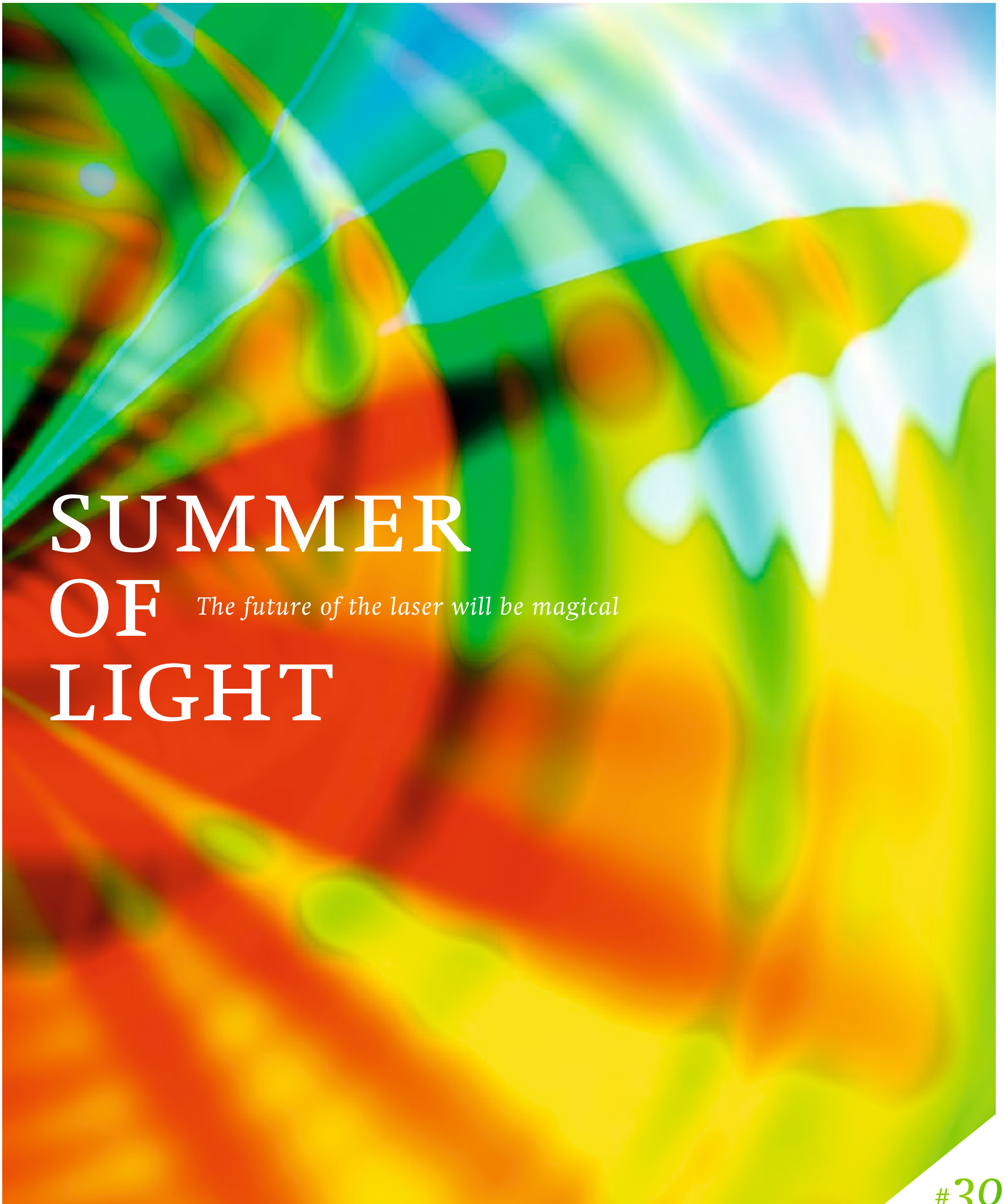
LASER COMMUNITY.

Of people and photons



SUMMER OF LIGHT

The future of the laser will be magical

#30

#30

MAY 2020

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Not old hat at all!

The laser turns 60 this year—and round-number anniversaries are always a good excuse for a retrospective. In 1985, while working as a young mechanical engineer at the German Aerospace Center (DLR), I came face-to-face with a real laser for the very first time. I don't want to sound corny, but seeing a laser start oscillating for the first time is a fascinating, even emotional, experience. The beam leaps into life, yet is so completely different from normal light. That effortless transfer of energy from the beam source to the workpiece—at the speed of light!—captivated me right from the start, and the thrill has never gone.

A few years after that first encounter, I got chatting to a doctoral student in chemistry during a train journey. He was amazed when I told him I was working on the development of the CO_2 laser. "The CO_2 laser?", he said. "That's old hat!" It reminded me how long the journey is from scientific lasers to industrial lasers. By the late 1980s, it really was common knowledge that the laser worked in both theory and practice. But most people had no idea how many years of development it took to get a laser out of the lab and working reliably around the clock in an industrial setting.

Laser technology flourished in the years that followed. But this isn't the place to go through all the milestones in laser development, because I prefer to look ahead. You can see from this issue of Laser Community that light still has plenty of new potential as a tool. That's especially true for one of my favorite technologies, ultrashort pulsed lasers. These lasers, which work with pulses of such incredibly short durations, will open the door to previously unimaginable new applications in biology and chemistry. Above all, however, I'm confident that we will also find new ways of using ultrashort pulsed lasers in traditional material processing. The laser technology start-up GLOphotonics has already laid some important foundations with its hollow-core fiber. I highly recommend reading our interview with the company's founder and CTO Fetah Benabid, starting on page 8.

This is such an exciting time for laser fans like me. Sensors are getting smarter and delivering more and more data—and artificial intelligence is helping us use that data to develop ever more advanced laser processing strategies. Equally exciting is the use of lasers for secondary beam sources, in other words creating a beam indirectly by converting laser light into a different type of radiation. EUV technology is probably the best-known example of this right now. Starting on page 12, we take a look at the future of laser technology. Without wishing to give too much away—and, again, I don't want to be corny—I'm confident it will be magical!

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Gernot Walter

LASER

Snapshots

This photo shows two men united by an extraordinary success story. If pioneers like Michael Bass (right) hadn't started experimenting with laser light in 1960, our photographer Marc Schmidt wouldn't have been able to use a smartphone to make a visual record of their stroll through Vero Beach in 2020. Join them for a wonderful walk on **page 20.**

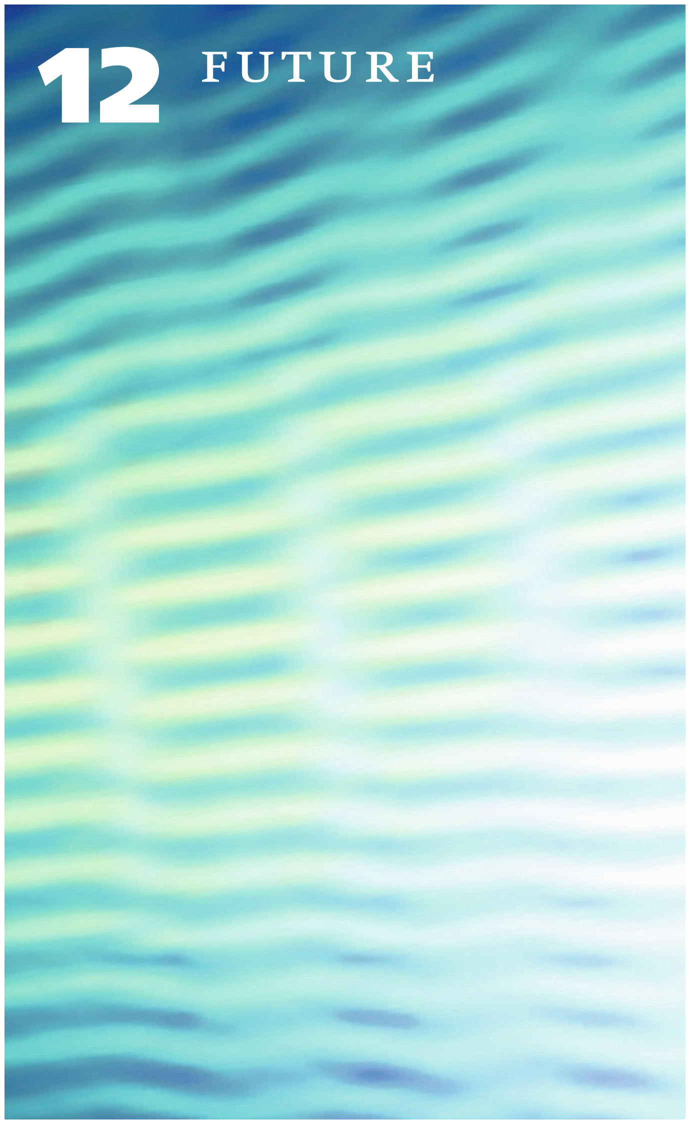
X-rays

Researchers from all over the world flock to the tunnels beneath Hamburg. One of these tunnels features the world's most hardcore laser show. We got the chance to check it out and take a fantastic photo. It shows diagnostic equipment used by researchers at the European X-Ray Free-Electron Laser Facility (XFEL) to check their X-ray pulses. **See back cover.**

Sounding off

Our motorcycle on **page 28** goes "vrrrooom". That prompted some disagreement from engineers at motorcycle manufacturer KTM, who argue that their motocross bikes make more of a "brrraaap" sound. We stuck to the standard sound for the sake of simplicity, but we admit they may well be right!

