02:13

Laser *Community*

THE LASER MAGAZINE FROM TRUMPF

Aluminum, at last

Viessmann welds with a record-breaking machine

The laser, at last

Zwilling, of all companies, could not cut. That's been taken care of.

WWW.TRUMPF.COM

HELLO, MR. PRESIDENT

YONGFENG LU TALKS ABOUT EVERYTHING EXCEPT HIS PRESIDENCY OF LIA

→ Page 26

May the Powder be with you!

Additive manufacturing is the future of production. But what will this future look like?

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Truly impressive is what can be achieved by an interdisciplinary meeting of creative minds. Together, developers Dirk Sutter (TRUMPF), Jens König (Bosch), and Prof. Stefan Nolte (Friedrich Schiller University, Jena) succeeded in transforming the ultrashort pulse laser into a tool ready for use in industrial mass production. The team has now been nominated for the prestigious German Future Prize. This award is given by the President of Germany for excellence in technology and innovation, but it's fair to say that it ultimately honors entrepreneurial farsightedness. After all, it usually takes research projects almost a decade to go from the original idea to profitable implementation and production. That's why the support Germany gives research networks is such a stellar example. Only if experimental physicists at universities trade ideas with mechanical engineers, production engineers contribute their practical experience, suppliers deliver the right components, and qualified and skilled workers make top-quality products — only then can the transition from laboratory to production be a success.

The power of interdisciplinary teams is also the key ingredient in our cover story on additive manufacturing. This is a new discipline and its journey from the laboratory to practical implementation in factories is receiving support from the European Union. The EU's AMAZE project fosters development collaboration between the European Space Agency (ESA), eight universities, and 19 companies, including TRUMPF. Additive manufacturing processes create components out of virtually nothing. Whether by selective laser melting (SLM), powder bed fusion, or laser deposition welding (also called laser metal deposition, LMD), objects emerge layer by layer straight from the 3D CAD program — objects like our cover star, Yoda from *Star Wars* used by many 3D printers as a reference model. It is created from powder by laser power. While additive manufacturing has already enjoyed some initial successes, we're still a long way from the revolutionary transformation of factories promised by some forecasters.

Success through teamwork!

The perseverance shown by the knife makers at Zwilling, in the town of Solingen, is also paying off in this field, too. Only after they perfected the automated interaction of robots and laser systems could they finally use the laser to cut out the blanks for the knives. The power of teamwork can also be seen here, with team members scrutinizing processes from completely different perspectives, getting ideas and inspiration from each other, and working together to resolve issues. The secret to success is found in the free exchange of ideas, in open discussion without dogmatic restrictions, and in having the courage to take far-sighted entrepreneurial decisions.

PETER LEIBINGER, D.ENG. H.C.

Vice-Chairman of the Managing Board
Head of the Laser Technology / Electronics Division
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COMMUNITY

Lasers and people at a glance PAGE 06

TOPIC

COVER STORY

Try a lot you still must

The vistas opened up by additive manufacturing are exciting. And the reality is no less so – it just diverges from expectations. PAGE 10

Along the right lines

Laser deposition welding is developing into an additive method all of its own. PAGE 12

PERSPECTIVES

“The opportunity is there!”

For Fraunhofer President Reimund Neugebauer, realizing the commercial breakthrough of additive methods is all a matter of effort. PAGE 15

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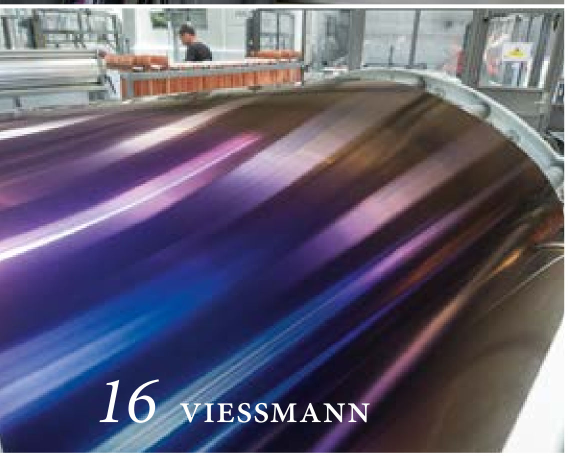

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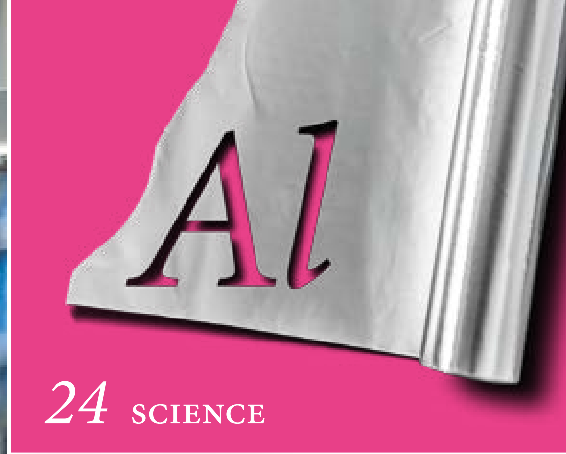
ZWILLING 19



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2013

S P O T

--- MINI-COLLIDERS

Using an ultra-high-power laser, researchers at the University of Texas are creating plasma that accelerates electrons. This will make possible particle accelerators small enough to fit on lab benches. *www.utexas.edu*

--- CUTTING AND GROWING

Analysts from MarketsandMarkets predict that the market for laser cutting will grow by 9.7% annually, to reach a volume of around 3.8 billion U.S. dollars by 2018. *www.marketsandmarkets.com*

--- INNOVATION CENTER

The University of Connecticut has opened an innovation center for laser-additive manufacturing. The workshop is part of the U.S. government's Advanced Manufacturing Partnership initiative. *www.uconn.edu*

--- MICRO-PRINTERS

The Nanoscribe company has developed a system that prints micron-scale, three-dimensional structures at top speed via laser lithography, for applications such as optical circuits. *www.nanoscribe.de*

--- FROSTY LIGHT

Progress in optical cooling: Using lasers, scientists at Nanyang Technological University in Singapore have cooled a small semiconductor component by 40 kelvin from room temperature to minus 20 degrees Celsius. *www.ntu.edu.sg*

--- MORE MARKING

TRUMPF is doubling production space for marking lasers at its location in Grüsch, Switzerland. To cope with high demand, a new building was inaugurated in June. *www.trumpf-laser.com*

--- LASER SCHMIDT

German parents may now call their child "Laser", if they want, as decided by the Association for the German Language after an enquiry. The association decides which first names are permissible in Germany. *www.gfds.de*

Dr. Dirk Sutter is head of research and development for ultrashort pulse lasers at TRUMPF.

When research becomes a tool

Ultrashort pulse lasers have arrived in mass production

The interconnectedness of academic research and industry is a German success story. To illustrate: Collaboration between developers Dirk Sutter at TRUMPF, Jens König at Bosch, and Prof. Stefan Nolte from Friedrich Schiller University in Jena has succeeded in transforming the ultrashort pulse laser into a tool for mass production. Bosch is already mass producing various items, in numbers running to the millions, using ultrashort pulse lasers. For example, the lasers drill extremely precise holes in state-of-the-art gasoline injectors and direct injectors. That makes them cost-effective even for medium-sized and small engines. They reduce fuel consumption by up to 20 percent. Now the team has been nominated for the prestigious German Future Prize, an award given by the President of Germany for excellence in technology and innovation. "The nomination alone is an honor," said Sutter, "and commends all the employees who work every day to make ultrashort pulse lasers a success. After all, potential USP applications are far from exhausted." *www.deutscher-zukunftspreis.de*

The VDMA Industry Report predicts stable demand for laser systems.

Laser tops GWP

Global market for lasers experiences reliable growth

The global market volume for laser systems and laser sources used in materials processing was 8.7 billion euros in 2011. That corresponds to nominal average growth of 7.7 percent annually since 2005 — a growth rate twice that of of gross world product (GWP). These findings were laid out by the German Engineering Federation (VDMA) in its Photonics Industry Report for 2013. Experts predict that the market for lasers as a tool will continue to grow by 7.9 percent annually until 2020, by which time it will have reached 17.8 billion euros. *www.vdma.org*

“My mission is to explore – and push back – the frontiers of ultrafast technology”

Prof. Ursula Keller

This year’s recipient of the Laser Institute of America’s Arthur L. Schawlow Award is Ursula Keller, Professor for Experimental Physics at the Swiss Federal Institute of Technology Zurich (ETH Zurich), who has been honored for her outstanding achievements in laser research. These include developing a technique that makes it easy to produce extremely short laser flashes, which made ultrashort pulse lasers industrially viable. Her semiconductor saturable absorber mirror (SESAM) has opened up a broad range of technical applications in metrology, medicine, and materials processing. She is currently conducting research into new, more compact semiconductor lasers. *www.lia.org*

“The principle behind our laser is completely new”

Dr. Sven Höfling

Laser from a quantum film: An international team of physicists coordinated by Sven Höfling has managed to create a so-called polariton laser, working entirely differently from conventional beam sources. “We create excitons — electron-hole pairs — in a quantum film. The excitons decay and emit photons, which we then use to generate the laser beam,” explains Höfling. The beam is no different than a conventional laser’s, but it requires much less energy. To date, however, the technology has worked only at impractical temperatures of –263 degrees Celsius or about 10 kelvin. *www.uni-wuerzburg.de*

“This alliance will strengthen photonics”

Elizabeth Rogan

The Optical Society of America (OSA), the Laser Institute of America, and four other U.S. photonics societies have come together to launch the National Photonics Initiative. The alliance’s goal is to bring industry, academia, and government experts closer together to identify and advance areas of photonics that are relevant to U.S. competitiveness and national security. Co-founder of the alliance and OSA CEO Elizabeth Rogan explains: “With photonics we will continue to create jobs and save lives.” *www.lightourfuture.org*

ESPACE LASER
November 27 – 28, 2013, Paris / Villepinte, France; Trade fair for laser in industry and medicine www.espace-laser.biz

