BUILD IT WITH LIGHT

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

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

But let's return for a moment to that steel truss. If Prouvé were to take a tour of the TRUMPF Smart Factory that opened in Chicago in 2017, his heart would probably skip a beat. The 45 x 55-meter cantilevered roof in this fully connected factory is supported by eleven steel trusses welded from individual pieces of steel (on right, fig. A). All the pieces were cut using the factory's own machines. As a result, visitors—and not just imaginary ones like Prouvé—can appreciate this roof as a great example of what the smart factory's machines can do and experience first-hand just how much laser machines can offer the world of architecture. So what might Prouvé have asked fellow architect Frank Barkow from the architects' firm Barkow Leibinger, which designed the TRUMPF Smart Factory? His first question would probably have been how the building could possibly have had a budget high enough to include such extraordinary structures. He would have been amazed to discover that it wasn't nearly as high as he might have expected—all because TRUMPF laser machines were on hand to cut and weld the steel trusses and make the whole roof construction financially viable.

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

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

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

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

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

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

Simon Menges, Gazpromneft Eastern European Projects

fig. C

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

Stefan Müller

fig. D

Hermann Köpf

David Franck

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

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

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

EXTERNAL VALUES MATTER Ironically, it's the superb seam quality of laser welding that sows doubt in the minds of some structural engineers: can something that is hardly visible really be tough enough to do the job? That's a question Eisele has heard many times. Recently, Edelstahl Mechanik GmbH supplied sections for a new building at Harvard University (fig. G, page 18) and was faced with the same doubts: "The U.S. structural engineers were skeptical, but they had no choice but to wait and see how it all turned out. After all, the required penetration depth for the largest sections would have been impossible without the laser," says Eisele.

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

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

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

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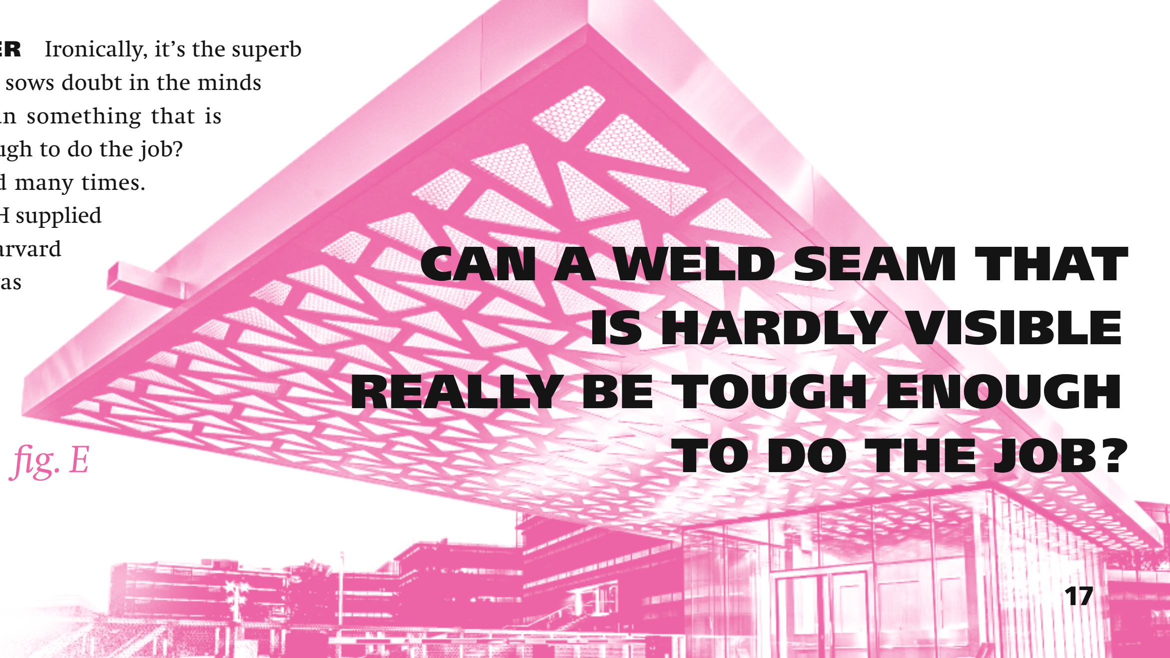