Marc Schmidt, Jan Hosan, KTM



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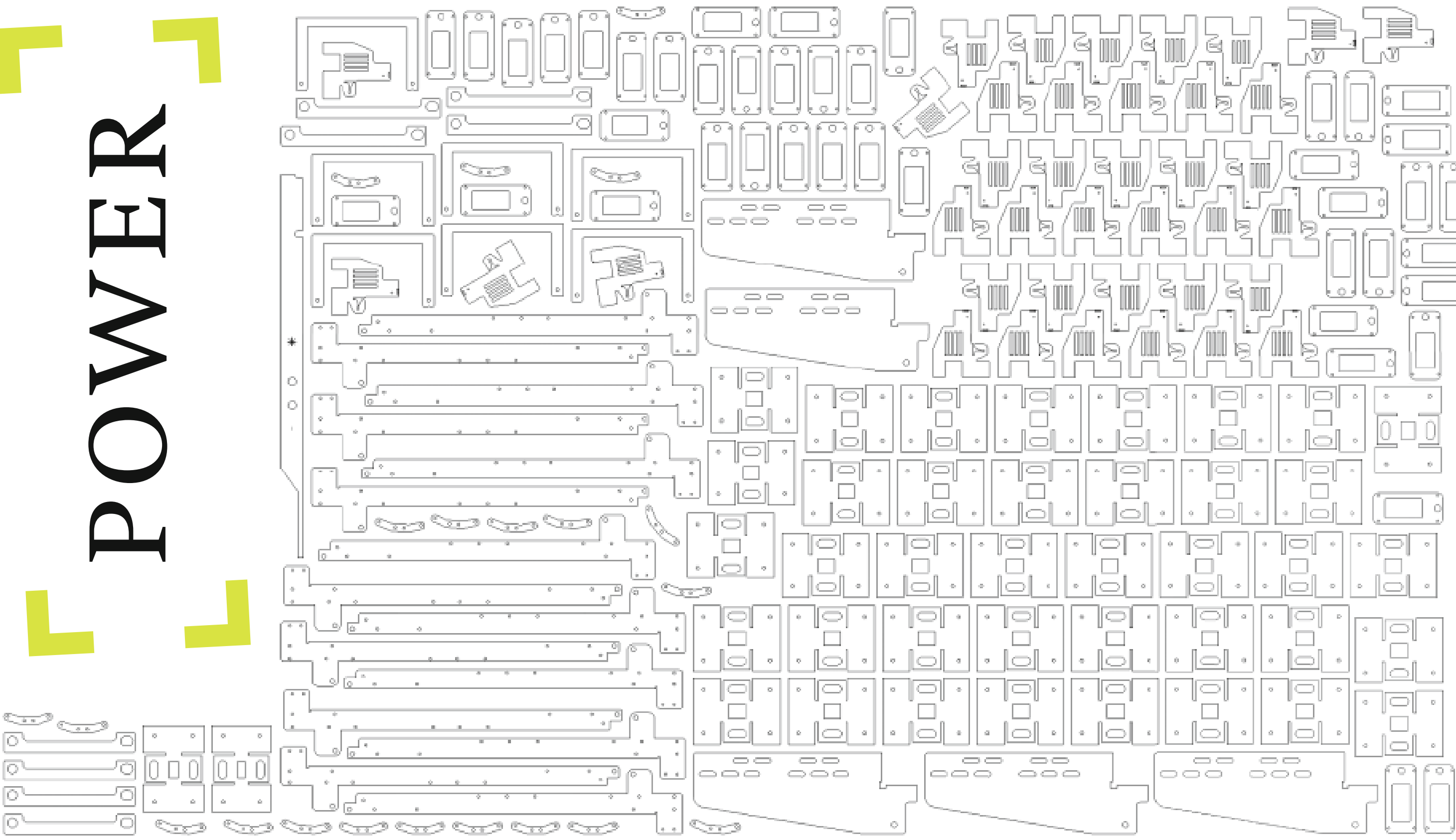


Nesting for laser cutting will be left to quantum computers in the future—and they'll do a better, faster job!

QUANTUM PUZZLE SOLVING

Google's impression of a quantum processor in a cooling chamber.

What tasks might we entrust to quantum computers? Nesting sheet metal parts for laser cutting could be one example.

A quantum computer is the ultimate dream of hackers and spies everywhere. Nothing could beat its ability to trawl through countless permutations in next to no time, so it would be the perfect tool for cracking codes, passwords and the like. But could quantum computers also be put to more productive use? How could their skills at puzzling out the options be harnessed in industrial manufacturing, for example?

That's the question TRUMPF is currently tackling as a partner in the PlanQK research project. One area it has already identified for quantum computers' puzzle-solving skills is nesting—in other words, laser-cutting the greatest possible number of parts out of a single sheet of metal by optimizing how they are arranged on the sheet. Machine operators currently carry out nesting manually or using software. With today's computing power, the software does a good job of laying out differently shaped parts, but it struggles to cope with many other key factors, such as arranging the parts so that they don't tilt during cutting.

And even the very latest supercomputers raise the white flag when confronted with tricky questions such as "When's the best time to manufacture the parts?", "How urgent is the job?" and "Which machines are free right now?" Experts hope breakthroughs in quantum computing could help solve these computational challenges.

Even though it is likely to be at least ten years before this becomes a reality, TRUMPF engineers are already gathering data and determining which factors make for the perfect nesting strategy. That way, they can hit the ground running once quantum technology is ready. A few floors down, their colleagues are working on the very latest advances in laser technology—something that may actually hold the key to making quantum computing possible in the first place. That's because even quantum computers can't operate without the help of high-tech lasers.

TRUMPF, Forest Stearns / Google AI Quantum Atrist in Residence

GLORY

Gernot Walter

*** Scientists started out by measuring laser power in Gillettes—in other words, how many razor blades the laser could burn through! In 1970, laser co-inventor Arthur Schawlow fired nitrogen lasers at various flavors of Jello. His aim was to pump the gelatin dessert and make it lase, but it didn't work until he spiked it with a special dye. This experiment was the first step toward distributed feedback lasers and, ultimately, semiconductor lasers.**

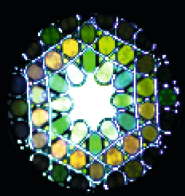
“We’re

Laser light tamer and GLOphotonics founder Fetah Benabid.

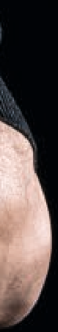
Thierry Laporte / Fotogloria

stretching the boundaries of physics”

For the first time, hollow-core fibers from GLOphotonics are delivering ultrashort laser pulses and high-power laser light. But they can do much more than that.



Cross-section of hollow-core fibers: they conduct light by means of an interference mechanism.



Mr. Benabid, delivering laser energy through an optical fiber is nothing new—so what makes your optical fiber so special?
We have taken hollow-core fiber technology to such an advanced level that we can now use it to deliver ultrashort laser pulses. It was previously thought that the laws of physics would make this impossible, so we are actually stretching the boundaries of physics! Our optical fibers are also robust enough to carry extremely high-power laser light without being destroyed in the process. That’s something else people thought was impossible.

So what are the benefits?
The obvious ones: we finally have a simple way of delivering ultrashort pulses and high-power laser light over long distances, just like we have long been able to do with light from continuous-wave and long-pulse solid-state laser sources. That means machine makers can come up with simpler and more flexible designs for laser systems. It’s no longer necessary for the beam source to be close to the workpiece and the light no longer has to be guided around corners using mirrors in a complex, free-beam-based optical set-up. The advantage for users is that they can now put the laser wherever they have space. So they could even choose to have it in a separate room for safety.

How do your hollow-core fibers work?
Conventional optical fibers propagate laser light along a fiber through the well-known mechanism of total internal reflection. Hollow-core fibers work with different mechanisms that are based on the principles of quantum mechanics. In a hollow-core fiber, the cladding is microstructured to form what is known as a two-dimensional photonic crystal. The cladding is designed to ensure that light in the fiber core cannot “escape” through the cladding. We currently have two ways of propagating light in hollow-core fibers. The first is based on the concept of a photonic bandgap, while the second makes use of inhibited coupling guidance. As a leading exponent of this latter technology, GLOphotonics offers hollow-core fibers that combine the best of many worlds. One of the biggest benefits is that—unlike other optical fibers—GLO fibers can convey high-power laser beams and ultrashort pulses without compromising their spatial and temporal integrity.

