circles, the buzzword is architecturally exposed structural steel (AESS). As the name suggests, this involves making the steel structure of a building visible. In the past, it was relatively unimportant whether the weld seams on steel components looked good or not—but not anymore.

“What lies behind AESS is a reclassification of high-quality steel products,” says Michael Stumm, vice president of Swiss steel profile manufacturer Montanstahl SA. “Today's architects have completely new expectations with regard to steel sections and profiles.” The corners play an important role in this context. Architects are increasingly clamoring for a specific type of steel profile known as a sharp corner profile (SCP). That's because a sharp corner—in other words, a small radius—does not jar the eye when the viewer turns their gaze on the support structures of a facade or roof. “Architects have always been keen on sharp corners,” says Stumm, “but previously they were only possible with aluminum and thin-walled steel profiles, both of which are too weak to bear any heavy weight.”

FREE-FORM REPLACES EGG SHAPE So how does Montanstahl create these sought-after sharp corners on large steel profiles? Take sharp-edged rectangular hollow sections (see box on page 19), for example, which are a popular choice of support structure for facades. These are conventionally produced by bending a flat bar of sheet metal into a four-sided shape and welding it on one side. The disadvantage of bending lies in the outer radii, which are subject to the traditional rule of thumb of two times the material thickness. So a piece of steel that is 20 millimeters thick yields an outer radius of 40 millimeters, creating more of an egg shape than a rectangular hollow section. An alternative is to take four flat bars of metal and weld them on all sides. That offers the added benefit of being able to use different material thicknesses that are precisely tailored to the structural requirements, which saves on steel. But there's a catch: this four-metal-bar method is extremely expensive and time-consuming. Unless, of course, you take a tip from Montanstahl to achieve fast, deep and highly durable laser weld seams. Laser welding makes sharp-edged rectangular hollow sections so economical that they finally become a feasible option for an increasing number of construction projects.

DEEP INSIDE Another interesting example is sharp-edged T sections (see box on page 19). The most that conventional methods could manage was to create sharp corners on short and thin-walled T sections. But the thicker the metal, the harder it got. What's more, the cut has to be clean and consistent along the entire length in order to create a gap-free join where the edges meet. The laser makes it easy to achieve that at Montanstahl.

Things get trickier with welding, however, because conventional methods such as MIG and MAG leave protruding weld seams in their wake that subsequently have to be ground down to make them more aesthetically pleasing. Even more challenging in the case of thicker materials is heat input, which can warp long steel sections into oversized corkscrews. To tackle this problem, Montanstahl uses laser welding, which relies on high penetration depths combined with low heat input to create a clean weld seam. A T section machined with a laser

BUILD

MODERN
ARCHITECTS
LOVE STEEL AND
FREEDOM. LASER
TECHNOLOGY
ALLOWS METAL
FABRICATORS
TO OFFER THEM
BOTH

Simon Menges, Gazpromneft Eastern European Projects



fig. A

TRUMPF Smart
Factory in Chicago,
USA (left, fig. A),
Lakhta Center
in St. Petersburg,
Russia (fig. B,
large image)

fig. B

IT WITH
LIGHT

fig. C

Multistory parking garage in Bietigheim-Bissingen (fig. C), parking garage in Ditzingen (fig. D), TRUMPF main gate (fig. E, opposite page) in Ditzingen, Germany



Stefan Müller

ARCHITECTURE

doesn't just look better—it is also quicker and cheaper to produce. One striking example of why laser welding's high penetration depth makes sense is when a hurricane hits a building before it has been completed. That's what happened to the Novartis Headquarters in New Jersey, for which Montanstahl was fabricating the facade profiles. "For the ten millimeter thick metal, they had told us it would be enough to weld between one and four millimeters on each side. But with laser technology it made no difference to us, so we welded the full ten millimeters," says Stumm. The hurricane didn't bend a single profile—a great example of how to get additional peace of mind with no extra effort.

SPIRALING INTO THE SKY Anyone who can look into the eye of the storm without flinching is likely to be open to embracing new forms. Many modern building designs can only be realized using free-form profiles. But in the past, these kinds of unconventional shapes could only be created using soft and relatively unstable aluminum sections. But what happens when the wind gets hold of aluminum sections that protrude 15 meters into the sky at the top of a skyscraper? Can they withstand the force of the wind? That's something building designers no longer have to worry about. By building complex geometries out of steel sections, they can make even their most labyrinthine facade fantasies come true!

Standing 462 meters tall and completed in 2018, the Lakhta Center in Saint Petersburg, which is the headquarters of gas giant Gazprom, is the tallest building in Europe (fig. B). The design of the top 22 meters would have been impossible without a laser. It was fabricated by the company Edelstahl-Mechanik GmbH, which is based in Göppingen, Germany. "It was crazy," says managing director Josef Eisele, referring to the tight deadline of just four months from order placement to delivery. With the tower spiraling its way into the sky like a drill bit, every sheet of the outer cladding is different. The tapered and twisted stainless steel parts, up to 60 millimeters thick, were all 3D laser cut using TRUMPF lasers. And that wasn't the only time the laser was put to use for the Lakhta Center skyscraper: to prevent icicles from turning into potentially deadly projectiles, the tower's metal panels are heated from the inside. Edelstahl-Mechanik's employees also used the cutting laser to mark the positions of the bolts that hold these vital heaters in place, saving themselves the subsequent effort of marking them out with a stencil. "Without laser technology, it would have been impossible to get all that done in such a short time with just 100 people on the job," says Eisele.

EXTERNAL VALUES MATTER Ironically, it's the superb seam quality of laser welding that sows doubt in the minds of some structural engineers: can something that is hardly visible really be tough enough to do the job? That's a question Eisele has heard many times. Recently, Edelstahl Mechanik GmbH supplied sections for a new building at Harvard University (fig. G, page 18) and was faced with the same doubts: "The U.S. structural engineers were skeptical, but they had no choice but to wait and see how it all turned out.

After all, the required penetration depth for the largest sections would have been impossible without the laser," says Eisele.

The Harvard project also shows Eisele's outstanding capabilities when it comes to simply making things look beautiful: each individual piece of the facade features decorative holes cut by a laser. Eisele began taking on architectural jobs around 20 years ago when a production manager he knew asked him to use a laser to cut mirror-finish sheets for a decorative facade, because mechanical processing methods spoiled the shiny surfaces. The fact that people are now focusing more on "designer buildings where aesthetics play a major role," as Eisele puts it, suits him well. This increases the pressure on structural engineers and architects to get acquainted with laser technology, which is still new to many of them.

Binder Parametric Metal GmbH has also experienced the challenge of gaining acceptance in the market, as sales director Christian Geiger explains: "Talking to architects, we've noticed that many of them still haven't fully taken on board the benefits of making a decorative facade out of metal: it's easy to assemble, completely recyclable, very robust, economical and can be adapted to whatever shape is required." The company, which is headquartered in the Bavarian town of Karlskron, has carved itself a niche in 3D metal facades—and the laser is the perfect tool for cladding buildings in new forms. Precision is the key when it comes to free-form surfaces, whether they are fabricated for the facades of parking garages (fig. C, page 16) or for decorating the interior of all sorts of other buildings in a truly unique way. "For a good facade, you need the edge to be perfectly precise all the way around, even when it passes through three-dimensional forms," says Geiger. A laser has no trouble achieving this kind of precision whatever the shape, and it is equally serene in the face of small batch sizes and time pressure—two challenges that facade builders often have to deal with. "Lasers are fast and flexible. We can use our systems for so many different things because they are so quick to reprogram," says Geiger.