PRECISIEBEURS
December 3 – 4, 2013, Veldhoven, Netherlands; Precision fair: technologies, solutions and products
www.precisiebeurs.nl

AMS INDIA CONFERENCE
December 9 – 11, 2013, Mumbai, India; Conference on automotive manufacturing solutions india.amsconferences.com

NORTEC
January 21 – 24, 2014, Hamburg, Germany; Manufacturing trade fair
www.nortec-hamburg.de

SEMICON KOREA
February 12 – 14, 2014, Seoul, South Korea; Largest technology trade show in that region
www.semiconkorea.org

TECHNI SHOW
March 11 – 14, 2014, Utrecht, Netherlands; Fair for industrial production technology
www.technishow.nl

PHOTONICS WEST
February 1 – 6, 2014, San Francisco, CA, USA; Conference and exhibition for photonics, biophotonics and the laser industry
http://spie.org/x2584.xml

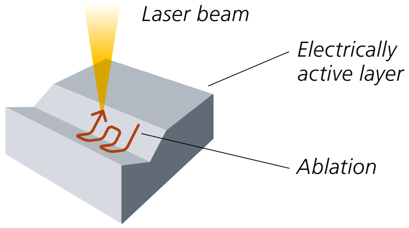
EALA
February 11 – 12, 2014, Bad Nauheim, Germany; European automotive laser application conference
www.automotive-circle.com

TUBE
April 7 – 11, 2014, Düsseldorf, Germany; Fair for tube production www.tube.de

AIRCRAFT INTERIORS EXPO
April 8 – 10, 2014, Hamburg, Germany; World’s largest event on aircraft interiors
www.aircraftinteriorsexpo.com

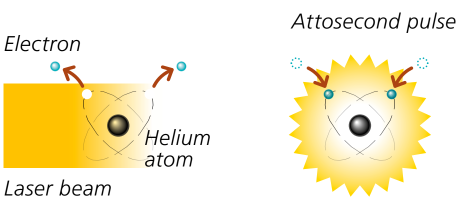
LASYS
June 24 – 26, Stuttgart, Germany; International trade fair for laser material processing www.lasys-messe.de

CONCEPTS



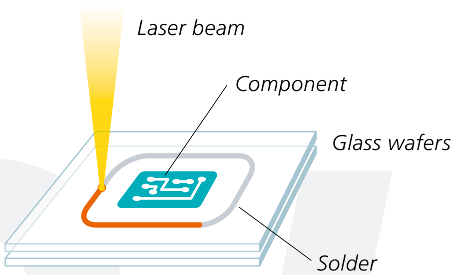
-- INSCRIBING SENSOR STRIPS

An ultrashort pulse laser applies sensor strips directly in hard-to-reach grooves in machine tools by vaporizing an electrically active layer, at precision down to the micron. The sensor monitors even the tiniest vibrations and deformations during operation. *www.lzh.de*



-- GENERATING ATTOSECOND PULSES

A picosecond laser ionizes the electrons of inert gas atoms with its electrical field. The electrons move away from the nucleus briefly, before plunging back into their atomic orbital, releasing attosecond pulses in the process. *http://www.trumpf-scientific-lasers.com*



-- LASER-BASED GLASS SOLDERING

Sensitive components are encapsulated between glass wafers for protection. Now this process can be carried out using lasers. The beam passes through the glass and heats up only the solder. *www.ilt.fraunhofer.de*

Laser cutting electrical steel makes motors more effective. Electric and hybrid cars stand to gain.

Great edge

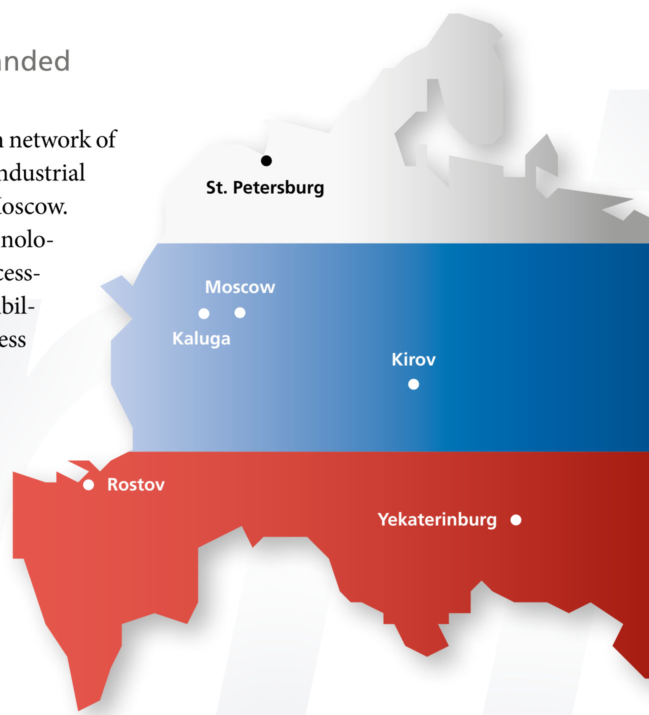
Researchers are optimizing laser cutting for electrical steel

On account of its flexibility, laser cutting is becoming increasingly popular for cutting electrical steel. Now scientists at Fraunhofer IWS have succeeded in optimizing the laser process so that the electromagnetic properties of the sheet metal are virtually unaltered at the cut edge. The better these properties are, the smaller the losses when electrical energy is converted into kinetic energy, making electric motors work more effectively. The researchers achieved this by carrying out metallographic analyses of the cut edges and developing new process parameters from the results, both for CO_2 lasers and for brilliant solid-state lasers. *www.iws.fraunhofer.de*

Lasers for Russia

Network of laser centers expanded

The sixth site in the German-Russian network of laser centers opened this year in the industrial city of Kirov, 900 kilometers east of Moscow. Here, the Vyatka Laser Innovation Technology Center, experts in laser materials processing assist regional companies with feasibility studies, process integration, and process development. In addition, the companies can send their employees to receive further training in the laboratories with their state-of-the-art equipment. The Hannover Laser Center coordinates the networked project, which is sponsored by the German Federal Ministry of Education and Research. *www.lzh.de/en*



“Trade fair? Don’t forget your goggles!”

Klaus Löffler, current president of the Laser Institute of America (LIA), sees marked regional differences in laser safety and explains how the LIA is working to raise standards.

Klaus Löffler is Head of Sales for Laser Technology at the TRUMPF Group. In recognition of his work relating to the application of laser technologies in sectors such as automotive technology, micro-applications, and medical engineering, the LIA presented to him its Fellow Award in 2011.

Why does an institution with “America” in its name operate worldwide?

The laser was invented in America almost 50 years ago. And the LIA has been active in the U.S. for 45 years. In the meantime, however, the laser has become a key technology worldwide. Consequently, the LIA’s work is now very international in its orientation, and that’s reflected in the nationality of our recent presidents. We’re busy spreading knowledge about laser applications and attracting new users around the world. At the same time, we try to ensure that lasers are used in compliance with applicable safety standards.

Are there regional differences in laser safety practices?

The effects of laser light on the human eye are exactly the same the world over. However, the safety measures and regulations in place vary greatly from region to region. The international success of laser technology has triggered a proliferation of new and sometimes unknown manufacturers of lasers and laser systems, including those in new markets, too. For instance, more and more laser systems are being installed in China, creating a big need for the appropriate education and training. That applies to both machine safety and the operators’ personal safety. Another challenge is to ensure that laser safety practices keep up with the rapid changes in laser technology: higher power, greater beam quality, shorter pulses, additional wavelengths.

Safety consciousness is often lacking, especially in Asia’s emerging markets. It has happened that high-power lasers are operated at trade fairs without adequate laser beam shielding.

Can you give specific examples?

Well, particularly in Asia, it’s not unusual to operate even high-power, solid-state lasers without any laser beam protection at all. The consequences for the operators — sometimes more or less unaware of the danger — can be be disastrous. A disregard for proper laser protection is also in evidence at Asian trade fairs. In fact, visitors to these trade fairs would be well advised to bring along a pair of laser safety goggles.

What specifically is the LIA doing to promote laser safety?

The LIA works together with the OSHA (Occupational Safety and Health Administration) to draw up and publish guidelines on safe laser use as norms adopted by the American National Standards Institute (ANSI). This makes the LIA the authority on matters of laser safety. We offer comprehensive laser safety training for users in research, industry, and medicine. These continuing training courses are conducted around the world and are available both on site and online. We train more laser safety officers than any other organization worldwide, and we are proud to offer both courses on both theoretical and practical aspects.

Gernot Walter; Mishal/Fotolia; Angelika Grossmann; LASERVISION GmbH& Co. KG

A favorite guinea pig among 3D printing fans: Yoda from Star Wars, printed from plastics.

★ ★ ★

TRY A LOT YOU STILL MUST

★ ★ ★

Everyone agrees: Additive processes such as 3D printing and laser deposition welding are the future of manufacturing. We had a look around to see what this future looks like now.

U.S. President Barack Obama affirmed that 3D printing “has the potential to revolutionize the way we make almost everything.” The media are brimming with dreams of 3D printers and decentralized, on-demand production. Opening its doors last year in New York City was a store selling 3D printers for home use. Such devices, however, which enable their users to “print” Yoda figures at home, are not the subject of this article. We will be discussing instead the real core of what Obama promised: additive manufacturing of metal components in industrial applications — whether prototypes that are fully ready for use or workpieces in small or long production runs. Here, too, the spirit of optimism is strong.

Prof. Reinhart Poprawe, head of the Fraunhofer Institute for Laser Technology ILT in Aachen, makes the following promise: “Engineers can develop products virtually free of production restrictions and are essentially limited only by their imaginations.”