What are you working on right now?
We’re currently working on a large family of beam delivery systems that conduct laser light over 20 meters with a power loss of just ten percent. We hope to improve that still further by delivering light over even longer distances and continuing to drive down the power loss—and we’re already making good progress. We’re also working on concepts that open the door to laser networks with ultrashort pulses. That would make it possible to supply several machines at the same time with a single laser. And this new microstructure offers plenty more exciting potential!

What else can it do?
It can actually modify the laser light within the fiber if you want it to. For example, we can compress ultrashort pulses even more in the fiber by adding a suitable gas, and we can also generate laser light in the ultraviolet spectrum. Multicolored laser light is also possible. ■

GLOPHOTONICS **French photonics start-up GLOphotonics develops and produces special optical fibers as part of its mission to deliver laser energy to the workpiece in a simpler, more reliable way—without loss of power. TRUMPF acquired a stake in the Limoges-based company in 2019.**

Glophotonic

LONGER AND STRONGER

Whether joining glass to glass, glass to metal, or glass to plastic, gluing is seen as the only efficient way of combining transparent materials. But that's all changing thanks to a new, industry-ready laser process.

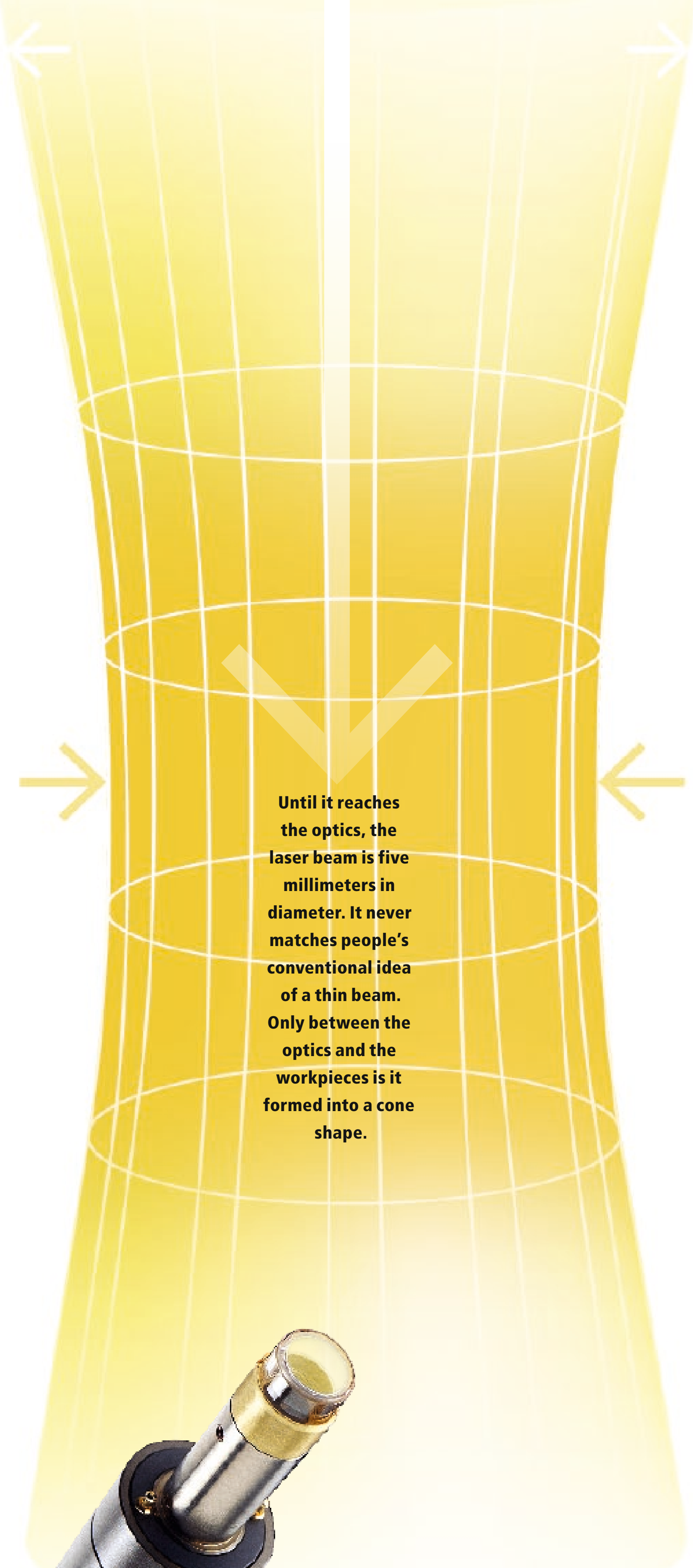
Welding glass with a laser—without extra materials or additional process steps—was previously only feasible in a lab setting. The laser offers a fast and reliable means of joining transparent materials. It briefly melts the material in the laser interaction zone, allowing a firm bond to be formed when the material re-solidifies. This is made possible by ultrashort pulse lasers. Focusing techniques generate extremely high intensities, causing some of the pulse energy to be absorbed by the material. This is key, because glass would otherwise be transparent to this wavelength of light. This method allows us to melt a small zone anywhere within the glass volume. Until now, however, there has been one major problem. The only way to weld glass with a laser was by painstakingly preparing the parts beforehand using techniques such as optical contact bonding. And the laser could easily be thrown off track by parts with different surface properties, for example. And it reached the limit of its capabilities with gaps of just four micrometers. So what worked well under lab conditions was simply not feasible for industrial manufacturing—at least until now. Fabricators had no choice but to rely on adhesives or other more complex processes. So we set out to give them another option.

At the TRUMPF Laser Application Center in Ditzingen, our advanced engineering team took a closer look at the process. They quickly realized that they would need to change the shape of the laser beam. Scientists previously used the Gaussian beam profile to weld transparent materials. This produces a localized focal spot in the glass, which means the laser power is concentrated on one particular area within the material. Keeping the focal point small is critical, because high temperatures and pressures occur around the spot. Enlarging the modification quickly leads to crack formation and a drastic reduction in the strength of the weld seam.

RESHAPING LASER LIGHT To give the beam a new shape, we first had to develop optics that could modify its profile. That's what led us to develop the TOP Weld optics. They enable us to stretch the laser beam lengthwise while maintaining the focal width. The result is a much larger and more uniform melt zone over which the laser energy is distributed homogenously. Compared to the Gaussian beam shape, this allows us to bridge bigger gaps. The seams created in this way are very strong across the entire modification length. Depending on the type of load applied, they can reach the strength of the welded material itself. This was a decisive step forward on the road to a stable process.

The new beam shape also offers advantages in terms of focal point tolerance. In other words, the larger spot size means the laser can cope better with part tolerances and shifts in seam position. This is a key benefit, especially for complex welding geometries. The laser simply scans across the part and produces a stable weld seam. With the Gaussian beam shape, however, the process quickly aborts when attempting to do the same thing.

FELIX ZIMMERMANN
conducts research into promising new laser processes with his colleagues on the advanced engineering team at TRUMPF's Laser Application Center.



Until it reaches the optics, the laser beam is five millimeters in diameter. It never matches people's conventional idea of a thin beam. Only between the optics and the workpieces is it formed into a cone shape.

BRIDGING GAPS WITH PULSES We also looked at what modifications could be made to the laser itself to help us reliably bridge larger gaps. Useful leverage was provided by a feature of the TruMicro 2030 that allows us to time-modulate the laser energy. Instead of constantly welding with the same laser power, the laser increases and decreases the laser pulse energy in a sine wave pattern. The frequency of the modulation, which is tailored to each specific process, is typically 500 hertz. The important thing is to keep the average laser power constant or not increased compared to the unmodulated case, whereas the pulse energy must be significantly higher at the maximum. This can lead to further improvements in the seam and thus in the focal point tolerance and the gap sizes that can potentially be welded.

Direct comparison with the standard process without energy modulation shows that modulated pulse energy allows us to bridge gaps of up to 8 micrometers when using the same average laser power of just 1.8 watts. Without modulation, only 4 micrometers are possible. The short, defined pause between two pulses also has the effect of significantly reducing stresses in the material. The process can therefore handle significant variations in the thermal expansion of the parts being joined. This is a huge advantage over existing methods. It paves the way for joining a wide variety of material combinations, including glass of the same or different types, glass to silicon, glass to metal and glass to plastic. The joins are extremely strong and impermeable to gas and liquids. In industrial settings, such joins are currently made using adhesives or highly complex laser methods. The new beam shape and the ability to bridge bigger gaps now makes the laser the number one choice. This offers a number of additional benefits. For example, users no longer have to worry about the curing of the adhesive or impermeability of the parts. By not using adhesives, they can also make do with smaller flanges. A fraction of a millimeter is all it takes to produce solid laser weld seams. That means the parts themselves can be smaller, which allows for greater design freedom.