TRUMPF demonstrates how these systems work together at its Smart Factory in Chicago. But what would Jean Prouvé have to say about laser machines as he gazed down on Industry 4.0 from the skywalk? Perhaps that he had always known the machine industry was capable of inspiring architecture? Maybe he would even see the TRUMPF Smart Factory as the successful realization of a fusion between industrial architecture and architecture from industry? Or perhaps he would simply be too flabbergasted to speak! ■

Contact: Klaus Löffler, phone: +49 (0) 7156 303-30962, klaus.loeffler@trumpf.com

fig. D



Hermann Köpf

David Franck

fig. E

CAN A WELD SEAM THAT IS HARDLY VISIBLE REALLY BE TOUGH ENOUGH TO DO THE JOB?



TRUMPF staff
restaurant
in Ditzingen,
Germany (fig. F),
TRUTEC Building
in Seoul, Korea
(fig. H)



David Franck

fig. F

WELD SEAM AESTHETICS: BEAUTY BECOMES
A FACTOR ONCE YOU START USING VISIBLE
PROFILES AND TRUSSES.

fig. G



Harvard John A. Paulson
School of Engineering and
Applied Sciences in Boston,
USA (fig. G), Stavros
Niarchos Foundation
Cultural Centre in
Athens, Greece
(fig. I).

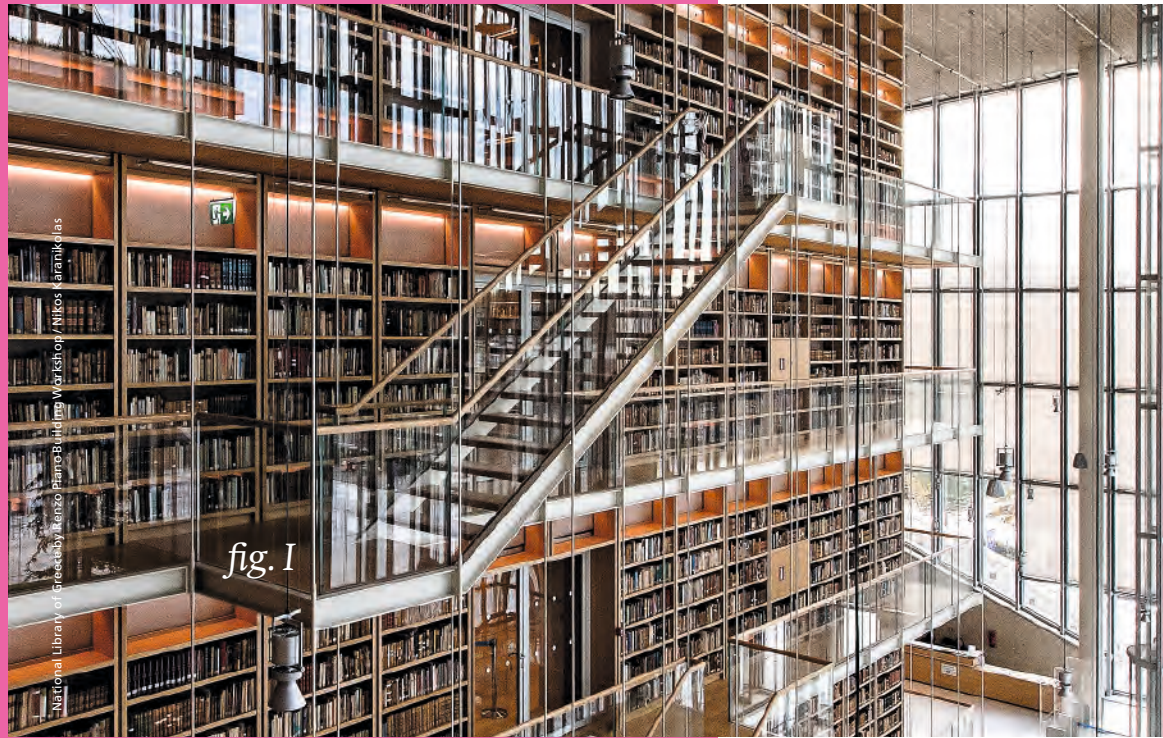
Belmisch Architekten

fig. H



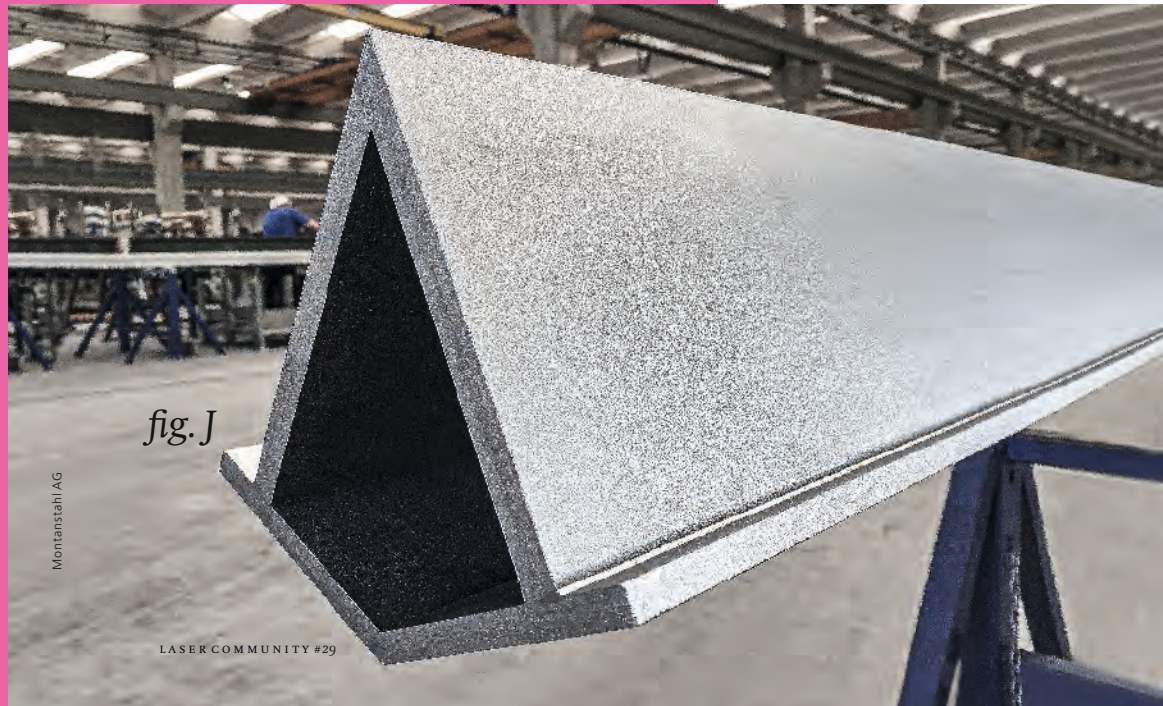
Christian Kutsche

fig. I



National Library of Greece, Kostas Pantazis Workshop, Nikos Karamanolis

fig. J



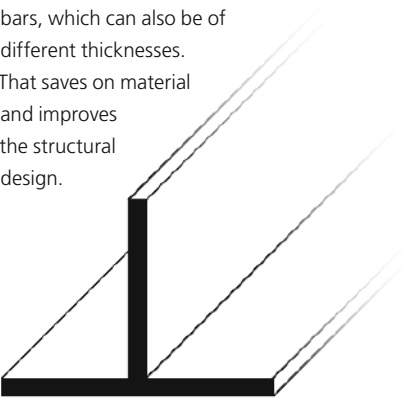
Montanstahl AG

PROFILING
STEEL
CONSTRUCTION



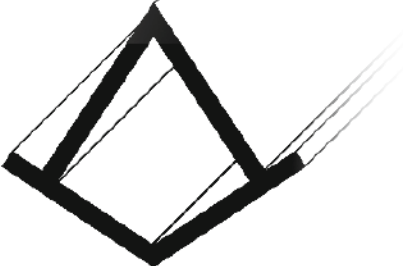
RECTANGULAR HOLLOW
SECTIONS

The problem with conventionally welded rectangular hollow sections lies in the external radii. A laser can be used to create sharp corners by welding together four flat metal bars, which can also be of different thicknesses. That saves on material and improves the structural design.