Dr. Terry Wohlers, publisher of the annual *Wohlers Report* on additive processes in industry, expressed similar optimism, but more in terms of economics: “A growing number of industries and geographic regions are embracing additive manufacturing. Additive processes have had a tremendous impact on design and production, and this impact will increase in the coming years.” Additive manufacture of metal parts in industry always involves building an object layer by layer, usually from powder and most frequently using a laser. The method that has become synonymous with additive manufacturing in people’s minds and in the media looks like this: In a powder bed, a laser fuses metallic powder to form layers of material. The process occurs in a chamber flooded with inert gas. It is called selective laser melting (SLM) or powder bed fusion. The process creates highly complex components with internal structures or components that are the image of their internal strains. Material is consolidated exactly where it is required to accept and conduct stresses.

Second career for LMD

Many components, however, do not have internal channels, cavities, and complex power flows. In addition, it is often favorable to apply additional material to existing components — adding a threaded mating surface to a pipe, for instance. In the past, a pipe would have been manufactured with a larger diameter than required and then everything except the connection would have been milled away. Or let’s say you wanted to change the surface geometry of a tool. In these cases, a different process becomes attractive.

Laser deposition welding, also known as laser metal deposition (LMD), inserts the filler material — powder or wire — directly into the melt pool formed by a laser beam, creating a layer of beads welded to each other. The powder-based version is particularly promising, as it is 3D-capable:

Pore-free, fully welded beads: a workpiece generated by LMD magnified under a scanning electron microscope

DeltaMaker www.deltamaker.com—3D model by Jonathan Wong, www.thingiverse.com/thing:14104; TRUMPF

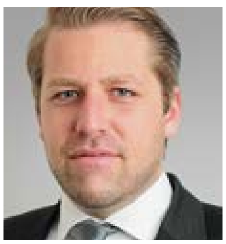
ALONG THE RIGHT LINES

The way additive manufacturing should work is clear: The engineer creates a 3D CAD model and the machine picks up the data and starts building. At present, however, engineers first have to painstakingly translate the model data, point by point. That is why TRUMPF is currently researching the optimum process strategy for laser deposition welding, starting with basic geometric shapes: How do you make a cuboid? Should the laser move in wavy lines or meanders? How close to each other should the lines be? Where should the laser decelerate and where should it travel smoothly? What are the optimum parameters for power, speed, and powder flow? Where do you need to have variations so that the corners, for example, do not ablate and sink? Once this fundamental understanding of basic shapes is in place, it will be possible to program perfect processing strategies, even for complex component geometries.

many layers build up to produce a body that — because the metal powder is supplied coaxially to the laser beam — can grow in every direction. What makes deposition welding so exciting as a second additive process is not only the fact that the equipment technology is already fully developed and available, but — and more especially — the deposition volume and speed it can achieve. With volumes of up to 500 cubic centimeters an hour, it beats conventional manufacturing processes not only from a technological perspective but often in terms of cost-effectiveness, too. And it imposes scarcely any restrictions on developers with respect to combining materials: it can produce almost any kind of sandwich structures and graded layers. The process is carried out on the component in the ambient air. This reduces non-productive and setup times and means that even large components can be processed. All this reduces the costs per part.

Hopes and reality Despite the huge potentials of additive manufacturing, skeptics point to many obstacles. The materials are still relatively expensive and the building an object layer by layer is very time consuming. Heat input, melting times, cooling times, the volume that can be processed — all these things put limits on speed. And then there is the whole business of programming the process. Although the CAD model contains all the necessary data for the component, the machine still needs to be shown a path — from the first welding line to the last dash of powder — and the thermophysical processes in the workpiece have to be taken account of. At some point in the future, the software will be able to calculate this path on its own. But only now are engineers are laying the groundwork for this capability.

"Laser deposition welding is one potential route. Wherever it's the right one, then we'll take it."



Maximilian Meixlsperger, BMW

"The process is so good that, on the whole, we can repair the blades more often."

Dr. Stefan Czerner, Lufthansa Technik

This fundamental research is being supported by the European Union, which is sponsoring development collaboration between the European Space Agency (ESA), eight universities, and 19 companies, including TRUMPF. The objective of the AMAZE project is to manufacture metal components up to two meters tall using additive methods by 2016 — with zero waste. The aim is for production costs to be only half those of conventional processes. TRUMPF is heading and coordinating the laser deposition welding project group. David J. Jarvis, head of new materials and energy research at ESA and chief coordinator for AMAZE, observes: "When talking about laser additive manufacturing, our conversation must without fail include laser deposition welding. It is an interesting way to conduct repairs, rescue components, and augment existing parts."

Prototypes and repairs Companies are well aware of this. The BMW Group manufactures functional prototype parts for test vehicles by means of laser deposition welding. For exam-

Additive laser deposition welding: a large number of beads produces an object that behaves mechanically just as if it were a conventionally manufactured piece of steel.

★ ★ ★

IN THEORY, the machines can generate any shape. But you also have to be able to TELL THEM HOW.

★ ★ ★

ple, the developers modify existing parts, altering their shape or thickening the material when components are required to withstand higher strains, for instance. "It used to be that we would manufacture a tool for every prototype," says Maximilian Meixlsperger, project manager for advanced development of additive manufacturing processes. "That could sometimes cost six-figure sums and take up to half a year. And then, as soon as the next redesign came along, the tool was obsolete. With 3D LMD, we have the first prototype within a week." The BMW Group's strategy is to use the best method for the job at hand according to the following general scheme: They create prototypes of small components, using the powder-bed-based SLM method. From a certain component size upward, they opt for additive laser deposition welding to modify existing components — where those components are available, of course. In the case of extensive alterations or if engineers need the parts in larger volumes, it becomes more economical to make a new tool. Meixlsperger explains: "We weigh what the right course is on a case-by-case basis. And sometimes it turns out to be laser deposition welding."

Lufthansa Technik also employs additive laser deposition welding and, beginning in 2014, it will use the method to repair the high-pressure compressor blades in aircraft engines. As well as having to withstand extreme temperature differentials, these blades suck in ash, sand, and water during flight. That soils and damages them at the edges of the air inlets and exhaust outlets and on the leading sections of the blades. To achieve optimum performance, the blades have to be overhauled again and again. Dr. Stefan Czerner from the engines division at Lufthansa Technik explains: "Working with material which in some cases is just 0.2 millimeters thick is beyond even our best manual welders. We need high-precision positioning — accurate to a hundredth of a millimeter — and precisely metered energy input. The only way to do that is with a laser." Aviation engineers grind or mill the damaged areas to a defined

BMW Group; Lufthansa AG; Oliver Graf

geometry. Then the laser gets to work, all around the part, and builds the missing volume back up again with powder — near-net-shape and up to a depth of two millimeters. The laser machine uses the same material the blades are made of: a nickel alloy specially developed for aviation, containing chromium, aluminum, and other substances. The whole operation takes just a few minutes. Finally, everything is given a quick polishing, and the blade is returned to the engine. “The process is so good that we can repair the blades more often — with longer intervals between repairs,” says Czerner. He and his colleagues expect a significant drop in costs for the components affected, for each engine overhaul.

Another person expecting many new repair applications from additive laser welding is Prof. Michael Rethmeier, head of joining and coating technology at the Fraunhofer Institute for Production Systems and Design Technology (IPK) in Berlin. Rethmeier’s team is currently working on a portable method for bringing the machinery to the workpiece: “What we have in mind are things like the huge turbine blades in power stations, which we could reconstruct on site. Or take the boilers in chemical plants, where we could turn cracks into shaped grooves and then fill them in by means of laser deposition welding.” Rethmeier wants to teach his students to think about the possibilities afresh. “Today, deposition welding lets us repair things that the text books say are unweldable. If we want to repair a workpiece with great susceptibility to thermal cracking, then we mix the ideal metallurgical material from the powders where possible. Then it’s no problem.” The heat input during laser deposition welding is so low that the structure remains intact, even with heat-sensitive materials.

After the hype

As we have seen, additive mass production has achieved its first concrete successes. But we are still a long way from the visions of utterly transformed factories that the excited media are conjuring up for their audiences. Trends greeted with euphoria often don’t turn out as expected. In the 1960s, experts trumpeted a revolution in cooking: in future, everyone would make their meals in the microwave; the stovetop and oven would soon disappear from kitchens. We all know how the story turned out. The microwave did in fact trigger a revolution — and also established a huge market for convenience foods. Instead of listening to the experts, consumers used their microwaves not for cooking and baking but for reheating. Today, almost every household in industrialized nations has a microwave, and the technology is neatly integrated into domestic food “production” alongside the glass ceramic stovetop and high-powered oven.

So what comes after all the hype? Usually not what was expected. David Belforte, editor-in-chief of *Industrial Laser Solutions*, recommends that industry should simply sit back and enjoy the mass media enthusiasm about additive manufacturing. It will run its course soon enough — and that’s when things will get interesting. Hyped-up events in the past have shown that the actual productivity phase only really gets going after the media circus has moved on and it becomes clear how people will actually be using the new technology. The era of additive manufacturing is on its way. You can see it shimmering on the horizon. ■

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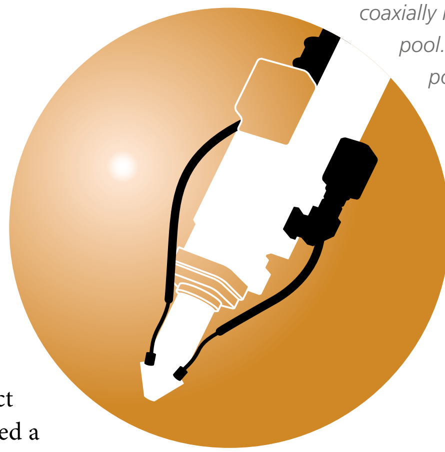
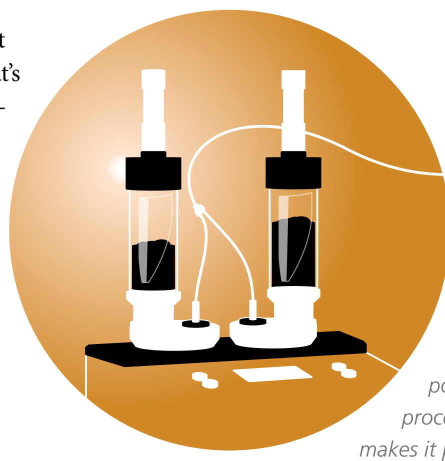


Laser deposition welding: The nozzle sprays metal powder coaxially into the melt pool. This makes it possible to deposit material in every direction.