MOVING INTO PRODUCTION There are already some cases on TRUMPF's own production line where the laser has replaced adhesives. For example, we now weld the protective caps on the fiber-optic cables for our solid-state lasers instead of gluing them. The welding of transparent materials offers exciting potential, particularly for customers in the medical device, consumer electronics and microelectronics sectors. This new process brings us one step closer to incorporating this technique in industrial manufacturing. ■

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The protective glass cap on this fiber-optic cable was laser welded.

TRUMPF

SOUND OF THE FUTU

FUTURE REMASTE

Even after 60 years, the laser is still hitting the right note. New ways of as a tool are music to our ears. Read on to check out our recommended

Have you heard the sounds of laser technology? Listen to our special playlist to celebrate the 60th anniversary of the laser at: https://sptfy.com/summeroflight

TRACKS

RED

using light playlist!

The laser is the smartphone of industrial tools. It seems only recently that these two pioneering technologies were proudly displaying their abilities to a chorus of astonishment from an admiring public. Smartphones and lasers are still miracles of engineering even today, but people are no longer amazed by what they can do. As an integral part of daily life, they have become too normal and widespread to impress us. But unlike smartphones, laser material processing is currently on the verge of a grandiose new beginning. Researchers and developers are breaking boundaries on several fronts at the same time—and the view of what lies beyond is truly spectacular. It includes beams converted into thousands of focal points, machines that have something approximating senses and "self-awareness", new kinds of controllable beams, and insights into previously hidden depths. Things that seemed pure fantasy just a short time ago will soon be filling manufacturing shop floors.

Laser users in industry are learning to look outside the box. Ten or twenty years ago, all it took to gain a competitive edge was to have a laser on site, but today almost anyone can put together a decent marking laser from an online store with minimal investment. In future, new gains in productivity will only be possible if we start viewing laser machining as part of a bigger process. Experts around the world are busy puzzling over a series of key questions: How does the beam get to the workpiece? What exactly does it do when it gets there? Where does potential still lie to optimize workpiece processing? And what's the best way to integrate lasers and laser machines into my overall production process?

Some of the answers are even more extraordinary than the questions! So if you are keen to get a better grasp of the future of laser technology and put lasers to even better use in the years ahead, we recommend keeping an eye on the promising topics presented on the next few pages.

When laser experts finally succeeded in using ultrashort laser pulses to drill tiny, closely spaced holes in rapid succession a few years ago, it was an incredible feeling. So what's next? Drilling thousands of holes simultaneously of course! But this huge leap in productivity will require a fundamental shift in perception. We used to talk about a laser beam hitting a material at the focal point, but experts now prefer the more precise definition of a laser wave being generated within the material and a focus that is a spatial distribution of intensities. This new way of thinking is called wave optics. The predominant model of ray optics describes light as a ray and the focus as a point where converging rays unite. Wave optics is far more complex, describing laser light as a wave and the focus as an intensity distribution. This is not merely a theoretical exercise. It is driven by what certain materials and specific applications actually need from laser light. Glass can be intrinsically modified and divided by the laser (this no longer has anything to do with cutting). In laser lift off—for example debonding an OLED layer from a carrier—the energy takes effect beneath the material and separates it from the substrate. In ablation processes, the focal point is simply transformed into a complete bar of light—a snow shovel instead of tweezers. It's even possible to divide a laser beam into a thousand parts. Each individual part then has the same intensity distribution as the other 999 parts. The result? Processes that are a thousand times faster. The task in the future will be to form, bend, squash and stretch this coherent bundle of waves, to chop it into pieces and deliver it to the precise place where we want it to act everywhere simultaneously. That requires very different things from process development—and from optics. Put simply (and please don't take this personally!), focusing is a beginner's game, because over the next ten years the real interest will lie in diffraction. Constructing models for this is a highly complex task requiring Herculean mathematical efforts. But once the systems are running, laser operators will enjoy incredible gains in productivity and hitherto undreamt-of applications. Applied wave optics will enable us to form and control mysterious laser waves in a way we would never have imagined possible. And as soon as ultrafast quantum computers are available, nothing will stand in the way of the next revolution. Laser light will become calculable—and thus manipulable—on the quantum electrodynamic level. And that will open the door to a new world. →

Foo Fighters

The Colour and the Shape

The first five-axis machine was the pinnacle of precision engineering: it held the part under the optics in exactly the right position and at exactly the right angle, with micrometer accuracy—only for the optics to fire blindly into the chamber! But soon that random element will be a thing of the past. In future, when we put part X in the machine, sensors in the optics will immediately identify the type of part, material, position and welding points, and the laser will make the welds in exactly the right places and to exactly the right depth. The whole crazy complexity of high-precision clamping will suddenly become much simpler once machines can align themselves automatically—and machine design will be turned on its head.

Recent years have seen a huge increase in the number of sensors installed in all laser systems. This comes as little surprise, since sensors are the logical answer to a number of questions that industry is currently asking itself: How can we deal with ever stricter standards of quality and precision? How can we verify the results? What's the best way to capture data for simulations, artificial intelligence and documentation? How can we increase the level of automation in order to boost productivity? The answer to all these questions is to give machines the ability to sense their environment, to perceive and interpret the world around them. For example, sensors designed to monitor penetration depth or markings can help us ensure detailed documentation and rapid intervention when things go wrong. The next level up are sensors that can be used to control things. For example, if a machine exceeds the target heat level, they automatically reduce the laser power; and once the laser head reaches the desired joining path, they bring it to a halt. More and more new types of sensor are entering industrial environments and finding their way into laser optics, from where they have an excellent, direct "view" of the unfolding process.

This has far-reaching consequences. The sensors deliver a continuous flow of data, which is perfect for data-hungry artificial intelligence and simulation systems. This paves the way for designing and realizing entirely new applications that would be impossible without machine perception, such as automatically ablating surfaces without requiring programming by using a camera that can identify exactly what has to be removed where. Talking of programming, as databases of parameters continue to grow in size, many programming tasks will become superfluous. When we feed a part into a laser machine in the future, it will automatically detect what needs to be done and get straight down to work. We're probably already close to achieving this in laser marking—and all the other laser applications will follow suit in the years ahead. →

Buzzcocks
Do It

Blind as a fool who won't see
Suddenly taking control again

[3/6]

DIGITALIZATION AND ARTIFICIAL INTELLIGENCE

WE ARE ANYTHING YOU WANT
WE ARE TUNED JUST TO DO IT, OH YEAH
IT'S NOTHING BUT MECHANICS
WE'LL PLAY IT AUTOMATICALLY

Polysics
Domo Arigato Mr Roboto

When the first programmable robots created a bridge between machine A and machine B, we were amazed. But essentially each machine was still acting on its own. Today, we have software that connects machines in an interactive and interlinked production process. Physically unconstrained and formed by parameters alone, the laser beam has emerged as the perfect tool for connectivity. Yet we are still a long way from completing the transition from a shop floor to a smart factory. Perhaps the best illustration of this fact is an aspect of digitalization that is often dismissed by trend enthusiasts as too boring, even though it has an enormous impact on real-life applications, namely remote maintenance and remote condition monitoring. The big question is one of availability and uptime. Obviously every user wants their laser system to run reliably all the time. But things have moved up a gear since the semiconductor industry and consumer electronics threw their weight behind lasers. These two industries take system availability requirements to an almost absurd level, so their expectations are currently driving the whole laser technology sector forward. That's good news for all industries. Even long-suffering and ever-tolerant laser users from the research community are starting to call for broad guarantees of availability, and the promise of near-100 percent availability is now within reach.