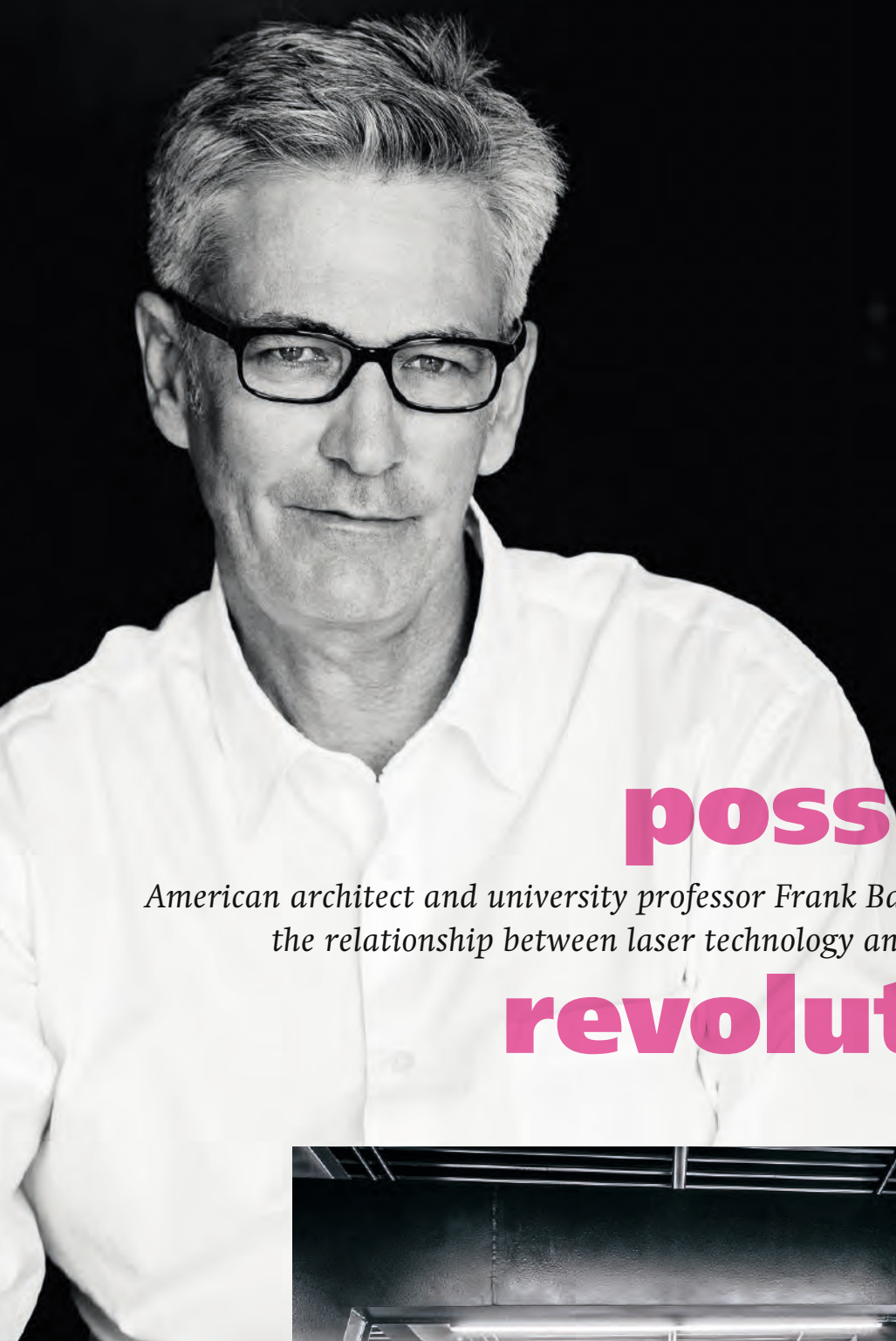
SHARP-EDGED T SECTIONS

Lasers cut sharp corners along the metal's entire length and weld the T sections with a high penetration depth and low heat input. The result is clean seams and zero warpage.



FREE-FORM SECTIONS

The laser makes a quick and clean job of welding complex profile geometries in stable steel (fig. J).



American architect and university professor Frank Barkow discusses the relationship between laser technology and architecture.

"The possibilities are revolutionary"



Mr Barkow, the architects' firm Barkow Leibinger has been designing buildings for the past 20 years – and one of its clients is the machine maker and laser manufacturer TRUMPF. What impact has this collaboration had on your work as an architect?

I have often found myself thinking "Wow! These machines offer amazing potential for architecture—and that potential hasn't

ARCHITECTURE

really been properly explored". When my partner Regine Leibinger and I were studying at Harvard in the 1980s, architecture was undergoing a transition toward digital technology—so making digital drawings and then producing them on the shop floor. When we started working with TRUMPF at the end of the 1990s and I took a proper look at machine tables that a laser had cut and welded, I thought to myself, if we can put these applications into practice on the scale of a building, we can use them to produce completely new kinds of structures and facades.

So you were breaking new ground in architecture?

What was new was the opportunity offered by digitalization, because even back then it was already fairly standard to use products from the mechanical engineering industry for facades and furniture. But we were interested in where the

digital era was going to take us. And then, almost 15 years ago, we began developing buildings like the main gate and the staff restaurant at TRUMPF in Ditzingen—buildings that would simply have been impossible without digital and laser technologies.

Could you explain that a bit more?

There are some projects that we couldn't have brought to fruition 20 years ago. The TRUMPF Smart Factory in Chicago, which opened in 2017, is one example. The trusses for the main hall were laser cut and laser welded using TRUMPF machines. That was very fast, and very economical. In the past, it would simply have been too expensive. Without laser technology we would have been forced to use analog tools to come up with something more conventional—something that would have probably taken five times as long and cost three times as much! If you look at what is now technically and economically feasible, the possibilities are, in a sense, revolutionary. The new technology is essentially paving our way into the future.

How does that affect the way you plan a new project? Does it mean you always consult with technicians first nowadays?

It used to work like this: we designed something, then a few months later we called in the structural engineer and, a few months after that, we brought on board a facade company that fabricated sheet metal, for example. Now, we try to hold a workshop with the fabricators as early in the process as possible to discover whether our ideas can actually be realized in practice. That knowledge then influences the design process.

Has laser technology become so widespread in architecture that it is used in every single project?

It's not a dogma. The technologies we choose for our building projects always depend on the specific project in each case, and in many cases we opt for a combination of high-tech and low-tech. The laser might be capable of doing everything, but that doesn't mean it should! If we need a hammer, we use a hammer. It's that simple. But I always have the possibilities of laser technology in the back of my mind and draw on them as a kind of archive.

An archive that is constantly growing ...