★ ★ ★

Like all NEW TECHNOLOGIES, additive manufacturing for metal will quickly diversify. The emergence of the LMD method is just the beginning.

★ ★ ★



The conveyor unit mixes the powder during processing. That makes it possible to create alloys, gradients, and sandwich layers.

Illustration: rotwerk

"The opportunity is there!"

Prof. Reimund Neugebauer, President of the Fraunhofer Society, outlines the current state of additive manufacturing and reveals how a commercial breakthrough can be achieved.

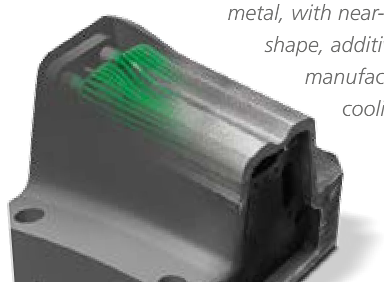
Additive manufacturing machines, products, and services are in demand across the globe. Current market volume is 1.3 billion euros[1] and is growing by 26 percent annually. When we consider that market penetration is between only one and eight percent, we can extrapolate a market potential of up to 130 billion euros.

Many large companies in the automotive and electronics sectors as well as aircraft and engine manufacturers already use additive manufacturing technology for prototypes, preproduction parts, and initial mass production parts. One example is the fuel injection system for GE Aviation engines, which is manufactured as an integral complex part using additive methods, replacing a twenty-part assembly with 19 soldering operations. In the field of medical engineering, series parts have been manufactured in large volumes for some years now. These include hearing aid cases and plastic orthodontic splints manufactured to patients' individual requirements. In the case of additive metal products, I am thinking particularly of dental prostheses such as crowns and caps.

The potentials of additive processes can also be realized in the fields of tool- and mold-making. Tools manufactured using additive methods have a direct effect on mass production, because they enable additional or improved functions. Researchers in the Green Car Body Technologies project demonstrated this effect. They managed to slash the cycle time for the hot forming of sheet metal by 20 per cent and save 715 MWh of energy by means of tool inserts manufactured using additive methods and fully suitable for mass production, with near-net-shape, geometrically complex cooling channels. Similar savings are possible in plastics injection molding, light-alloy die casting, and forging when laser-melted tool and mold inserts are used. In this way, additive methods pay for themselves quickly in the form of cost savings, reduced resource use, and improved component quality.

In spite of very promising approaches, a lot still needs to be done to help additive processes achieve a commercial breakthrough. Universities and companies are called on in equal measure to propagate knowledge about additive methods. Further research and development will make additive processes more robust, repeatable, and cost-effective. In the Fraunhofer Additive Manufacturing Alliance, eleven institutes throughout Germany are carrying out research covering the entire process chain. One of the questions the alliance is exploring is how to increase productivity — and hence reduce costs — in laser-based additive manufacturing processes. One solution is to increase laser power from the 100 to 400 watts generally available today to a full kilowatt. Developers at the Fraunhofer Institute for Laser Technology ILT in Aachen are working to make this a reality. Working with project partners, the institute has already presented initial machines that allow aluminum engine blocks to be manufactured from a single piece.

The need for monitoring quality is another aspect. To meet exacting standards, comprehensive quality management systems are required. Fraunhofer researchers are busy here, too, working on methods to monitor manufacturing processes in real time. These methods will allow processes to be fully documented and irregularities to be identified. The long-term goal is to give manufacturers the ability to intervene in the running process and make adjustments as soon as a problem arises. Additive processes offer huge potentials as regards efficient production and sustainable value creation. Now it's a question of taking these opportunities. ■



Tool insert for hot forming sheet metal, with near-net-shape, additively manufactured cooling[2]

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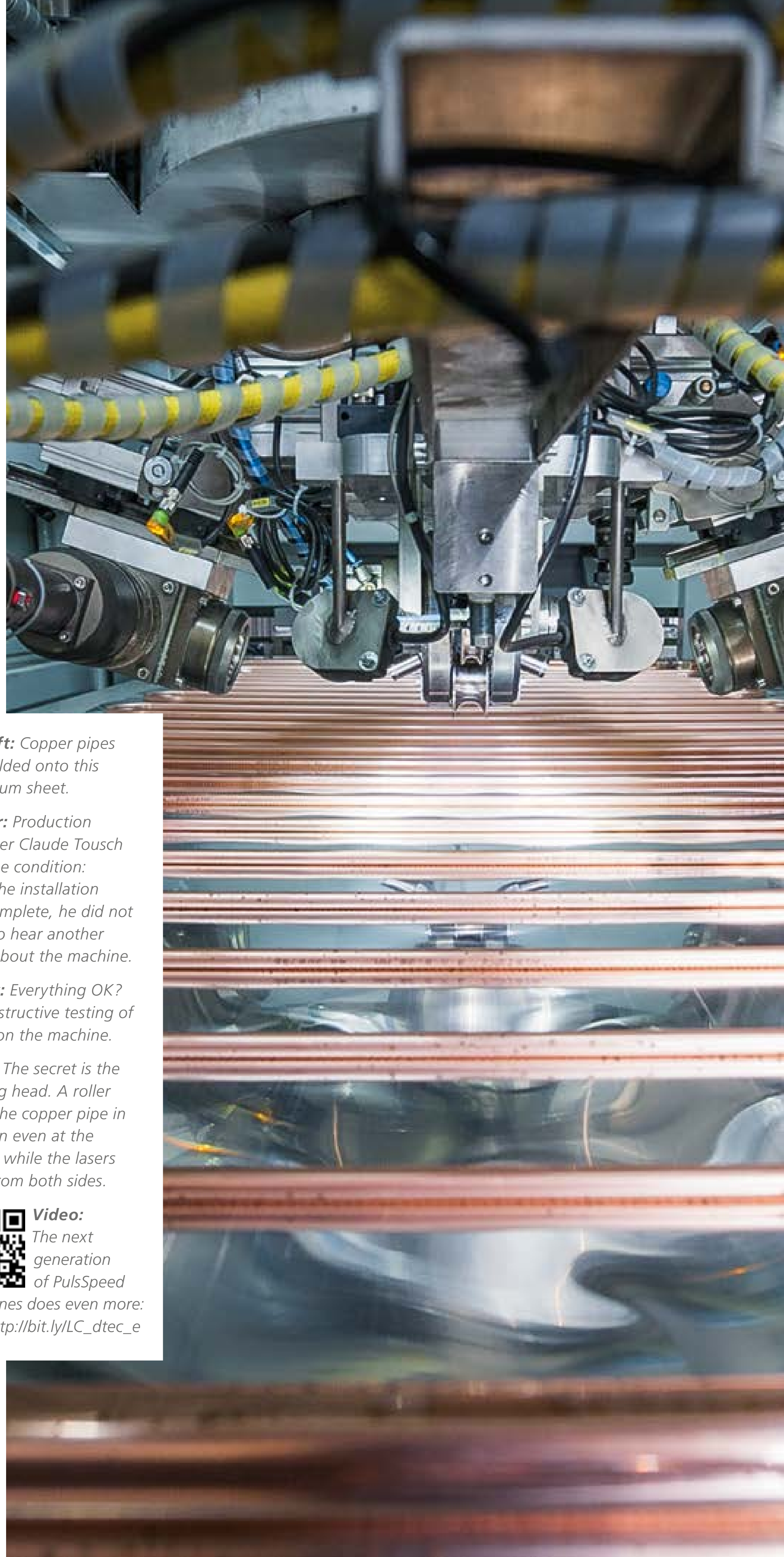
Prof. Reimund Neugebauer, D.Eng., is President of the Fraunhofer Society. His principal research interest is resource-efficient production.

[1] Source: Wohlers Report 2012 [2] Photomontage of a rendering and an original part



Top left: *Copper pipes are welded onto this aluminum sheet.*

Center: *Production manager Claude Tousch had one condition: Once the installation was complete, he did not want to hear another word about the machine.*

Below: *Everything OK? Nondestructive testing of welds on the machine.*

Right: *The secret is the welding head. A roller holds the copper pipe in position even at the bends, while the lasers weld from both sides.*

Video: *The next generation of PulsSpeed machines does even more: http://bit.ly/LC_dtec_e*

Mr. Tousch's quest for peace of mind

With a cycle time of 72 seconds and high tensile strength, Viessmann has got itself precious breathing space.

The hall hasn't reached desert-like temperatures yet — that happens only at the height of summer. It's still pretty warm though. The two machine operators are spraying their faces with mists of water. Streaks of light and patches of shadow form patterns on the sheet aluminum, the copper pipes, and the fastest laser machine in the solar collector industry. The machine has held this distinction since 2010.

The hall is a former warehouse and is part of Viessmann's plant in Lorraine, in northeastern France. This is where the German company located its production of solar collectors for solar thermal systems and operations soon expanded rapidly. In the shadows at the rear of the hall, special machines bend and join copper pipes, forming meanders. At the front of the hall, the record-breaking machine is busy welding those meander pipes and sheet aluminum to create absorbers, the centerpiece of a solar collector.

The laser machine owes its presence there in large part to production manager Claude Tousch's powers of persuasion. "We hadn't planned to invest in new equipment at all. All we wanted to do was replace copper with aluminum."

That is because copper is expensive, and back then absorbers were still made entirely out of copper. Not only is the metal a very good conductor of heat, it is also extremely corrosion-resistant. However, it is only for the pipes that corrosion resistance is of significance. "As far as the backing panel was concerned, we knew that we could switch over to aluminum without any concerns," says Tousch. "It has no impact on the collector's performance or service life. And yet it brings down material costs significantly."