Meanwhile, artificial intelligence (AI) is making its way onto the factory floor. AI's strengths used to lie more in non-physical processes such as production planning, but it is steadily getting closer to the machines themselves. Over the next few years, these electronic brains—fed with data from sensors and simulations—will come up with completely new kinds of laser processing strategies, refining each step in the process as they learn more and eventually taking over the programming of connected machines themselves. This will lead to huge gains in productivity. →

LASERS FOR SECONDARY BEAM SOURCES

Produced in particle accelerator tunnels that are several kilometers long, hard X-rays provide insights into nature that previously seemed out of our reach. So what's next? These kinds of particle accelerators will soon be available to labs and hospitals in a format the size of a small car, in part thanks to the use of stable disk lasers. Scientists can use reliable high-power lasers to create beams indirectly by converging laser light into other radiation. This approach makes it possible to generate and use various different forms of radiation, including plasma radiation, terahertz waves, electron and neutron radiation, extreme ultraviolet light (EUV), and so on. This is paving the way for new applications that extend well beyond the realm of research. One example is non-destructive material testing: in future, laser-driven X-ray or neutron beam sources will routinely inspect all safety-relevant parts such as turbine blades to detect even the tiniest defects. This concept can even be applied to entire structures: experts currently determine the condition of a bridge by closing it and drilling holes in several places to take a look at the steel girders inside but, in the future, mobile, laser-driven particle emitters will be used to X-ray the entire bridge. In a matter of hours, they will reveal whether the bridge needs repairing or not—and the bridge can remain open the whole time. These new kinds of beam sources will also increase safety in other areas. Port authorities will be able to inspect cargo containers at high resolution without opening them. Doctors will enjoy ultrafast disinfection, using hard UV light to disinfect operating tables and medical instruments. The number of possible uses is only limited by our imagination. Concepts are already emerging that, at first, seem nothing short of incredible, such as using a laser-generated stream of particles to bombard reactor waste and accelerate its rate of decay from 10,000 years to just a few weeks. That would solve the whole problem of nuclear waste. High-power lasers are also keeping our dreams of nuclear fusion alive: laser-induced X-ray blackbody radiation could finally compress hydrogen and helium or deuterium and tritium to produce a clean and inexhaustible source of energy. →

You electrify my life
let's conspire to ignite

Muse
Starlight

[5/6]

UNDERSTANDING PROCESSES THROUGH SIMULATION

It's NOT easy with this complexity

Eagles of Death Metal
Complexity

Theory isn't grey—it's expensive. In industry, it's always been cheaper to see what happens when you turn this knob a bit to the right, and that one a bit to the left. As a result, good process strategies in fields such as laser welding have tended to be an odd combination of luck and hard work. Anything was simpler than attempting to actually understand what was happening inside the material. But now things are changing—and for three key reasons. Today, computing power is cheap, sensors and connectivity are supplying masses of ostensibly useful data, and the demand for improvements in processing speed and precision is so high that it is actually worth putting some real thought into theory, modelling and simulation. One recent example of how fruitful this can be was the simulation of keyholes in lap and corner joint welding at General Motors. The physical forces that affect the keyhole are extremely complex and highly variable, depending on selected parameters such as laser power, welding speed and travel distance.

Once you have reached a certain level of manufacturing, it's no longer good enough to just keep trying out new things randomly. But by applying a sophisticated model and plenty of computing power, General Motors obtained such accurate and reproducible projections that they were able to develop a completely new welding process strategy that runs faster and cleaner than ever before. This is set to become the new industry standard over the years ahead: increasingly complex models and AI-based simulations will increase our understanding of processes and enable entirely new processing strategies. →

[6/6]

NEW BEAM SOURCES

DSince the 1970s, it's been common knowledge that beam source concepts are essentially based around CO_2, solid-state, diode and fiber. But there's still plenty of room for improvement. Engineers are constantly finding new ways of getting more out of their laser systems, from higher pulse energies and higher average power to shorter pulses and better beam quality. This looks set to continue in the years ahead. But apart from the race to set new records in this or that aspect of industrial lasers, what are the key developments that users should be keeping an eye on?

Firstly, the increase in the range of wavelengths. In theory, we already have access to laser light at all possible wavelengths, it's simply a question of finding the necessary power. This obstacle is gradually being overcome in all wavebands: the reliability of the disk laser has given us the tools we need to generate high-power laser light in all possible colors ready for industrial use. One of the most recent examples is green laser light, which is readily absorbed by nonferrous metals, making it the perfect choice for applications in e-mobility. Soon it will be possible to generate powerful beam sources at exactly the right wavelength for all conceivable applications.

Secondly, things are getting smaller. Semiconductor lasers, direct diode lasers and other lasers are steadily shrinking into miniature formats. This makes them easier to use in all kinds of systems, from cell phones to operating rooms. It also paves the way for entirely new applications such as laser-based scanning of the environment in autonomous vehicles and quality control.

The first developers are already working on ways to pack the laser medium into an optical fiber, allowing laser light to be generated "on the go". Although such beam sources are not fundamentally new, they illustrate how old concepts are revealing a level of flexibility that most people would have thought impossible. ■

The Smiths
There's a Light That Never Goes Out

Well,
the pleasure—the privilege is mine
Oh, there is a
light
and it NEVER
goes out

"*Innovation is what happens while you are* working on

One of the founding figures of laser technology, Michael Bass began working with lasers in 1961.

Marc Schmidt / Fotogloria

One of the pioneers of laser technology, Professor Michael Bass has been responsible for numerous innovations in this field since 1961. We talked to him about unfinished research, the remarkable potential of diode lasers—and Bass's future as a TV reporter.

something else"

Professor Bass, your achievements in the realm of research and development are both numerous and legendary. Has there ever been a nut you simply couldn't crack?
Actually it was a diamond rather than a nut! Obviously I've come up against all sorts of perplexing problems in my career, but the whole business with the diamonds still irks me even now.

What exactly happened?
Some eight years ago a colleague and I were commissioned by a diamond producer to investigate the optical properties of synthetic diamonds, specifically CVD diamonds. We got some excellent results for the absorption of laser light from the near ultraviolet to the 10 micrometer wavelength region. But when we started using shorter wavelengths we were surprised to see a violet-hued luminescence that varied in intensity and color depending on where we started on the diamond's growth axis. That didn't bother our client because he was satisfied with the results we had achieved already and didn't want us to probe any further. My supposition is that this variable luminescence has something to do with the diamond's growth process. It still irritates me that we had to leave that research unfinished!

Well, I guess it was a minor issue...
Unfortunately not! You shouldn't underestimate the importance of diamonds in laser technology. In the future, diamonds will play a major role in the methods we use to convey high-power laser light without it causing damage along the way. The thing that makes them so interesting is their high thermal conductivity. This means that optical elements made of diamond, such as mirrors, lenses or coatings, can dissipate the heat of a high-power beam while maintaining its power. Obviously we already use high-power lasers without diamonds, but only by splitting the power and using large optics to cope with the high heat input. Diamonds could enable us to build smaller systems that would probably also be more robust. So why not use them?

Perhaps because they're so expensive?
Sure, but that high price is artificial. It all comes back to the jewelry industry and the monopolies established by dealers who can fix the price at whatever level they choose. But, from a technical point of view, it would be easy enough to turn synthetic diamonds into a cheap, mass-produced product. Diamonds have so much potential as an optical material for laser systems. So I hope someone else completes my research soon!

"If I was 30 again, I would opt to work on ultrashort pulsed lasers."

If you were suddenly 30 again, what would you choose to work on?
Ultrashort laser pulses, without any doubt at all. There are three reasons I find that area of work so exciting. Firstly, the physics behind it is simply fascinating, studying how light interacts with materials on such a tiny time scale. Secondly, there are so many potential applications in biology, chemistry, physics and many other fields. And, on top of all that, there are numerous applications in material processing. If I was 30 again, I would opt to work on developing simpler optical systems and more robust configurations for ultrashort pulsed lasers and achieving higher average powers on a reliable basis. If we could make this amazing technology even better and simpler, I think industry would use it even more.

What other developments should we be striving for in laser technology?
Back in the 1960s, who would have thought that the most popular laser would turn out to be a semiconductor diode laser? Yet now they are everywhere, from laser printers to data acquisition devices and data transmission systems. And they still have so much more to offer. In material processing, diode lasers are primarily used to pump solid-state lasers. I think we can turn them into even better pump lasers by tweaking them to improve their beam quality and increasing their range of wavelengths. But why limit them to the role of pump lasers? I think we can further improve diode lasers in the future and then use them more often as a direct beam source for lots of other material processing applications. Maybe even for ultrashort pulses. I'm sure it will take researchers a long time to get there, but I don't see any reason not to try.

Are you still actively engaged in research work?
Luckily for me, the internet keeps me in the loop. I'm currently collaborating with a former student who is now a full professor. We're working on a special case in which ultrashort pulses cause damage to optical materials. We can swap views on the subject without actually having to be in the same room. I also regularly get requests from students or post-docs to check something they've written, which I'm always happy to do. And I try to keep up with the latest developments by reading scientific articles. As I said, it's marvelous that the Internet makes everything so easy, especially when I think how I used to spend time rummaging through card files in libraries hoping to find the information I needed! But my latest project is something quite different.