Absolutely. Whenever TRUMPF develops something new, we always try to send some of our employees to Ditzingen so they can check out the possibilities the machines offer and think about how we could use the new laser in architecture. Let me give you an example: when TRUMPF launched the tube cutting system TruLaser Tube, we had all sorts of ideas about how it could be put to architectural use. You can see one of the results of that thought process in the new, recently opened TRUMPF multi-story parking garage in Ditzingen, which has a facade made of laser-cut metal fins. The aim is that these kinds of elements help the architecture to convey something about TRUMPF's core competencies and, ultimately, its identity.

When you're working with your students at Harvard, Princeton and the Architectural Association in London, do you specifically

discuss the benefits lasers offer in bringing architectural concepts to life?

Yes, absolutely. In our lectures, we talk about the opportunities offered by modern technologies such as lasers, and we also involve the students in our research work. We show them a machine and ask them how they would make use of it in their work. The ideas they come up with are amazing.

What other changes do you think laser technology might introduce to architecture in the future?

I think the possibilities offered by additive manufacturing will enable us to create entirely new architectural forms. We're already seeing some initial structures that were built, at least in part, using this technology, such as bridges. At the same time, lasers also allow us to cut and weld synthetic materials that can then be used in our projects, opening up all sorts of new opportunities. These kinds of materials have completely different properties. That, in turn, will enable us to think, design and build in completely different ways. I'm also fascinated by the concept of "Building 4.0", a construction site featuring machines that are connected to each other digitally and physically. Just like the machines in TRUMPF's fully connected Smart Factory in Chicago. ■

Frank Barkow
Born in the U.S. in 1957,
Barkow founded the
firm Barkow Leibinger in
Berlin in 1993 together with
Regine Leibinger. The two
partners had met while studying
architecture at Harvard. Barkow
has taught as a visiting professor
at various universities including
EPFL in Lausanne, the State
Academy of Fine Arts in Stuttgart
and Harvard. He has been teaching
at Princeton University since 2016.
Barkow Leibinger has received
numerous awards for their
architectural work, including
the 2018 German Steel
Construction Award
for the TRUMPF
Smart Factory in
Chicago.



The roof of the production facility at the TRUMPF Smart Factory in Chicago is supported by eleven steel trusses, each made up of many individual pieces welded together.

BETTER THAN CHROME

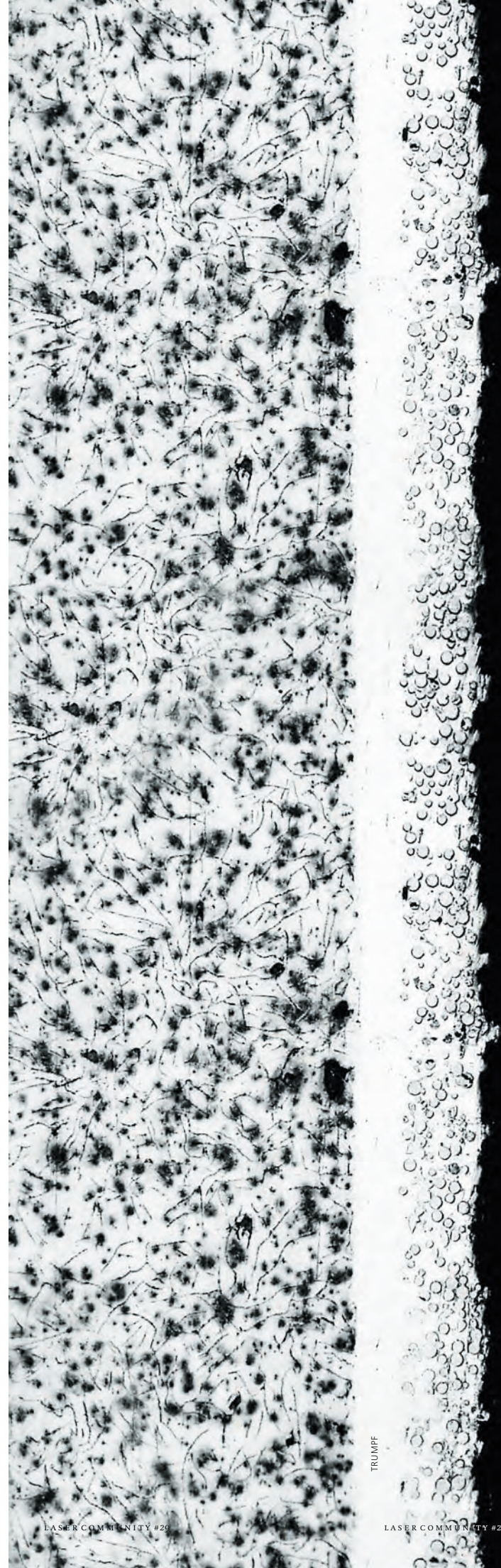
The extreme high-speed laser deposition welding technology EHLA is the most cost-efficient and safest alternative to hard chrome plating.

Regulatory pressure is mounting worldwide to curb the once common process of hard chrome plating, and nowhere more so than in the European Union. Its REACH regulation lists chrome trioxide—the material used in hard chrome plating and commonly known as chromium (IV) or chromic acid—as a hazardous substance. This does not ban the substance from the industry altogether, but REACH does attach very strict conditions to its use. For one, companies have to prove that there is no suitable alternative available, which is fast becoming an increasingly implausible argument. From an occupational health and safety perspective, several new wear and corrosion protection technologies look to be a far friendlier alternative.

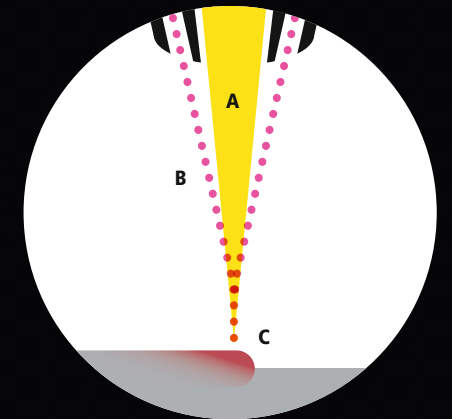
ADVANTAGES OF THE EHLA PROCESS One such recent innovation is particularly promising—extreme high-speed laser deposition welding, which also goes by the name of its German abbreviation EHLA. A step up the evolutionary ladder from laser metal deposition welding (LMD), EHLA was developed by the Fraunhofer Institute for Laser Technology ILT and RWTH Aachen University. The biggest difference between the two is that an EHLA laser beam melts the metal particles before they hit the component rather than after

they settle on its surface (see illustration). Our application tests show EHLA is superior to hard chrome plating in several points of process, quality and cost-efficiency:

- (1) EHLA enables users to deposit the material in exceedingly thin layers of 25 to 300 micrometers each.
- (2) The resultant protective layer's surface roughness is very low at Rz = 10–20 micrometers. Remarkably smooth after the material is deposited, the coating's surface requires little finishing, or none at all.
- (3) The heat-affected zone measures just five to ten micrometers across. This means even heat-sensitive substrates such as aluminum or cast iron alloys can be protected against wear—an industry first.
- (4) EHLA requires no chemicals and its energy consumption is relatively low.
- (5) The speed of this process is certainly the most interesting economic aspect. Able to achieve coating rates as high as 1000 cm²/min. at feed rates of 250 m/min., EHLA lends itself to coating large components at low cost. These high processing rates are easily achieved for rotationally symmetrical components, particularly hydraulic cylinders or work rolls, which can be guided at high speeds.



This cross section of a coating with EHLA clearly shows the quality of the bond between the two materials. The substrate is cast iron, the adhesive layer consists of nickel, and the wear protection is provided by tungsten carbides in a stainless steel matrix.



EHLA: The laser beam (A) melts the powder (B) above rather than in the melt pool (C). This results in higher coating rates and high processing speeds.