A 423 kelvin gap Where the material did make a difference, however, was in the laser spot welding process, which was already widely used in the sector at that time. The melting points of the two metals are far apart: copper melts at 1,083.4 degrees Celsius; aluminum at just 660.4 degrees Celsius. In other words, by the time copper is gently expanding, aluminum has long melted and gone. Nevertheless, the materials are not unweldable, as Tousch explains: "It's a matter of fulfilling a series of conditions."

To deal with the extreme differences in melting points, the welding laser is not pointed at the contact point where pipe and sheet touch. Instead, the pulses hit the copper pipe a few hundredths of a millimeter above this point. The copper pipe passes a portion of the heat generated to the aluminum. And when everything is just right — when the pipe is in seamless contact with the sheet metal, when the focus is perfect, and when pulse energy and pulse power are precisely metered — the hot, melting copper conducts exactly the right amount of energy to the aluminum, causing it to melt, too. The resulting series of welding spots joins the workpieces. However, the decisive question is: How securely does it actually join the pipe to the sheet?

Because Viessmann's solar collectors have to satisfy very high quality standards, Tousch set a detachment force of 30 newtons as the target, which was double the amount the spot welds have to be able to withstand. But: "In hundreds of welding tests, we didn't even get close to the target with the old machine."

A road trip "It was in this state of mental frustration that I went to Austria," remembers Tousch. Michael Dietl, managing director at machinery manufacturer DTEC, had promised Tousch something special: tests on DTEC's new welding machine for absorber sheets — on a real installation, belonging to a real Viessmann competitor. Tousch and his colleagues unpacked their metal sheets and meanders, got started welding, and were amazed at the results. Every single spot was welded perfectly the first time! That was something that had mostly eluded the team back home. Then came the critical tensile test. The spots held at forces up to 45 newtons — far beyond what is required. And over the following tests, DTEC's PulsSpeed machine also reliably satisfied the many "musts" of the copper-aluminum welding process, for every single weld spot. →

Left: *The weld seam on the front of the absorber. On the rear, the two lasers have applied weld spots every three millimeters.*

Right: *In the background, you can see the entrance to the production line where the modules are assembled. In the foreground, no more than 50 absorbers are in temporary storage awaiting the forklift. That number used to be closer to 125 — at least.*

In the past it was common practice in the solar thermal sector to use sensors to guide the head along the pipe. But the fractions of a second between sensor signal and control command kept causing small deviations in the focal position. In the case of copper on aluminum, that is enough to jeopardize the process. "Instead, we employ a non-displaceable mechanical guide system: A roller presses the pipe to the sheet and the swiveling welding head follows the contours of the pipe — even around the bends," explains Michael Dietl. "That ensures that the heat flows correctly, the position of the pipe is always exactly defined, and the lasers simply have no option but to hit their mark."

No breaks, no snags

Of course, they were not giving this engineering feat away for free. "I was certain that our future lay in this machine," says Tousch. "If the machine worked fast enough, it would allow us to tighten up the whole process and we would be able to reduce our inventory." For Tousch, there was an important prerequisite: he had to be able to rely on the machine one hundred percent. The machine had to work without interruptions, without snags, and without unplanned additional costs, idle-time costs, or repair costs. He wrote all that down for DTEC in the performance specification. As for the cycle time: he wanted a finished absorber every 72 seconds. DTEC designed the machine to have two laser chambers. That way, the machine can continue working with one chamber while the other is being maintained. Seven tables controlled by the machine move between the loading station and the chambers. Four TRUMPF TruPulse lasers supply the pulses. The solid-state lasers work reliably even in the face of the reflectance that is so typical for copper. "We've never had any trouble with the beam sources. We replace the lamps on schedule and then forget about them until the next maintenance cycle comes around," says Tousch.

The DTEC machine has been in operation at Viessmann's plant in northeastern France for three years now, welding 17 different types of solar absorber. "We pushed the button and since then it has been working away. We haven't even had to correct the parameters yet," notes Tousch. The reliability of the machine is neatly illustrated by the lack of clutter: there are 50 absorbers at most in interim storage. That would feed the downstream production line for exactly four hours. "In the past, my palms would start to sweat whenever we had fewer than ten hours' worth of stock in reserve," says Tousch, before adding: "Today we make far fewer absorbers to have in reserve; I know I can rely on my machine." He looks at the laser welding machine. "We paid a bit extra for it. But we got peace of mind. Everyone wants peace of mind. And we've got it." ■

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VIESSMANN
With over 10,000 employees, Viessmann is one of the leading international manufacturers of heating systems. The family-run business is headquartered in Allendorf in the German state of Hesse. Its solar thermal factory is located in Faulquemont in northeastern France.

DTEC
The company in the Austrian town of Spital am Pyhrn is a machine construction and automation technology specialist for the solar, automotive, and home appliance industries. Founded in 2007, the family enterprise now has 20 employees.

KD Busch

WELCOME TO THE CLUB

German knife manufacturer Zwilling really wanted to use laser cutting, but there were obstacles to be overcome first.

Down comes the forging hammer on the bead in the center of the blank to form the bolster, located between the blade and the tang. This will later serve to protect the hand. The force of the blow drives the steel out in all directions and destroys all reference points for the workpiece's edges. This rules out laser for cutting the contours of the knife. After all, without reliable edges, there can be no reliable positioning.

Yet laser cutting was so tempting. The contours could be user-programmed, the process wouldn't need any tools, and the mechanical stress on the steel would be zero.

Tempting as it was, however, it just wouldn't work. Not in the process that knife manufacturer Zwilling was using. Ulrich Nieweg, head of Zwilling's prefabrication department, explains: "Fifteen years ago, we introduced upset forging so that

Knife blanks: When the screw press strikes and forms the bolster between the blade and the tang, all other reference points are instantly lost.

we could form the blade, bolster, and tang — the piece in the handle — from a single blank." The piece of blade steel is heated and compressed, and the resulting bead that forms in the middle is then forged by a screw press to create the finished bolster. With its defined shape, the bolster is the only constant reference point. "During subsequent contour cutting, the die would hold the bolster and use it to determine the position of the workpiece in the tool. All other dimensions were secondary for us," says Nieweg.

> "It became clear that laser cutting was the only sensible option for us."

Although the upset forging line worked well, two drawbacks became increasingly apparent: tool costs and changeover times. "We used to design a new punching tool for each item and each change in shape. That devoured a lot of time and money, as did the need to regularly reset the tools. In addition, the punching process introduced additional stress into the blade." This led in turn to more rejects, rework, and downtime.

Given the trends toward more frequent changes in blade design and special series, more and more dies and set-up operations were needed. And so Ulrich Nieweg set out to find a user-programmable alternative to the punching machine: "Water jet cutting doesn't work, because the workpiece has to remain dry for further processing inside the machining cell. Plasma cutting makes for too much burn-off and more rework. That leaves the laser as the only sensible option available to us."

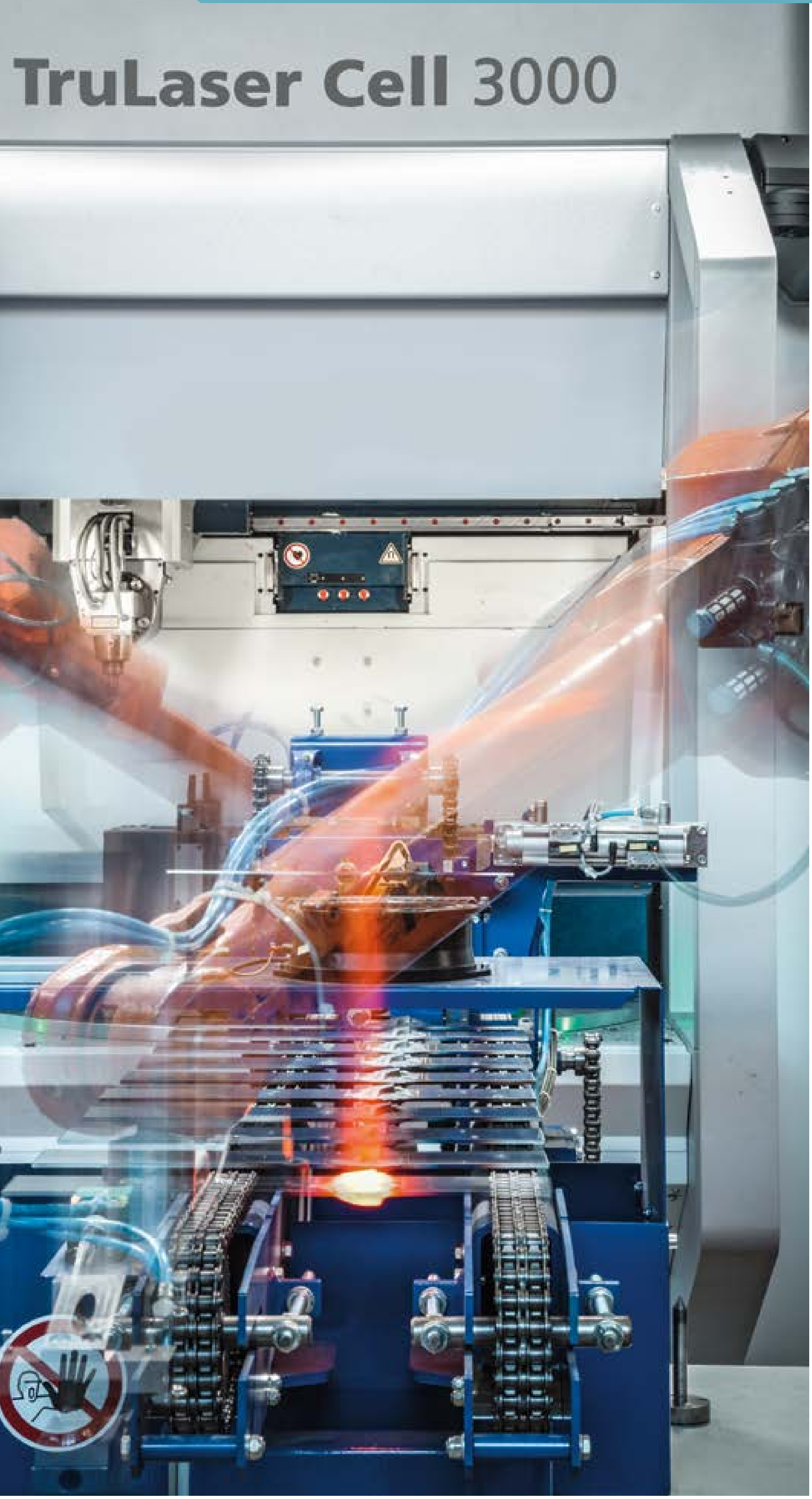
All down to the handling

So far, so good. But Nieweg couldn't position his workpiece in the clamping fixture using the shape of the bolster, as the cutting path passes directly along the bolster. "Visual positioning isn't precise enough in this special case. We want to align a long workpiece using closely spaced points. Small measurement tolerances add up to deviations of several millimeters over the length of the piece," explains Nieweg. "It was only once we stopped racking our brains about the set-up in the laser machine and took a look at automation as a whole that we hit on the solution."