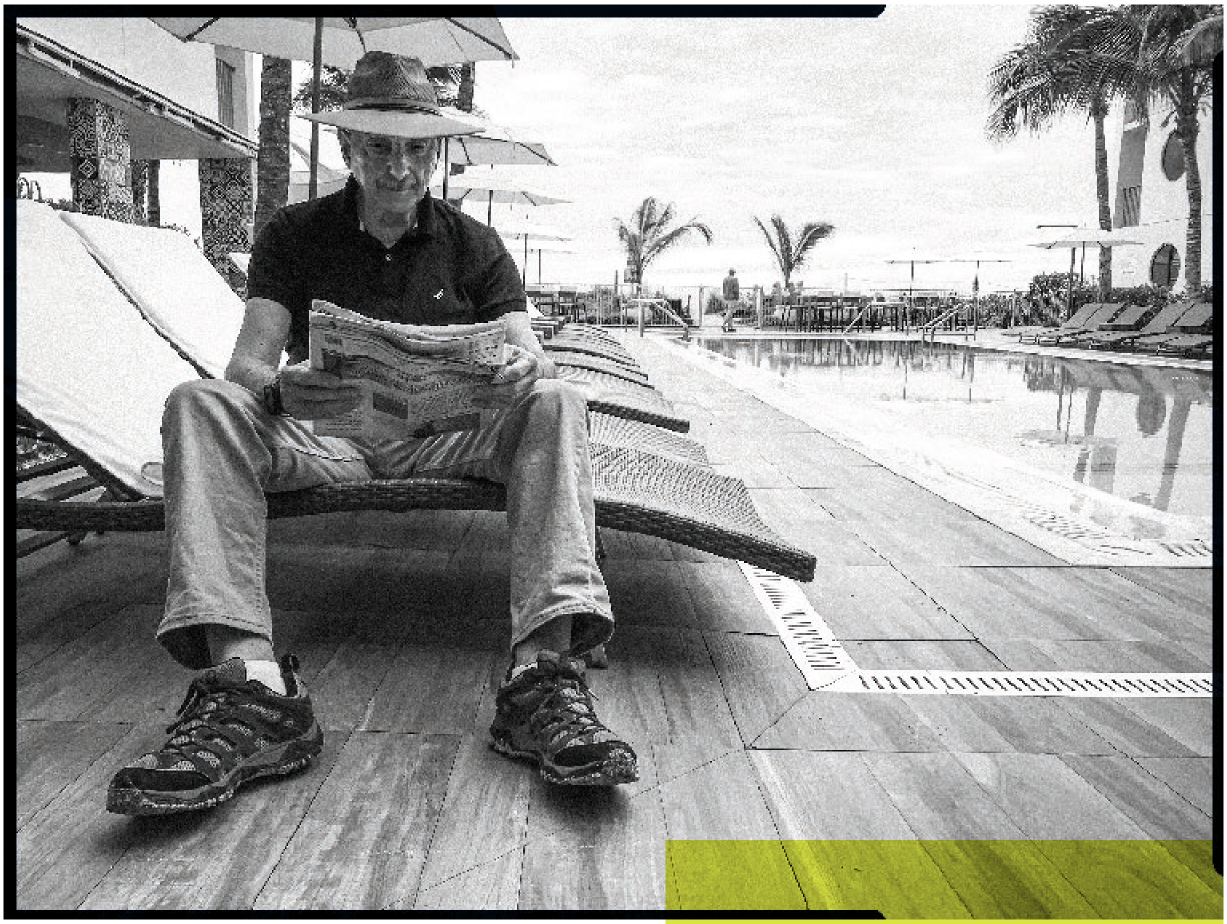
How so?
I'm helping a friend set up a new local broadcast TV channel here in Florida. Until recently I knew nothing about the television industry, so first I had to puzzle out how it all works. Now we're almost ready. The new channel will launch this year—and I will be appearing on screen, too!

A second career in television? Doing what exactly?
Exactly what you're doing now, interviewing people! One new show that I am working on will be all about medicine. My aim will be to help people gain a better understanding of the diagnosis and treatment they get from their doctors.

Nothing to do with lasers?
Not this time. Although, to be honest, is there any aspect of modern life that doesn't involve lasers?

Good question! What do you think?
Perhaps politics, but even that can't escape the reality of computers, cell phones and fiber optics. Every area of modern life, including politics, relies on communication technology, and all communication technologies depend on lasers. In fact, this is an excellent example of the speed with which laser technology has penetrated our daily lives. I always feel that the year 1980 gave us two miracles: firstly, the US beating the Soviet Union at ice hockey in the Winter Olympics and, secondly, the fact that millions of people watched the game live on television. It was transmitted using a laser-based fiber optics system just ten years after the development of the world's first low loss optical fiber. The second miracle is arguably the most significant one!

What's the secret to achieving those kinds of miracles? You have come up with so many inventions over the course of your career. What is your top tip for creating innovations?
As I've often tried to explain to my students, creativity is often the result of a happy accident. Take my own example: in 1973, shortly after I arrived at the University of Southern California, I met a couple of frustrated gastroenterologists who could see ulcers bleeding in patients with their endoscope but had no way to treat it. I casually suggested using optical fibers to guide laser light into the stomach and cauterize the bleed. I thought it was a pretty innovative idea—and it was, we received a patent for this concept—But it turned out that there were no fibers robust enough to do the job at that time. So I set about working with what we could get and encouraging others to develop the kind of fibers we needed. It was this



Professor Michael Bass
One of the founding figures of laser technology, Bass has been working with lasers since 1961—almost since they emitted their first pulse. He is responsible for numerous developments in solid-state and dye lasers, uses of semiconductor lasers, optical glass fibers and models of fiber lasers. The recipient of many prizes and awards, Bass was inducted into the Florida Inventors Hall of Fame in 2019. He lives in Vero Beach, Florida.

development process, motivated by the problem of bleeding ulcers, that gave rise to the new optical fibers that could be used in medicine that were the real innovation! That's often how it works. Many of the things I've developed originated from ideas I had that initially didn't work. In each case, I puzzled out what I needed to make the idea work. And it was often the inventions that emerged from that secondary process that were the more significant ones, if you see what I mean. You could almost say that innovation is what happens while you're working on something else!

No concrete tips then?
The directors of research labs and development departments will tell you that you need to create an environment where lots of creative people can share their ideas. Something like everyone standing around the coffee machine and new ideas emerging one by one. I don't deny that an open and creative atmosphere is important. But you can't force innovation and breakthroughs and you certainly can't teach them. New ideas either emerge or they don't—and the reason for this success or failure is often a mystery.

Crazy, isn't it?
Not really, I think it's actually rather comforting! ■

"Don't underestimate the importance of diamonds in laser technology!"

Marc Schmidt / Fotogloria

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Winning with 5G

A WIND OF CHANGE IS BLOWING THROUGH THE MANUFACTURING SECTOR: THE ADVENT OF 5G PROMISES TO RAISE SMART MANUFACTURING TO THE NEXT LEVEL.

The new 5G cellular network will be many times faster than its predecessor, 4G. That in itself won't change things much for the average cellphone user. But for industry it opens up a series of long-awaited opportunities, including reliable data rates of up to 10 gigabits per second, wireless low-latency control systems, and the ability to connect more devices in a single network than ever before. In the not too distant future, industrial machines will be able to communicate with one another in real time and transmit huge quantities of data simultaneously. Benefits include smart production scheduling and the automated analysis of vast amounts of process data—and that's not all. 5G enables deeper data capture methods that can also be used with existing machines. Backward compatibility is no problem, because the new cellular communication standard can handle the increased data traffic without slowing down processes. In other words, companies can continue operating their existing networks and yet capture and evaluate more production data. Moreover, 5G is more stable than comparable network protocols such as Wi-Fi. One reason is that it allows companies to install their own standalone 5G networks in the 3.7—3.8 gigahertz frequency band, which is reserved for industrial applications. In this way, they can create a network of which they are the exclusive owners, and in theory is immune to interference by adjacent networks. All in all, 5G is a highly reliable infrastructure for digital communication.

However, we expect it to take at least another three years before the new cellular communication standard is universally adopted throughout the manufacturing industry. Nonetheless, it would be wise for companies to consider how they can exploit the new technology and start preparing a course of action. For example, it is technically impossible to make maximum use of all three strengths of 5G—high data rate, low latency, and high number of users—at the same time. Manufacturers therefore have to decide which of these is most important in their particular case. One possible solution is to split the proprietary network into subnetworks, each optimized for different functions (slicing).

For this and other reasons, it is high time to learn more about 5G, because it can be used to make manufacturing smarter in many more ways than are evident at first glance. But rest assured: TRUMPF is on hand to offer advice, support and all the expertise you need. TRUMPF is the co-founder and an active member of the 5G Alliance for Connected Industries and Automation and has been shaping the technological and regulatory framework for the introduction of 5G for many years now.

Christian Bauer heads up R&D Basic Technologies Machine Tools at TRUMPF. He also represents TRUMPF on the board of the 5G Alliance for Connected Industries and Automation. In this role, he works together with other industry players to define specifications for 5G and its future evolution.