- (6) Qualitatively speaking, the bonding of the substrate and adhesive layer is the most interesting aspect. In contrast to hard chrome plating, EHLA produces a dense bond without cracks or pores. The protective layer cannot flake off, and its quality is enduring, remaining stable even when exposed to considerable stress.

HIGH MATERIAL UTILIZATION Again, with regulations tightening on hard chrome plating and the industry gradually phasing it out, the makers of wear and corrosion coatings have cause to contemplate which alternative best suits their purposes. Our tests to compare EHLA with established alternatives provide some interesting points to consider.

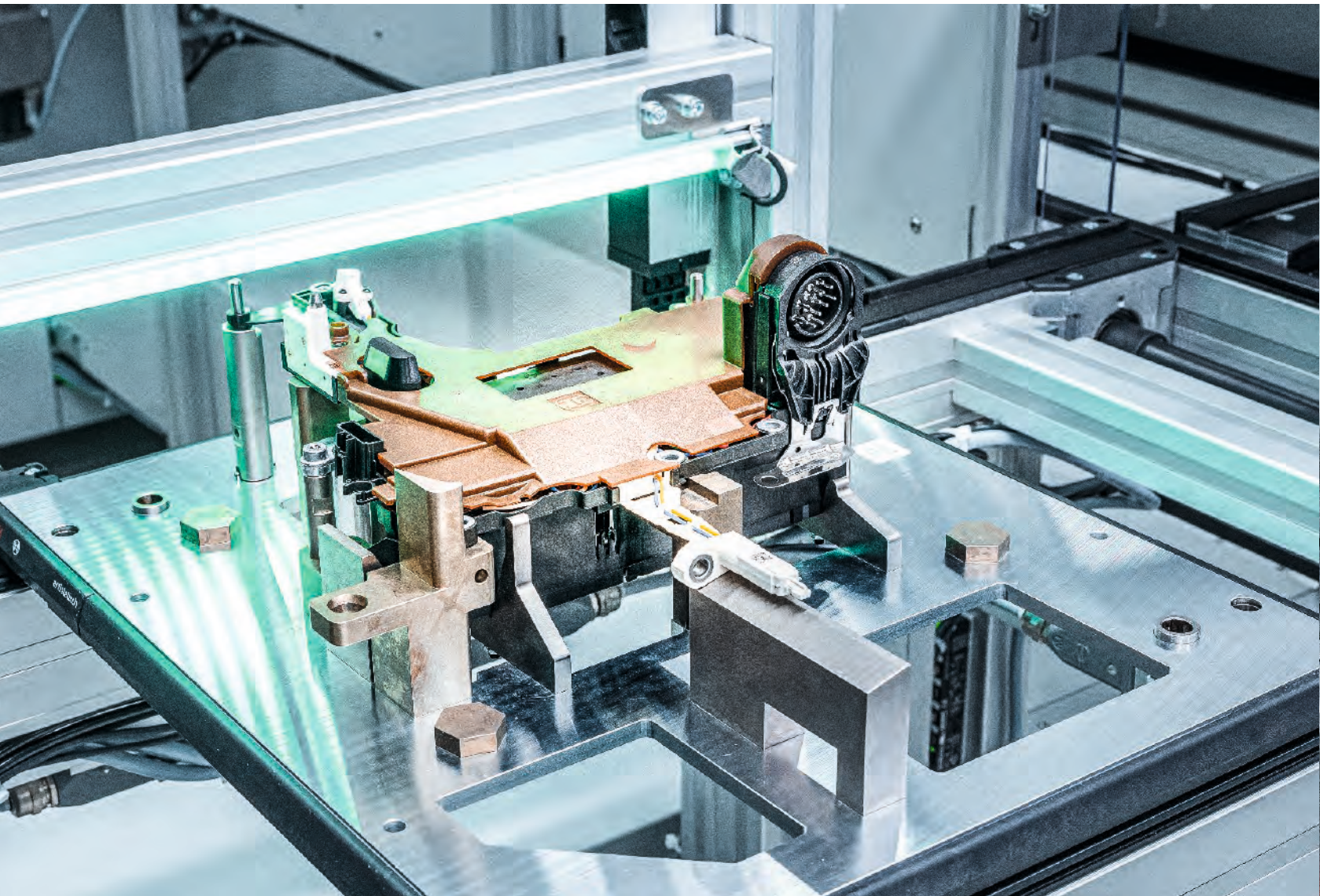
As it stands, High Velocity Oxygen Fuel (HVOF) coating, better known as thermal spraying, is the prevailing option on the market. This process involves a flame melting the applied material's particles, which are then sprayed onto a surface at high velocity. The particles deform on impact and cling to each other as

well as to the substrate. However, the resultant layers' bond with the surface is weak, which is why per-layer and overall thicknesses are subject to greater limitations than with EHLA. One similarity to hard chrome plating is a commonly occurring problem: the coating is more likely to flake and require repair for lack of a substance-to-substance bond. Resource consumption is a big factor in production, as our comparison shows: HVOF requires far more process gas than EHLA. And powder efficiency is a substantial cost factor: HVOF converts just 50 percent of the powder into coating; EHLA achieves conversion rates as high as 90 percent.

Our tests show that EHLA is currently the most attractive process for producing wear and corrosion layers in terms of (1) technology, (2) quality and (3) cost-efficiency. ■



SABRINA VOGT is responsible for laser surface technology at TRUMPF. She is striving to establish extreme high-speed laser deposition welding (EHLA) in new industries.



A sounder seam

The soundest seam in plastic welding—that’s what ZF Friedrichshafen is striving for. A diode laser equipped with a pyrometer delivers the results, and all the process data as well.

The safety of the transmission control unit in the ZF’s new lightweight eight-speed automatic transmission hinges on a plastic cover’s 22 welding ribs. This unit does an impressive job of shifting the engine’s power to the wheels in midrange sedans, luxury sports models and SUVs. These power electronics are sensitive, however, so if any metal chips or debris find their way into that control unit during assembly or operation, the motoring fun is sure to be finite. That’s why engineers put a lid on it. So how do you make sure all those

seams on the plastic are tight? Patrick Czekalla, project engineer at ZF’s Plant Engineering department at Auerbach, has the answer: “We weld with a diode laser and monitor with a pyrometer.” This device is built into the TruDioder’s laser control system.

A VIEW INTO THE MELT ZONE The pyrometer measures the melt temperature in real time precisely where the parts join. The laser control unit registers the intensity of the thermal radiation in the specified wave-

length spectrum and, if necessary, adjusts the laser power to the target temperature. “External pyrometers always lag a bit behind the laser beam,” says Czekalla. “The built-in system gives us more reliable measurements and we can be sure that the cover is properly welded to the assembly.” This makes it easier to spot flaws: for example, a change in heat absorption is a tell-tale sign of a stranded wire trapped between the base module and the cover. “One big advantage is that we can detect flaws during the lasering process. And now we only have to perform destructive tests when the job order is approved,” says Czekalla.

IN WRITING, PLEASE ZF manufactures the transmission control units on specially designed lines at plants at Auerbach, Bayreuth, and in the Czech Republic. It’s good to know that the welding is done

properly, but that insight alone is not nearly enough in today’s automotive industry. Traceability of all products has long been compulsory for all process steps, modules, and lines. That’s why collecting and assessing manufacturing data has been a top priority at ZF for years. “Data analysis helps us set and continuously optimize process limits,” says Czekalla. “But it also helps us fulfil an obligation to our customers.” The TRUMPF TruDioder laser has the interfaces needed to connect to databases. This makes it possible to capture and store all the parameters that are critical to the process in a quality assurance database. “We record the exact date and time when each transmission control cover was produced, and in which facility. The laser’s other process-critical parameters are also captured. A laser later adds all this data to a data matrix code on the product,” notes Czekalla. ■

The brown plastic cover is welded to the transmission control unit with 22 welding ribs. Patrick Czekalla relies on the pyrometer integrated in the optics to achieve the desired results.

i4.0

View through the powder clouds

SMART INDUSTRY 4.0 LASER MACHINES NEED INPUT—EVEN WHEN VISIBILITY IS POOR.