This was to consist of three steps with two handover points. At handover point one, a robot takes the 1,200-degree blank out of the screw press and deposits it on a cooling section. At handover point two, the robot takes the blank, which has cooled down to 200 degrees, and places it in the clamping fixture. "Normally it would be the clamping fixture that aligns the workpiece so the laser can reliably cut it," explains Nieweg. "That wouldn't work for us, so now it's the robot's job."

The robot deposits the workpiece in an exact position at a precisely defined angle — without cameras or sensors, using only its hand, which consists of a gripper molded to the exact negative form of the bolster. Since the gripper forces the bolster — and the whole workpiece along

SOLINGEN AND ZWILLING The city of Solingen, near Düsseldorf, has been famous for its sharp knives and top-quality blades since the 13th century. Alongside other Solingen knife manufacturers, Zwilling J.A. Henckels AG upholds the reputation of this "City of Blades". In addition to manufacturing high-quality knives and scissors, it also makes cooking pots and cutlery. The company was founded on June 13, 1731, and its zodiac sign supplied the name: "Zwilling" is the German name for Gemini. Zwilling is one of the world's oldest brands.



Left: *Ulrich Nieweg heads Zwilling's prefabrication department.*

Bottom left: *The molded gripper forces the blanks into a defined position, aligning them with the laser machine's reference system.*

Right: *The robot on the right takes the blank from the press and lays it on the cooling section. Using the molded gripper, it then takes a cooled, pre-positioned blank and puts it in the clamping fixture on the laser machine's rotary shuttle table. The robot on the left does the unloading.*

with it — into a defined position, this position can now be deemed fixed when programming the process. To let the robot grip blindly at the end of the cooling section and still catch the workpiece exactly on the bolster, a cylinder first shoves the blank to a programmed position.

Next, the robot places the blank in the clamping fixture on the rotary shuttle table of the TruLaser Cell 3000, and the fixture closes. Only then does the mold gripper open, since the blank is now clamped in the position in which the robot deposited it. Again, the programming can work with a defined position — with no need for additional communication between robot and machine. Nieweg explains: “The robot picks up something positioned at x-y-z. It swivels and deposits it at position x1-y1-z1. Then the table rotates and the laser machine runs blindly through the programmed cutting coordinates.”

As quick as a new data set!

Nieweg is impressed by the flexibility and programmability. “Previously, we had to make and set up a new punching tool for every little variation in blade shape. Today we just send over a new data set and the job's done.” In the summer of 2013, the Zwilling team integrated the laser machine and automation into the line. Now they are running at full capacity. The line produces around 100 blades an hour in 15 versions. “It now takes us half an hour less to change the line over,” says Nieweg. “That means 50 extra blades every time!”

Ulrich Nieweg was on summer vacation during the final installation phase. “When I came back and saw the thing in action, I felt proud to have become a member of the laser club.” ■

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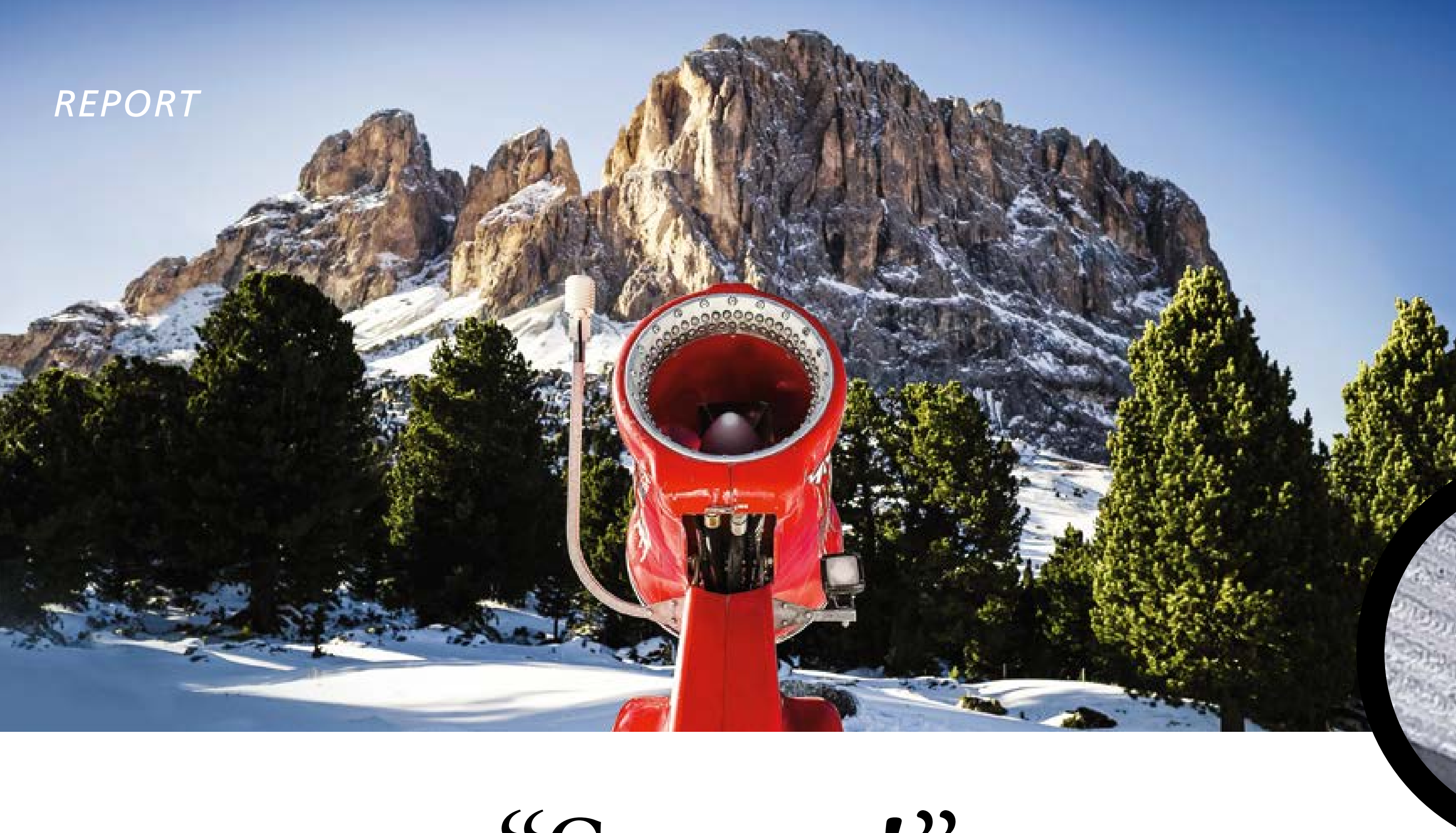

"Super!"

The Austrian company Seiwald Blechform is one of the very first job shops to offer hybrid laser welding. Deputy general manager Dieter Achleitner explains why the move paid off.

The hybrid process comes from shipbuilding. Here we are at the foot of the Alps. What do you weld?
It's true enough that we don't have any shipyards among our clientele. We do a lot of work for the vehicle construction sector. But there is also one thoroughly Alpine application: snow cannons.

Snow cannons?
The mouth is actually an aluminum ring incorporating water nozzles. Channels inside the ring supply water to the nozzles. The manufacturer first takes a solid component and then turns the channels in the form of open grooves. We close them off by welding them shut from above. The seams have to master intense variations in stress and withstand test pressures of up to 120 bar.

Was this design developed for hybrid welding?
No, but it is a very nice illustration of what makes hybrid welding interesting for us. By rights, automatic welding of the seams should work wonderfully well. But their tolerances, the qualities of aluminum as a material, and the weld depth make normal laser welding impossible. So instead, the parts were always welded by conventional means. Our hybrid laser welding robot, by contrast, has absolutely no trouble dealing with the material, tolerances, and weld depth, and it completes the six continuous seams in a fraction of the time.

Outside of shipbuilding, hybrid laser welding is normally associated with the high output and long production runs typical of automotive manufacturing. That doesn't really fit the profile of snow cannons.
That's right — we don't have these huge lots of two or three hundred thousand units. But getting large contracts wasn't our aim either. That would mean fundamentally changing our business, handling a few big orders for a few big customers. What we were actually looking to do was to procure an advantage for our many customers — big and small — by installing a new technology for their short and medium-scale batches.

How did your specific requirements as a job shop affect the configuration of the machine?
When we started planning the machine together with Fronius, the main condition was great flexibility. That's why it masters three different processes: hybrid laser welding, the pure laser process, and CMT — cold metal transfer — welding, an arc welding process developed by Fronius, one that is very quiet and can be controlled precisely. The machine is based on a TRUMPF TruLaser Robot 5020 with a TruDisk 4002 solid-state laser generating four kilowatts of power. To be able to weld very long components such as crane jibs and truck trailers, the machine has a longitudinal axis of seven meters. For more modestly sized components, there is a turn-and-tilt table, so that we can reach areas that are hard to get at. And we have installed a shuttle table to handle large manufacturing runs.