SLM FOR NICKEL-TITANIUM SHAPE MEMORY ALLOYS

Nickel-titanium shape memory alloys are frequently used in self-expanding stents due to their elasticity and their suitability for minimally invasive therapy in humans. However, their visibility in X-ray images is low. As part of her doctoral thesis for the University of Birmingham in England, Hollie Leigh Baker (28) developed a method of using selective laser melting (SLM) to manufacture shape memory alloys containing palladium. This improves the alloys' biocompatibility, corrosion resistance and X-ray visibility. The full paper is available online:

https://etheses.bham.ac.uk/id/eprint/9155/

PRINTING AND POST-PROCESSING OF METALLIC OPTICAL COMPONENTS

How can improvements be made to the quality of additively manufactured aluminum parts used in the metallic mirrors of high-power laser systems and space telescopes? And how can the cost of these parts be reduced? These questions are tackled by Ahmed Maamoun (37) in his doctoral thesis submitted to McMaster University in Canada. To answer them, he summarizes the results of various studies. His findings should make it possible to produce aluminum parts for a wider range of applications in the future. Find out more:

http://hdl.handle.net/11375/24032

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

LASER SURFACE HARDENING OF BEARING STEELS

In his doctoral thesis for Nanyang Technological University in Singapore, Niroj Maharjan (29) investigates microstructural changes in steel produced by laser surface hardening. He concludes that ultrashort pulsed lasers are well suited to repairing steel surfaces. His thesis offers important insights into hardening processes for gears, bearings, shafts and load-bearing components in industry. Find out more:

https://dr.ntu.edu.sg/handle/10220/48060

USING ARTIFICIAL INTELLIGENCE TO IMPROVE CUT QUALITY

In her doctoral thesis for the Karlsruhe Institute of Technology (KIT) in Germany, Leonie Tatzel (28) investigated how artificial intelligence can be used to improve cut quality in laser cutting and how the process parameters and the condition of the machine affect the properties of the cut edge. Her goal is to develop a laser cutting machine that automatically optimizes the cutting process and tailors the process to the desired cut edge and to any material or machine tolerances.

Images: private collection, Atelier Bauer Karlsruhe

GET MOVING!

Sixty years ago, the world was eagerly awaiting the first flash of a laser. Engineers, researchers and futurists drew up long lists of what possibilities bundled light rays might open up, from communications and surgery to material processing and so on. But, even in their wildest dreams, they couldn't have imagined atomic traps or slingshot effects for interstellar travel.

02

OPTICAL TWEEZERS

Concept: A tightly focused beam of laser light applies two forces to a particle, one along the direction of beam propagation and one at the point of highest intensity. Together, these forces hold the particle stable in the beam focus or move it by shifting the focal point.

Applications: Observing living cells, manipulating microscopic glass particles within cells as a tool for experiments and analysis

Example: Deforming cells to conduct measurements in or on the cell membrane

https://en.wikipedia.org/wiki/Optical_tweezers

01

MAGNETO-OPTICAL TRAP

Concept: Individual atoms are trapped at the point where three pairs of counter-propagating laser beams intersect and are then captured by a magnetic coil.

Application: Observing quantum phenomena, achieving Bose–Einstein condensation

Example: Quantum computer

https://en.wikipedia.org/wiki/Magneto-optical_trap

[FOUR CONCEPTS FOR MOVING MATERIAL]

MICROTRANSPORT USING HOLLOW-CORE FIBERS

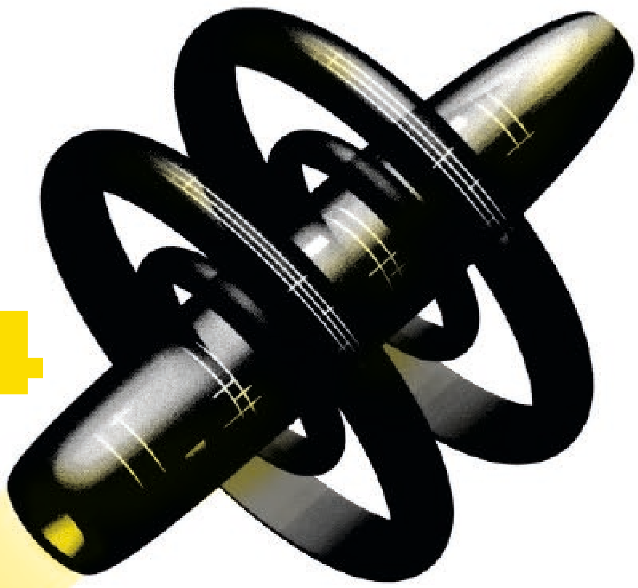
Concept: The light pressure of a laser beam pushes particles through the hollow core of a microstructured optical fiber or immobilizes them in a flow of a fluid.

Application: Transporting and manipulating tiny quantities of material or single living cells

Example: Transporting tiny quantities of chemicals into a cell and activating them optically
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6187474/

03

04



BOOST FOR INTERSTELLAR SPACE TRAVEL

Concept: Photons from a laser beam transfer their momentum to an object and accelerate it, potentially pushing it close to the speed of light.

Application: Laser propulsion to accelerate a generation starship on a mission to colonize distant solar systems

Example: The novel *Aurora* by Kim Stanley Robinson

Spoiler alert: Can also be used to help returning starships apply the brakes
https://www.goodreads.com/book/show/23197269

Gernot Walter

VRRROOO O

Motorcycle maker KTM uses laser technology to engrave its logo on the mufflers of its new offroad enduro bikes.

T

DOM

Sounds easy—but is it?

The engine roars and the rider focuses all his attention on the tight bend before the steep climb, his back wheel churning up mud and earth. Accelerating hard, he leaps over the edge. The front wheel comes down hard, and the enduro bike speeds off in a cloud of dust. Races with offroad motorbikes are the domain of tough riders—and tough materials.

COOL FEATURES Austrian company KTM—one of the world's premier manufacturers of offroad sports motorcycles—knows what its customers want: tough bikes that look seriously cool. As well as working on improving motorcycle technology, KTM also gives regular facelifts to its new models to keep things exciting. Launched this year, its latest Six Days limited edition model has a particularly eye-catching feature: A SIX DAYS logo laser-marked on the muffler leaves no doubt as to who made this impressive offroad machine. This addition may not seem very dramatic at first, but from a production point of view this marking is anything but simple. "The mufflers are made of anodized aluminum," says Florian Stadler, Production Coordinator Industrial Engineering at KTM. "So engraving is really the only way to add this kind of design feature."

HIGH-CONTRAST MUFFLER KTM tried out various processes before opting for the laser. "Right from the prototyping stage, we were very impressed by the laser's high-contrast marking performance," says Stadler.

KTM has been using TRUMPF marking systems for years. Just like part coding in the auto industry, motorcycles are also required to have component markings to ensure parts can be traced through their entire lifecycle. Laser marking is the best way to achieve this. But the Austrian company had some special requirements for their new 2020 range of bikes, says Stadler: "We wanted to put the 85 x 20-millimetre SIX DAYS logo on the outside of the muffler and the component coding on the inside, without having to manually remove the part from the marking station and turn it around." That's why they opted for TRUMPF's biggest marking system, the TruMark Station 7000.

CLEVERLY CONVERTED Yet even this machine's generous proportions were initially too small to engrave the muffler on both sides, says Stadler: "In order to reach all the marking positions without requiring any manual intervention, we installed a sliding table to pull out the fixture in the processing area, developed a swivel device with a pneumatic rotary drive and updated the system's control unit accordingly." TRUMPF supplied the CAD data and interfaces needed to make the adjustments. KTM now has two modified TruMark Station 7000 machines in operation, marking a total of some 700 mufflers a day. The TruMark 5050 solid-state laser produces razor-sharp results that remain perfectly legible—apart from brief moments hidden under thick mud after a tough race! ■

Florian Stadler's goal was to mark the muffler on the inside and outside without having to move it during processing.

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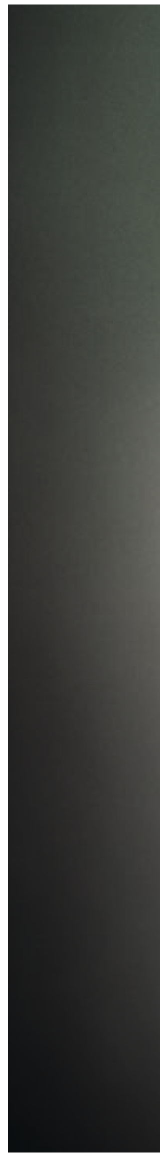
AND THEN THEY WERE FRIENDS



The International Copper Association spent ten years searching for a technology to produce thin copper tubes. Nexans came up with a solution in just one week.