Laser machines are perfectly suited to Industry 4.0. Using optical sensors, they can ‘see’ a live view of what is happening at the focus point, gather data, provide warnings if quality is at risk and even step in to make the necessary adjustments. The situation is a bit more complicated for machines that use laser metal deposition (LMD), however. Their view of unfolding events is blocked, or at least obscured, by the impenetrable cloudy haze of powder that surrounds the process, concealing it from the view of sensors. But now all that is set to change thanks to the wonders of optical coherence tomography (OCT). Based on the principle of the Michelson interferometer, we measure micrometer-scale changes in distance to the melt pool in real time through the laser head. Inherent in this principle is the fact that light and heat emissions generated in the process do not interfere with the measurements, so we have long been able to look directly through the keyhole during penetration welding, for example, and keep track of exactly when the desired depth has been reached. Recently we also succeeded in getting real-time, precise, micrometer-scale measurements of the weld bead height in LMD, too—even through the powdery haze. We take ultra-precise measurements of the deposited material and link these to the system control unit. For the first time, this allows us to precisely control the required geometry by adjusting the process speed, paving the way for a continuous comparison with the digital shadow and the CAD data on the digital level. That gives the machine all the information it needs to know when it has completed its task perfectly. So LMD has now joined the ranks of processes that are ready for autonomous monitoring and control—in other words, for Industry 4.0. ■



Dr. Markus Kogel-Hollacher is referred to as the “sensor man” by his colleagues. Some ten years have passed since he first transferred OCT technology from the medical arena into laser material processing. Kogel-Hollacher heads up the R&D Projects department at the laser and metrology company Precitec.

private, Gernot Waller

THERMAL JOINING OF THERMOPLASTICS AND METALS

For his doctoral thesis at the Technical University of Munich (TUM), André Heckert (31) produced high-strength plastic-metal connections by thermal joining. He did this by performing pulsed laser surface pre-treatment of aluminum and then analyzing the resulting surface structure. Among other things, this enabled him to determine the suitable temperature and

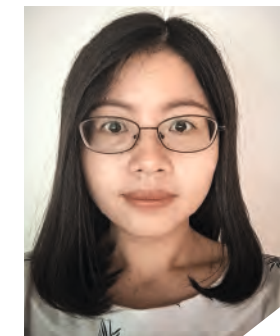


pressure for the thermal joining of plastic and metal, using an adhesive bolt as an example. Find out more:

<https://mediatum.ub.tum.de/1446387>

LASER WELDING OF METALLIC GLASS TO CRYSTALLINE METAL

Conventional manufacturing technologies often cause cracking when attempting to join metallic glass to crystalline metal. As part of her doctoral thesis at Missouri University of Science and Technology, Yingqi Li (29) joined the materials using laser-foil-printing. Her findings provide a basis for improving our understanding of the bonding of multi-material



components. This could be of interest in a variety of applications, including biomedicine, toolmaking and the aerospace industry. Find out more:

https://scholarsmine.mst.edu/doctoral_dissertations/2784

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

LATEST → RESEARCH

NEAR INFRARED LASER DEVELOPMENT AND MID INFRARED BEAM SHAPING

In his thesis at Stellenbosch University in South Africa Elijah Loyiso Maweza (48) developed a Q-switched laser in the near-IR region. This can be used in LADAR devices to quickly measure the distance to target objects. In addition, he shaped a mid-IR laser light for the first time, a technology



that allows data to be transmitted in free-space via light on a channel that is virtually unhackable. Read the full paper:

<https://scholar.sun.ac.za/handle/10019.1/105928>

COHERENT COUPLING OF AMPLIFIED LASER BEAMS FOR USP APPLICATIONS

As part of her doctoral thesis at Leibniz University Hannover, Maike Proßotowicz (27) is seeking a way to scale the average laser power and pulse energy of USP lasers. To do this, she is developing a novel combination system of microlens arrays to coherently couple multiple amplified beams. This concept



also facilitates highly dynamic control of the position of the combined beam.

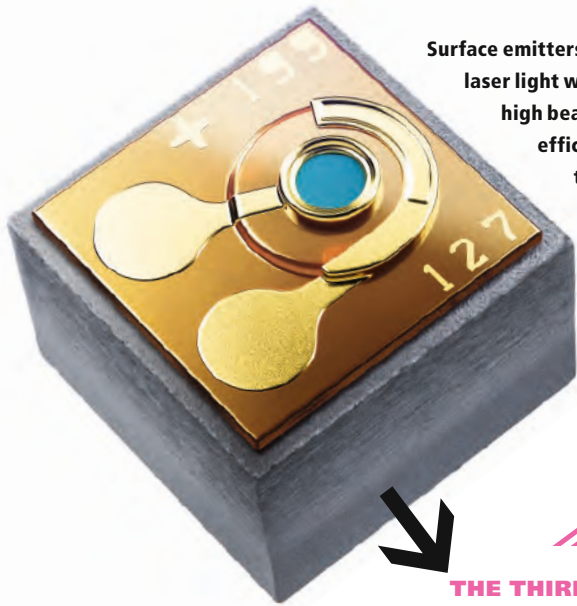
The results of her work will be published soon.

private

TINY TITANS

When discussions turn to **vertical-cavity surface-emitting lasers**, or **VCSEL** for short, many engineers beam brighter than the laser diodes that dazzle them, even if these are no larger than a grain of sand. So, what puts that sparkle in an engineer's eye?

200 μm



Surface emitters generate laser light with a very high beam quality. Their efficiency is unrivalled, and they are the next great leap forward in miniaturization.

1

The first VCSEL wave swept in on applications involving optical data transmission in data centers and consumer electronics. This wave has yet to subside with more and more applications arriving in its wake.



THE THIRD WAVE VCSELs may be the talk of the town, but the discussion is less about what they are and more about what they can do for facial recognition, mouse movements, cameras that track 3D objects and movements, data transmission, or cell phones recognizing that they're within earshot. Nearly all VCSEL applications have two things in common: one is that they allow the form, distribution, intensity and wavelength of light to be precisely controlled. The other is that their developers are unwilling to devote much space or energy to this light source. VCSELs have spilled over into the mainstream on two waves of applications that have been rolling in since the late 1980s—data transmission in data centers and sensors in the laser mouse. Now a third wave is surging in, carrying with it everything from smart gadgets and factories to self-driving cars. A new opportunity for VCSEL manufacturers has surfaced in its wake—the chance to integrate functions onto a single chip. This integrated VCSEL does more than merely emit light. It also captures, processes and relays messages sent via signals.

2



The laser mouse triggered a second wave, with the VCSEL emerging as a mass-manufactured electronic component.

STARTING FROM

TRUMPF, Gernot/Walter, AdobeStock/Gorodenkoff

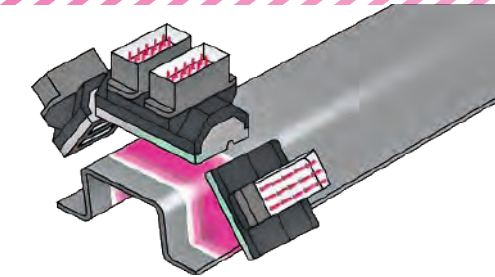
3

TIME-OF-FLIGHT CAMERAS These cameras are key components in applications as diverse as motion pictures, smart devices and autonomous vehicles.