Aluminum rings for snow cannons: the productivity gain due to using the automated process is huge, but the only way to achieve it is with the hybrid method.

Deputy general manager Dieter Achleitner standing in front of the machine, designed in collaboration with Fronius and TRUMPF. Behind him, across a travel path of 7,000 millimeters, is the beam source, a TruDisk 4002.

Robot-controlled hybrid laser welding (video): http://bit.ly/LC_seiwald_e

What do you consider to be long production runs?
Orders for a few thousand parts per batch are not infrequent. This is where the machine achieves its full potential. But recently we've been getting more and more enquiries about critical situations, where the weld's loading capacity and quality play a decisive role. In such cases, we are often talking about a few workpieces or even just one. The added value for our customers is that they have quality control and detailed documentation of the welding.

Pure laser welding already offers these advantages. What made you take the further step of acquiring hybrid laser welding capability?
Our machine gives us the option of working with a pure laser process whenever we want. But the laser method on its own is too narrow for us.

Narrow? Most people would say it has a broad range of applications. Isn't that what makes it so popular among job shops?
Again, that's a matter of perspective. Of course laser welding offers a great number of possibilities within a specific field. But we often have to deal with components that are thick, with deep welds. On top of that, more and more ultra-high-strength steels are coming into our shop, and these often pose problems for the pure laser.

Why is that?
One reason is that the tolerances after hardening are often too small for the pure laser process. And yet reworking is not an option. With the hybrid process, on the other hand, there is no need for finishing. It is also a question of heat input. A pure laser process has extremely short cooling times, which can lead to imperfections. The pure arc welding process injects too much heat and softens the material. By contrast, the hybrid process gives us the option of precisely metering the heat input by adjusting the laser and MIG/MAG torch parameters. That lets us weld with minimum structural change to the material. And the filler material in the welding wire allows us to further influence the properties of the weld — its toughness for example.

With your machine, you effectively have no competitors. Have you noticed any effects?
It's true that there are virtually no other job shops offering hybrid welding. On the other hand, there are still very few companies specifically looking for this service.

Putting it bluntly, does that mean you get a lot of orders not because of but in spite of the hybrid laser welding machine?
I wouldn't put it in quite those terms … The thing is, our market works like this: Most components that are sent out to subcontractors can be processed effectively using conventional methods. Consequently, when we suggest making a part on the hybrid laser welding machine, we often have to justify the benefit to the customer. On paper, the process often costs them more for small- and medium-sized series because, for one thing, we need more precise clamping mechanisms.

What is it that convinces your customers in the end?
Some welcome the fact that they can continue to design for conventional processes while also getting their workpieces back much faster and at better quality than before. Others discover that there can also be design advantages for them when they go the hybrid laser welding route. And all our customers value the reproducible quality of the welds and reliable process documentation — in other words, all the advantages offered by this high level of automation. ■

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Prof. Seiji Katayama

The unweldables

Joining materials that have long been considered unweldable is one of the biggest challenges in lightweight engineering. The laser offers some promising solutions.

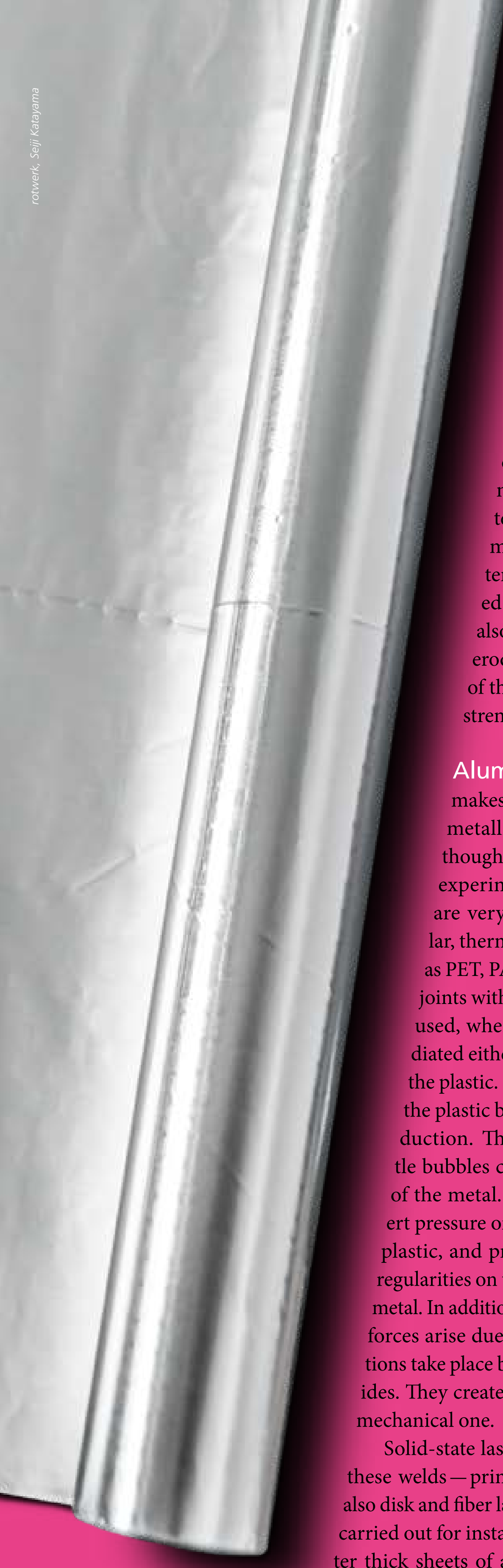
The shift toward lightweight construction is presenting industry with a growing challenge. The material mix is becoming more diverse while, at the same time, there is increasing pressure to develop mass-production joining processes that are fast, efficient, and add no extra weight. That is why we are seeing the emergence of a growing number of welding and soldering methods for joining lightweight materials such as aluminum, titanium, magnesium, and fiber-reinforced plastics. Laser methods are proving to be particularly flexible here. As well as being easy to integrate into existing production setups, they also obtain good results with many material combinations that had previously been considered very awkward or impossible to weld. Aluminum is playing an increasingly important role as one of the materials in these new welding endeavors.

Aluminum and steel Steel is one of the most commonly used metals. Experiments have succeeded in welding thin (less than 2 mm), low-carbon steel sheets to group A6XXX aluminum alloys (containing magnesium and silicon) in resilient, durable lap joints produced by diode or YAG lasers. In this process, the laser is focused for the most part on the steel, but without melting it. Heat conduction and a small amount of absorbed beam energy then melt the aluminum. This produces a thin layer of metallic iron and aluminum compounds at the interface between the aluminum and the steel. If this layer is thinner than 10 microns and if the iron-aluminum compounds with low aluminum content predominate, then the result is good fatigue characteristics and high tensile strength. The experiments have also shown that flux and filler materials such as aluminum-silicon wire further improve the mechanical characteristics of the welds. In a variation on the process, only the steel sheet is irradiated. The aluminum is melted via heat conduction, and the weld is subsequently rolled.

A completely different approach involves welding the lap joint through the steel or stainless steel sheet and anchoring the roots of the weld around 0.2 millimeters deep in the aluminum sheet. This method produces high resistance against shearing. On the other hand, the resistance against stripping is low, although it changes when the welded surface area increases — with three parallel welds, for example. In this case, the specimen fails in the aluminum base material.

Butt welding is also possible. Again, only the steel is irradiated and the aluminum is melted via heat conduction. The joint comes apart even at relatively low tensile loads or as a result of external shocks. An interesting approach compensates for this weakness. Here the steel component is fitted to a flange on the aluminum component. This creates a combination of lap and butt welding, where the laser melts the steel close to the butt. While doing so, it also melts, by heat conduction, a track in the aluminum in the flange below the steel, creating a lap joint. At the same time, however, the molten steel also melts the aluminum in the butt. This creates a double seam, which embeds the steel in the aluminum and anchors it in the aluminum base material via the roots for the lap joint, significantly improving the weld's mechanical characteristics.

Aluminum and titanium Aluminum and titanium alloys can be welded with lap joints. Generally, titanium is welded onto aluminum alloys. The laser beam heats up the titanium and melts the aluminum material by means of heat conduction. As with the welding of steel and aluminum, a thin layer of a titanium-aluminum compound is created on the bor-



rotwerk, Seiji Katayama

der between the titanium and aluminum alloys. The joint exhibits high tensile strength and the samples ultimately fail in the aluminum base material. Examination of the welds created using pure aluminum and titanium also showed that the molten aluminum erodes and thereby roughens the surface of the titanium, which contributes to the strength of the joint.

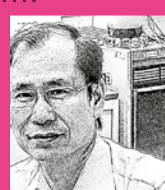
Aluminum and cast resin The laser makes it possible for the first time to weld metallic assemblies and plastic parts. Although such joints are still in the experimental stage, the results are very promising. In particular, thermoplastic materials such as PET, PA, and PC form durable joints with metals. Lap joints are used, whereby the metal is irradiated either directly or through the plastic. Then the metal melts the plastic by means of heat conduction. The plastic forms little bubbles close to the surface of the metal. These expand, exert pressure on the surrounding plastic, and press it into the irregularities on the surface of the metal. In addition, van der Waals forces arise due to the pressure, and chemical reactions take place between the plastic and aluminum oxides. They create a chemical bond in addition to the mechanical one.

Solid-state lasers are used mainly for these welds — primarily diode lasers, but also disk and fiber lasers. Experiments were carried out for instance with three millimeter thick sheets of aluminum alloy A5052 and two-millimeter plates of amorphous PET. The specimens were welded across the full width of the lap joint. Tensile testing revealed that when the weld surface is sufficiently large, the plastic workpiece stretches at the joint with the metal and eventually tears. This happened at a tensile load of around 3,000 newtons.

The ability to heat the parts differently, but with the same beam — that is the laser's great opportunity.