Our story begins a year ago, on a sunny day in May. Two men are eating breakfast on a seventh-floor hotel terrace in Times Square in New York City. Against the lively backdrop of the "Center of the Universe", as Times Square is often referred to, they are engaged in deep conversation. One of them is explaining a problem that has long been on his mind. The other has a happy feeling that he might already have a solution. The man with the problem is a representative of the International Copper Association (ICA), an organization that promotes the interests of companies worldwide that extract, process and use the metal. For more than ten years, the ICA has been searching for a method of manufacturing thin copper tubes that are several kilometers long yet have a diameter of less than five millimeters. The man sitting opposite is Ralf Egerer—and he already has a vague idea of what that manufacturing process might look like. He heads up the Machines and Automation department at Nexans, one of the world's leading manufacturers of cables and cable systems.

As he listens to the ICA representative explaining the problems of thin copper tubes, Egerer's thoughts turn to a machine that Nexans makes at its site in Hannover, Germany. "We developed a special forming and welding machine for thin-wall tubes that we use for applications such as producing semi-finished tube products for hypodermic needles. The machine forms the narrowest of tubes from ultra-thin stainless steel strips, and an infrared laser welds the tube together so precisely that the seam is invisible to the naked eye," he says. Egerer is keenly aware that copper and lasers are far from having a symbiotic relationship. Copper is difficult to process with a laser beam because it is so reflective. Yet Egerer has long ceased to see this as an obstacle.

A MARKET WORTH BILLIONS If Egerer's idea were to bear fruit, it would be a major coup for the ICA. Copper is a major issue in the heat exchanger industry. At stake are millions of heating systems, refrigerators and air conditioning units that incorporate copper tubing—a market that requires some 1.6 million tons of copper. Customers are calling for more compact heat exchangers, which means the tubing also needs to shrink. However, there is a limit to how small copper tubes can get: diameters of less than five millimeters are not technically possible because welding in non-ferrous metals is so unstable. Copper tubes are mass-produced, so it's clear what the industry needs: a production process that is efficient, fast, sparing with the material—and ideally also eco-friendly. If such a process existed for copper, it would be a huge boost for manufacturers—and for the members of the ICA. On this May morning, as his gaze drifts over the

BY LEARNING TO LOVE EACH OTHER, COPPER AND LASERS COULD CRACK A MARKET WORTH BILLIONS

{ The perfect couple are finally on the same wavelength: green laser light welds together copper tubes with diameters of less than five millimeters. One kilometer an hour, 24 hours a day. }

Gernot Walter, Ricardo Wiesinger / Fotogloria

"LEAVE IT TO ME," SAYS EGERER, DARING TO TAKE THE GAMBLE.

facades of the skyscrapers that surround Times Square, Egerer gets a sense of just how big this market is. There are hundreds, if not thousands, of air conditioning units here alone, all working to improve the air in offices, apartments and restaurants. Figures from the International Energy Agency (IEA) confirm his hunch and reveal just how huge the demand actually is: the IEA estimates that the number of air conditioning units installed in buildings worldwide will climb from today's figure of 1.6 billion to 5.6 billion in 2050. Egerer turns to his breakfast companion with a determined look on his face: "Leave it to me."

GREEN LIGHT FOR WELDING Back in Hannover, Egerer gets down to work. He's confident he can solve the problem, but it's still something of a gamble because he doesn't yet have a solution for the tricky combination of copper and laser light. "Using infrared lasers to process copper is something we've been doing for a long time, but the beam source is simply not reliable enough to create continuous weld seams in copper. As well as variations in the weld depth, you also tend to get spatter," says Egerer. The biggest problem is the sudden change in absorption behavior during welding. In its cold state, copper is initially highly reflective and energy input is low. Copper only absorbs five percent of the laser beam, reflecting the remainder of the light. After a while, however, the metal melts and starts absorbing considerably more light. This makes it difficult or impossible to come up with a stable, reproducible welding process. But Egerer has plenty of experience in this business and already knows that green laser light at a wavelength of 515 nanometers might be the solution. The laser light couples into copper better at this wavelength, pushing the absorption rate up to 40 percent—and offering the huge advantage of keeping welding results stable. What's more, green laser light is largely unaffected by the copper's surface properties, functioning equally well if the copper is polished or tarnished.

Egerer's first move is to call TRUMPF—his longstanding partner for laser-related issues—to find out what they have in the way of green lasers. His timing is perfect, because—after years of experimentation—TRUMPF engineers have finally succeeded in modifying a disk laser to make it emit green wavelengths with a laser power of one kilowatt. The focus of their work on green lasers is actually e-mobility (see page 6), but Egerer barely hesitates: "That's exactly what I need!"

Green lasers were actually developed to help build electric cars. But Ralf Egerer didn't see why he shouldn't use them in his industry, too!

The 0.08-millimeter-thick copper strips run from the coil into the machine, where they are bent into shape and welded into tubes with a continuous weld seam.

Ricardo Wiesinger / Fotogloria

READY FOR PRODUCTION AFTER ONE WEEK

Once the green laser reaches Hannover, things move fast. Just one week later, Egerer is ready to present his converted welding machine at a customer event. “The green disk laser is constructed in an almost identical way to the infrared laser, so it was easy to incorporate it in the machine. We only had to optimize a couple of parameters to get it running.”

The audience of industry experts—including the ICA representative and his colleague from the Heat Transfer Technologies department—are suitably impressed when they get their first sight of the high-speed manufacturing of tubes with a diameter of two millimeters from strips of copper that are just 0.08 millimeters thick. Five kilometers in five hours, with no breaks, and a seam that is flawless, tightly sealed and invisible. “This opens the door for heat exchanger designs and manufacturing processes that would previously have been impossible,” says Egerer.

Initial attempts to introduce the process in real-world shop floor environments are already underway in Germany and Japan. And the first steps have also been taken in the U.S., where the whole story began. ■

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Wormholes and Einstein

OR WHY IT'S BETTER NOT TO VOYAGE INTO THE PAST.

The laser was invented 60 years ago, which sounds like an eternity to me. I can't remember that far back, because I wasn't born yet and nor were my parents. But I work with lasers every day, all day long, so I know almost everything about that time. Well, "everything" might be a slight exaggeration, but I've read lots of books and biographies and articles. I would have loved to have been a lab assistant there in 1960 when the American physicist Theodore Maiman demonstrated the first operable laser. He saw with his own eyes that the light beam behaved in exactly the same way that Albert Einstein had described in his theory of stimulated emission more than 40 years earlier!

If I could travel back in time, I would tell Maiman about all the amazing things we can do with lasers now. I would reassure him that he was right, and that we have found countless applications for what his critics called a "solution looking for a problem."

But how do I become a time traveler? This dream of humankind has been the subject of hundreds of books and movies and TV series, proposing all imaginable ways of traveling through time. The problem is, they all belong to the realm of science fiction. So tough luck, Kaliudis, you can't tell Maiman what a brilliant invention the laser turned out to be. Or can you? What would Einstein say? After all, our modern-day perception of the universe is based on his theories of general and special relativity. And it was a laser interferometer that proved the existence of gravitational waves, as Einstein had predicted.

IN SHORT, if I follow Einstein's theories, I could travel back in time through a wormhole, provided it remains stable for long enough and creates a passage that links different points in the space-time continuum. So that's feasible. As for the vehicle for my journey through time, I would ask Elon Musk to lend me a spacecraft from his SpaceX project.

After witnessing the birth of the laser, I would climb back into my spaceship and return to Earth barely older than I was when I left, thanks to the time dilation effect. Accelerating the engines to close to the speed of light, I would cruise through space for a while, but time would pass more slowly for me up there than for the folks back on Earth. I would land in 2020 and be able to join in the party to celebrate the laser's 60th anniversary.

Of course, that's all on condition that my journey back in time doesn't trigger a butterfly effect, leading to a kind of grandfather paradox that would make my own future existence and that of the laser impossible. ■

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

→ *What past or future period of time would you like to visit? Let me know by email: athanassios.kaliudis@trumpf.com*

Gernot Walter

Jan Huber / Unsplash

WHERE'S THE LASER?

Keeping things running on time.

Why's my train late? It's in the repair shop. What's it doing there? Waiting. What for? A spare engine part, no bigger than your thumb. To prevent this happening in the future, Deutsche Bahn AG is relying on rapid assistance from 3D printers. In 2015, a group of job shops joined forces to launch the "Mobility goes additive" initiative. Since then, they've been printing metal spare parts for trains on TRUMPF machines and speedily delivering them to the German rail operator. This gets trains back on track quicker. Over the first four years, they printed a grand total of 70,000 parts. Look, here comes your train! ■

0.05 nm

The hardest, shortest and most intense X-ray flashes in the world are generated in a 3.5-kilometer-long tunnel beneath Hamburg. This is where the European X-Ray Free-Electron Laser produces coherent X-ray light with wavelengths down to 0.05 nanometers. In combination with ultrashort pulse durations in the femtosecond range, this allows scientists to make 3D films and images of structures and processes at the atomic level.

TRUMPF

LASERCOMMUNITY.31 *will be published in November 2020.*
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Jan Hosan / Sechsnull.de

LASER COMMUNITY.30