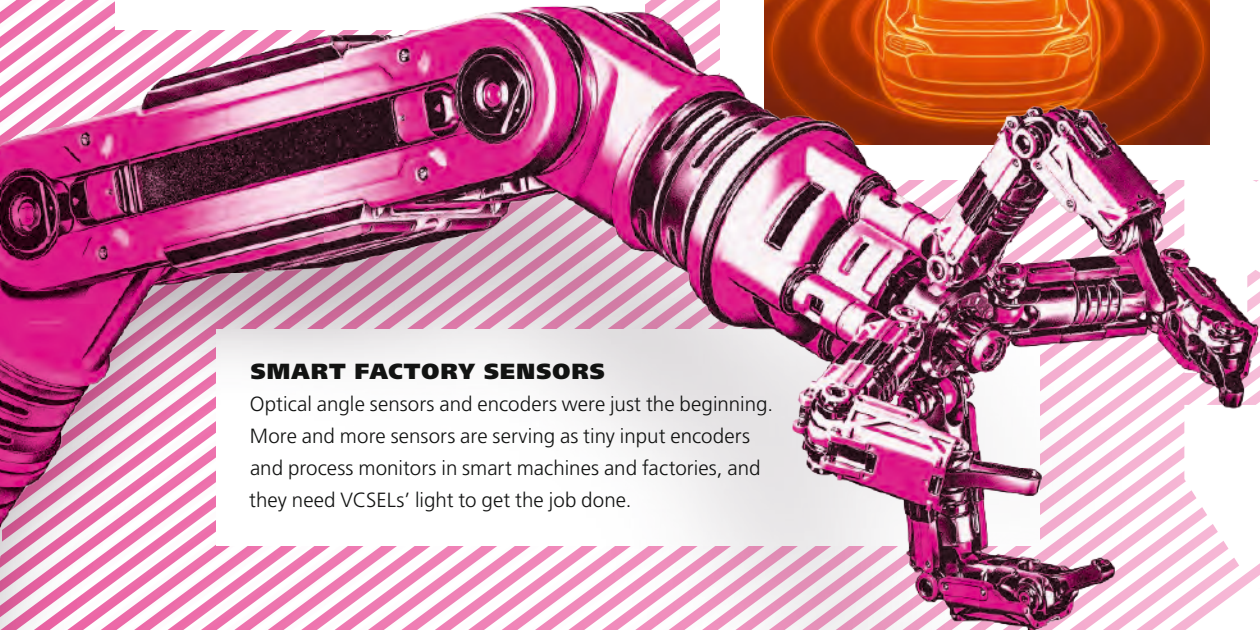
They flood an object, room or scene with infrared light, measure the round-trip travel time, and calculate 3D models based on this data. Large areas have to be illuminated uniformly and with high intensity for these cameras to work in static applications. Add motion to



the equation—for example, a moving car—and the light source has to satisfy far more challenging demands.



INTENSIVE IR SOURCES VCSELs are suitable not just for optical applications. Combined in arrays, they generate infrared laser light that heats components at specific spots. Automakers use these arrays to anneal high-strength steel components, thereby creating predetermined deformation points that afford protection in the event of a crash.



SMART FACTORY SENSORS Optical angle sensors and encoders were just the beginning. More and more sensors are serving as tiny input encoders and process monitors in smart machines and factories, and they need VCSELs' light to get the job done.

CONSUMER ELECTRONICS Energy-efficient VCSELs may be tiny, but they are already a big deal in the sensors that smart devices use to gauge their physical environment. Five examples of current and future applications:



Proximity sensors detect if a cell phone approaching an ear.

Time-of-flight cameras in virtual and augmented reality applications serve to map the environment or recognize faces.

Autofocus keeps on-board cameras sharp.

Light fidelity sensors transmit data securely via line-of-sight pulses from the transmitter to the receiver.

An added optical microphone to improve speech quality.

“

We're
hoping to
solve the
puzzle of
water

It's not easy to produce and control powerful light waves in the terahertz frequency range—but Professor Clara Saraceno has managed it. Now researchers will be able to investigate life itself.

Professor Saraceno, you've been working on terahertz waves.

Can you explain what they are?

Everyone's heard of infrared waves and microwaves. Well, sandwiched between those two in the electromagnetic spectrum there is a group of waves with frequencies somewhere between 0.1 and ten terahertz. These are what we call terahertz waves, and they have a number of interesting properties. For example, they are an excellent option for scanning living systems and obtaining imaging techniques for biochemistry. Unfortunately, researchers in the past have tended to somewhat neglect terahertz waves.

Why is that?

Terahertz waves are hard to produce and difficult to use. One problem relates to the fact that terahertz waves have rather long wavelengths. That makes it hard to focus them down into a small area, so they are more challenging to use than typical laser beams. For example, they do an amazing job of getting absorbed by water, and consequently by airborne water droplets—in other words the normal humidity in the air. So the light gets lost very quickly, disappearing almost entirely after

just a few meters of air, or a few millimeters of water. So to actually measure anything in biological conditions with terahertz waves you have to pump lots of power into them—and that brings us on nicely to the beam source.

Great, tell us more!

Here in Bochum and elsewhere, 200 scientists are working in one huge research cluster to understand the influence of solvents on biochemical processes. My group's job is to build more powerful terahertz sources which the other researchers can then use for measuring purposes. Our primary goal is to create a tool for observing the dynamics of molecules, in other words the changes from one state to another over time. Put simply, we want to make biochemical videos. The best tool for doing that is one that uses pulsed terahertz waves. Specifically, very short ones with exactly the right frequency and high-power values. To do this, we feed our system with a near-infrared femtosecond laser. We fire the pulses through a non-linear crystal that converts them into terahertz pulses. Perform a few more electro-optical tricks—technically referred to as terahertz time-domain spectroscopy—and you can use those

pulses to measure things. Our pulses are special because we have demonstrated for the first time that it is actually possible to achieve relatively high-power values of dozens of milliwatts. And we haven't finished yet—now we're aiming to get that up to the watt level.

How did you manage to push the power so high?

We were the first to use a high average power laser in time-domain spectroscopy. Nobody dared to do that before because it's so hard to control a system with so much power. We built our own laser using TRUMPF components with more than 100 watts of average power and operating with a very high repetition rate of 13 megahertz. The terahertz pulses it produces will help researchers gain fundamentally new insights.

But why use terahertz waves in the first place? What are you hoping to discover about the world?

Nobody really knows how water works—it's an old scientific puzzle that has never been solved. Water forms such an integral part of our everyday lives, and yet nobody understands it! It's really quite amazing. For example, water has a very high boiling point and various density anomalies, which is why ice floats on liquid water. We still don't understand how these macroscopic characteristics of water, which are so fundamentally important to life, tie together with

the microscopic properties on the molecular level. Water is very complex. H₂O itself is a simple molecule, but water molecules talk to each other in a tremendously complicated way. The oxygen atom of one water molecule can easily interact with a hydrogen atom of a different water molecule. And that's where it gets really interesting, because these intermolecular bonds—the movements that take place on that level—are exactly in the terahertz frequency!

And it's those movements you want to observe?

Absolutely. We want to film them and draw some conclusions on how water works. And, as well as those general findings, we're also interested in the specific role water plays in the body's cells.

What do you hope to discover by peering into the body's cells?