Mix for the future None of the above examples are welded joints in the classical sense, where parts are made of similar materials and those materials mix in a melt in the seam and create a joint. With such disparate materials, this would lead to weak, brittle seams that are very susceptible to hot cracking. Instead, all the above methods build on the possibility of treating the two parts differently. One of the parts is melted and the other merely heated, in order to transport heat and facilitate the distribution and adhesion of the pool. The only tool that permits such selective heating reliably and with reproducible results is the laser. While low-intensity diode lasers are also suited to the task, the ideal lasers for most processes are pulsed solid-state lasers, which allow extremely fine control of heat input.

Lasers achieve joints that welders had long thought to be either extremely difficult or entirely impossible. It is no great leap to conclude that the continued development of lightweight construction and of miniaturization will be closely associated with further developments for these methods. Although the number of manufacturing applications is still small, we are certain that continuing research work and the needs of industry will change this in future. ■



__Seiji Katayama__ is the general director of the renowned Joining and Welding Research Institut at Osaka University, where he has spent most of his career, starting from the late 1970s. His work at the JWRI revolutionized the aluminum laser welding as well as metal-plastic bonds.

"I am a hundred percent Nebraskan"

Dr. Yongfeng Lu's spiritual home is the international laser community.
This is a story of home – set in China, Japan, Singapore, and Lincoln, Nebraska.

You've traveled around the world. Is there an international laser community in your opinion?
Yes, and I believe globalization of the industry is growing the community. This shared identity is evident at conferences. Conferences reflect the world in terms of trends, integration and globalization. We cannot work alone. We must extend our community to overlap with and learn from the larger technology world. We communicate in the languages of different countries, but as laser professionals, we all speak the same technical language.

You learned this technical language first in your native country, China, and then in Japan. How did that happen?
There was an exchange program between the Chinese and Japanese governments and I thought it would be a good experience. I was a big fan of Japanese movies in 70s and 80s — they made quite an impression on me. I identified with the transition from traditional to modern society shown in Japanese movies. That sense of familiarity gave me the confidence to move to Japan.

Did you experience a culture shock?
At that time the Japanese economy was very strong. In China, lasers weren't yet popular as a high-tech product. University labs could only afford a few lasers, operated by specialized technicians. In Japan, even students could use lasers and other high-tech equipment. I was shocked to see how much more efficient and advanced the technology was in Japan.

Were there many students going from China to Japan at that time?
No, I think the language barrier kept Chinese students from going to Japan. Before I left, I trained in Dalian, China, for nine months as part of an intensive Japanese language study. I worked hard — from six in the morning until midnight. By the end, I could communicate and read textbooks in Japanese. It was really an amazing program, very effective.

What changed you more? Going from China to Japan or from Japan to the U.S.?
Don't forget the time in between, which I spent in Singapore, and which influenced me a lot. Research and industry are closely linked in

Kameron Bayne Images

Singapore, which is very manufacturing based. As a professor, I worked with companies involved with laser applications for the electronics and computer industries and developed a customer service approach to research. We were encouraged always to understand the market needs and industry requirements. Before that, my first experience abroad in Japan made me feel like I was finally part of the world rather than in a corner of it. It definitely made me more open-minded, but actually, I'd say coming to the U.S. after my time in Japan and Singapore was the biggest turning point. Japanese society was very homogeneous. As a foreigner who didn't grow up in the culture, it was difficult to know how to fit into everyday life. American society is more open, diverse and tolerant. The exchange of information and ideas is easier here. You can be your own person.

People around the world dream of California or New York and the New England States. But you settled in Nebraska.

Nebraska is a great place to work and live. I came here because of my interest in the work of a professor who I had met and who specialized in nanotechnology and lasers at the University of Nebraska. Soon, I really appreciated how straightforward, friendly and easy to work with the people are. And it may seem insignificant, but I really love having a house and mowing the lawn. I enjoy the American lifestyle and spending time with my wife and two children. They've traveled with me around the world, but are now 100 percent Nebraskan.

"For nine months, I studied Japanese from six in the morning through to midnight. By the end, I was able to communicate and read textbooks in the language."

Nevertheless, do you miss anything about China?

I still maintain ties to my native country. It's easy for me to communicate with people in China and they're doing a lot of research and development. I work with Chinese universities and bring students here to study.

How does their experience differ from yours?

When I studied in China, we learned mostly from textbooks, but could explore what we liked. In Japan, the lab was very well structured, with a clear research direction to follow. The research atmosphere in China has now become similar to U.S. in terms of being end-driven. Research is very competitive here. It's good real-world experience and American students transition easily after graduation. The drawback is that they don't have the time to experiment with what they like. If we had the luxury to explore our own ideas, we might develop some different or surprising results.

Right now, you are working on diamond coatings.

Yes, that is a catchy way to put it. Our lab produces nanostructured carbon materials: diamond, graphene, carbon nanotubes, and carbon nano-onions. There are many practical applications for nanomaterials. We use lasers to apply diamond coating to surfaces, for example, to improve thermal and wearing performance. We are cultivating nano-onions for use as an engine oil additive that improves the engine life and fuel efficiency of cars. We're also using lasers for nanofabrication and optical spectroscopy for material analysis. In one revolutionary application, we can use lasers to show differences in chemical makeup and, for example, help distinguish normal cells from cancerous cells.

What makes lasers a good fit for your work?

Lasers give us flexibility for a wide range of applications. For example, we use different wavelengths

LIFE After receiving his bachelor's degree in China and his master's degree and Ph.D. in Japan, and working in Singapore, Dr. Yongfeng Lu moved to the University of Nebraska. He's authored more than 250 journal articles and 300 conference papers on nanomaterial, optical spectroscopy, and nanofabrication research.

LASER An undergraduate laser annealing project designed to reduce defects in semiconductors sparked Dr. Lu's interest in laser applications.

ACHIEVEMENT Of his many professional honors, Dr. Lu considers his Berthold Leibinger Future Prize — won in 2000 for his work in laser microprocessing at the National University of Singapore — as the most meaningful.

and laser powers to realize conditions needed to control nanomaterials. Lasers are better at controlling nanotube growth than chemical reactions, which many researchers use. Our goal is to use lasers to improve the culture and location of nanotubes so we can integrate them into circuits and devices. I really like lasers' ability to create energy beams under ordinary atmospheric conditions, which makes the beams easier to manipulate when compared with ion and electron beams which demand a vacuum.

What effect do you hope your work will have on the world?
My goal is to make producing nanostructures easier, more cost-effective, and feasible for a wider audience without access to special, expensive equipment. I'd also really like to be remembered for my efforts to increase international collaboration and technology integration. My hope is that countries can learn from one another to make their research more effective. That would make me very happy. ■

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"We speak many different languages; but as laser professionals, we are united by a shared technical language."

China, Japan, Singapore, the USA: Dr. Yongfeng Lu has lived and worked in many different places. Now he is staying in Nebraska because the people there are open and he has a positive, straightforward working relationship with his colleagues.

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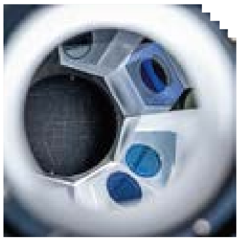

-- "ZUKUNFTSPREIS" AHEAD

Researchers from TRUMPF, Bosch and the University of Jena have been nominated for the Federal President's German Future Prize 2013. The team cleared the road into mass manufacturing for ultrashort pulse lasers.

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-- OPERATION "TABLE"

An operating table must be adaptable to every need and at the same time totally reliable. That is why the company that was to become TRUMPF Medical Systems adopted laser welding long before it joined the TRUMPF Group.

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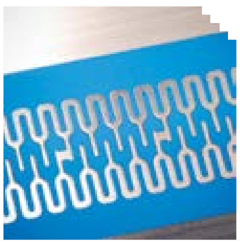

-- "NO ONE ELSE CAN DO IT"

The co-managing directors of LaserJob tell us how the ultrashort pulse laser matches up to the hard reality of job shop operations.

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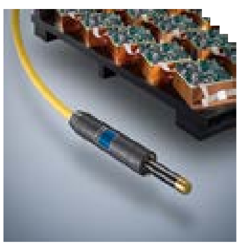

-- LASER MEETS PLASTIC

Lasers and plastics seem to be made for one another. Marking is becoming a standard use, applications for cutting are quickly picking up speed, and even welding is making its debut. New beam sources are driving these developments.

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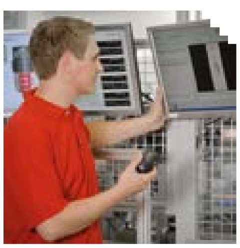

-- BETTER MARKING FOR SMALL BATCHES

perma-tec marks plastic housings by laser. A new software module saves a lot of time—especially with small batches.

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Deutscher Zukunftspreis / Ansgar Pudenz; LaserJob GmbH; perma-tec; TRUMPF

You will find these five articles only online. And we regularly post fresh articles about laser-based materials processing on www.laser-community.com

BONUS TRACKS

Where's the laser?

On the Queen: For the Queen's Diamond Jubilee celebrations in 2012, the best jewelers in the world competed for the honor of making a brooch to be presented as a gift. The monarch wore the winning brooch at Christmas. It is called The Eternal Dove and incorporates the national flowers of the four nations that make up the United Kingdom: the thistle, the daffodil, the shamrock, and the rose, each forged from rare Scottish, Welsh, Northern Irish, and English white gold. When it came to applying the hallmark—the authentication of fineness—to the rare precious metals, there was only one serious candidate: the laser. A marking laser inscribed perfectly legible numbers and symbols into the gold without impairing in any way the general impression of the filigree work. And so the Queen's brooch brought traditional goldsmithery and modern laser technology together in exquisite harmony.

Gernot Walter

60 *seconds*

That's how long researchers at Technical University at Darmstadt stopped a laser pulse in a crystal — as long as the wait at a red traffic light. The interplay between ions in the crystal and a second laser beam transforms the light into a kind of wave trapped in the crystal lattice. When the stop is lifted, the wave turns back into a pulse of light, which continues on its way. All the information transported in the original pulse — a striped pattern for instance — is retained.

Image Source / strandperle