Water in cells acts as a solvent for proteins, and proteins need water to work properly. That's one of the reasons why we can't survive without drinking. For a long time, people thought water was just a passive, background presence in the body. But that's not true. Take protein folding in cells, for example. Today, we understand that water actively influences when and how proteins fold. In some diseases, such as Alzheimer's disease, the proteins do not fold properly. Might that have something to do with the intermolecular bonding of water in the body? That's one of the key questions we're trying to answer.

WHAT ARE TERAHERTZ WAVES?

Terahertz waves lie in the frequency range between infrared and microwaves. The boundaries are not precisely defined, but in many cases we define terahertz waves as those with frequencies between 0.1 and ten terahertz and a wavelength of between a few hundred and one thousand microns. Accordingly, the photon energy of terahertz waves stretches from just a few to several tens of milli-electronvolts.

Carsten Behler

If you succeed, what could your findings be used for?

Well, as a fundamental researcher I'm always careful about making predictions as to where research might lead. Ultimately, we don't know. But that doesn't make the question any less interesting! In the case of Alzheimer's disease, for example, I could imagine some distant future where we might be using a terahertz light source to prevent protein folding problems and stop the disease from progressing. Focusing more specifically on the field of laser technology, I want to gain a more in-depth understanding of how we use light as a tool to control phenomena in biology and chemistry. It's all pretty exciting!

Indeed it is! Of course you're not the only ones producing new kinds of images on a molecular level. Your colleagues working on x-ray research are also making huge progress with the disk laser. Are they your competitors?

“Before we came along, nobody had dared to use a disk laser in this way.”

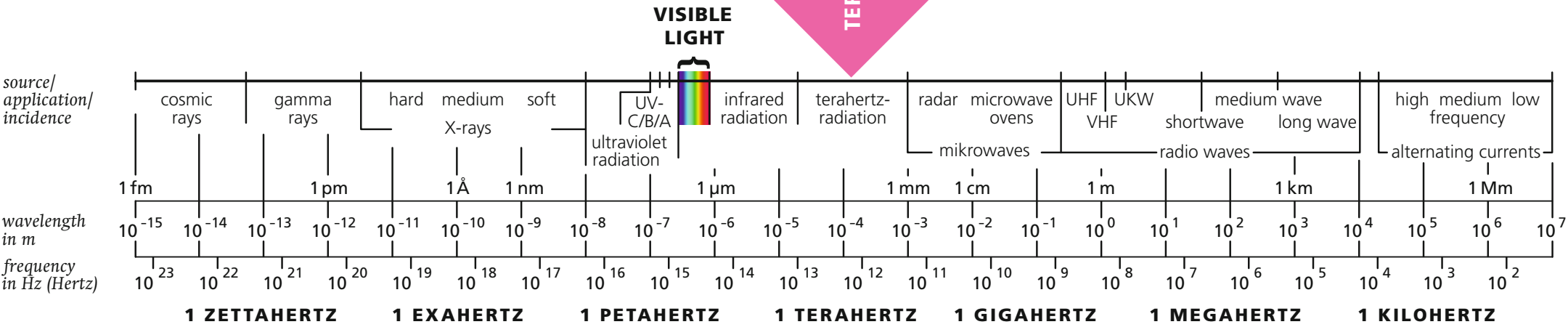
Goodness me, no! Quite the opposite. X-rays are great for observing structural changes, but terahertz waves are better for distinguishing complex coupled motions. So there's every reason to suppose we will be combining these two techniques at some point.

Every researcher experiences a magical moment at some point in their career. What was yours?

I'm hoping there's something really big still ahead of me! But I've had a couple of modest magical moments already. In my work, I focus on beam sources, which may sound a bit boring. But you can't do much without the right measuring instruments, can you? It's always an amazing feeling for me when the laser systems I build reach a level of performance that nobody has ever achieved before. I find myself standing in the lab and thinking “that really is five times more power than anyone has ever got out of this source”. And that's pretty cool! ■

CLARA SARACENO

is a Professor of Photonics and Ultrafast Laser Science at Ruhr-Universität Bochum (RUB). As part of a research cluster, she is working on ways of using terahertz light waves in research, for example in biochemistry. Saraceno's job is to develop more powerful beam sources.



Under the dome

THE LINK BETWEEN STEPHEN KING AND FUNCTIONAL SURFACES—
AND HOW THE LASER WILL HELP US EMIGRATE TO THE MOON.

The name Stephen King is not something you normally associate with lasers. It's more likely to prompt visions of clowns, zombies and psychopaths. That's the stuff this famous author's horror stories are made of—and the source of sleepless nights for so many of his readers! But take a moment to consider whether, and how, King's fictional worlds could ever become reality, and suddenly we see a link to the laser, at least insofar as it is a real tool that produces results which, at first glance, you would think were fictional. I admit that sounds confusing, so let me give you an example. (Spoiler alert!)

One peaceful October morning in Stephen King's 2009 novel *Under the Dome*, a group of aliens places a kind of glass dome over the small town of Chester's Mill, creating an impenetrable barrier that cuts off the inhabitants from the outside world. Violence gradually escalates in this confined environment, eventually leading to a devastating explosion that ends up killing almost everyone in the town. The few survivors are assisted by the military outside the dome who make a valuable discovery when blasting the dome with air from industrial fans: it turns out to be permeable to tiny, molecular-sized particles, allowing a slight flow of air to make its way through the barrier.

Using laser technology, it is actually possible to machine glass in such a way that it takes on similar properties to that of King's glass dome. This is referred to by experts as perforation, because the glass is perforated with numerous tiny holes, a bit like a coffee filter.

Recently, I read in the paper that the most important building material of our time—one we use to make buildings, streets, glass and even toothpaste—is running out. Yes, time is running out for sand! Perhaps surprisingly, one alternative could be moon dust. NASA scientists have discovered that concrete made from lunar dust would actually be cheaper and more durable than conventional concrete. So it's time to head to the Moon, which is probably best since we are running short of space on Earth anyhow.

FICTION? In 2021, researchers at Laser Zentrum Hannover (LZH) are aiming to launch the Moonrise project, which will send a lunar rover to Earth's closest celestial neighbor. Its mission will be to form building materials from moon dust in order to lay the foundations for a moon village—a kind of human outpost in space. The lunar rover is equipped with a real tool that produces results which, at first glance, you would think were fictional. ■



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

➔ What architectural dream would you love to see materialize?
Let me know by email: athanassios.kaliudis@trumpf.com

WHERE'S THE LASER?



In the train restroom:

Most people only use them when there's no other choice. But touching the toilet handles or handholds—those notorious hotbeds of germs and bacteria—strikes fear into

even the bravest soul! Not so

for the company Universal Engineers from Chennai, India, which takes a somewhat more tolerant view of the matter. Maybe because they owe their early success to laser-cut toilet handholds for train restrooms.

Nowadays they also make doors, train car exteriors and window frames. Their

team of seven gradually grew to a workforce

of 750. So the next time you use your elbow rather than your hand in the train

restroom, remember to handle the

handle with care! ■



Since July 21, 1969,
a small grey box has been
sitting in the lunar dust at
these Moon coordinates,
looking up at the blue planet
above it. Every now and
then, it reflects an incoming
flash of light that hits its
triple prisms. It's called a
retroreflector, and anyone
interested can aim a laser at
it from Earth and
demonstrate two things by
measuring the time it takes
for the light to travel to the
Moon and back: firstly, that
the Moon is receding from
Earth at a rate of 3.8
centimeters a year and,
secondly, that Neil
Armstrong und Edwin
"Buzz" Aldrin really did
land on the Moon.

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