fig. E

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

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


fig. F

David Franck

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

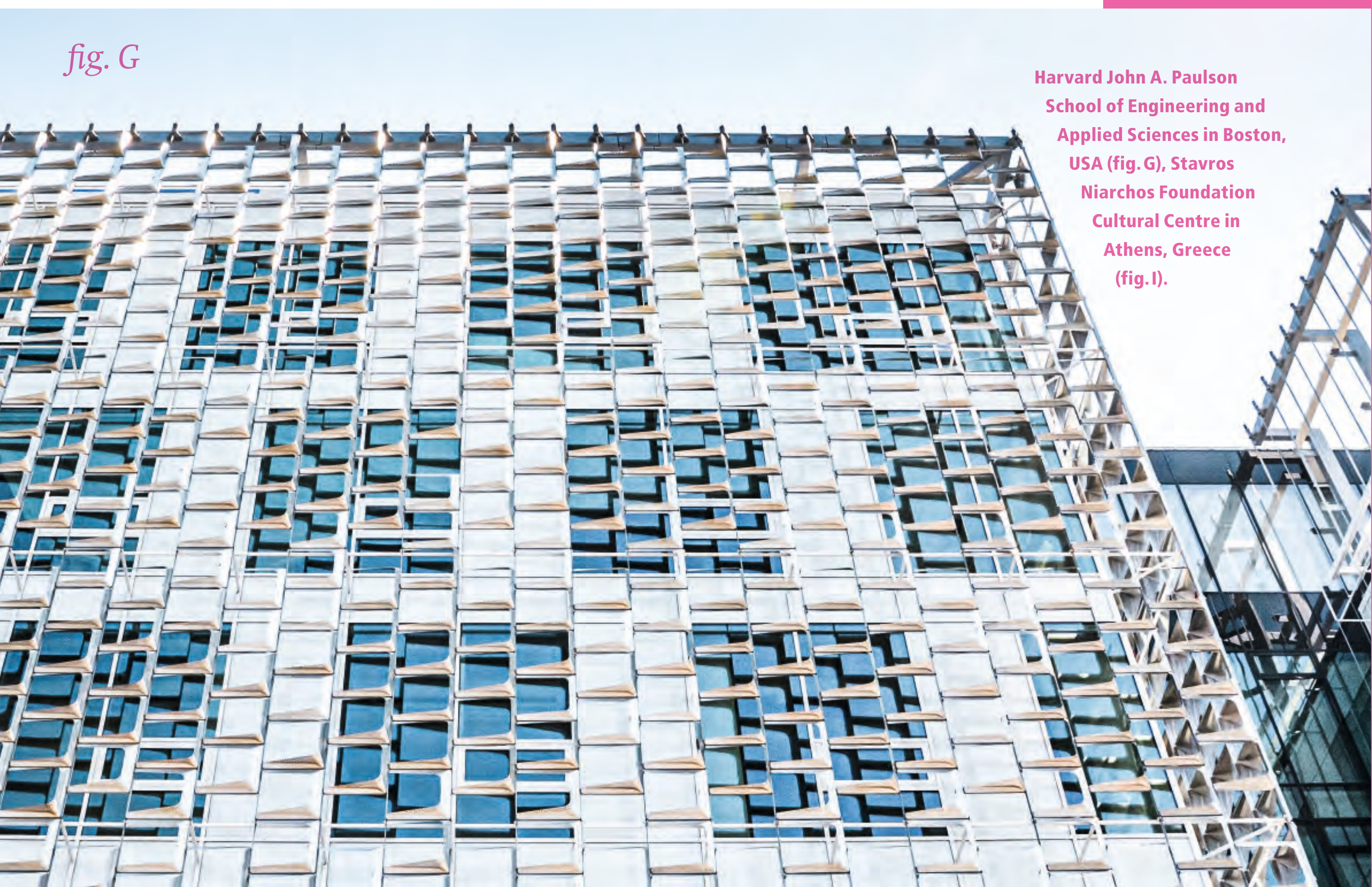


fig. G

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

Behnisch Architekten


fig. H

Christian Richters

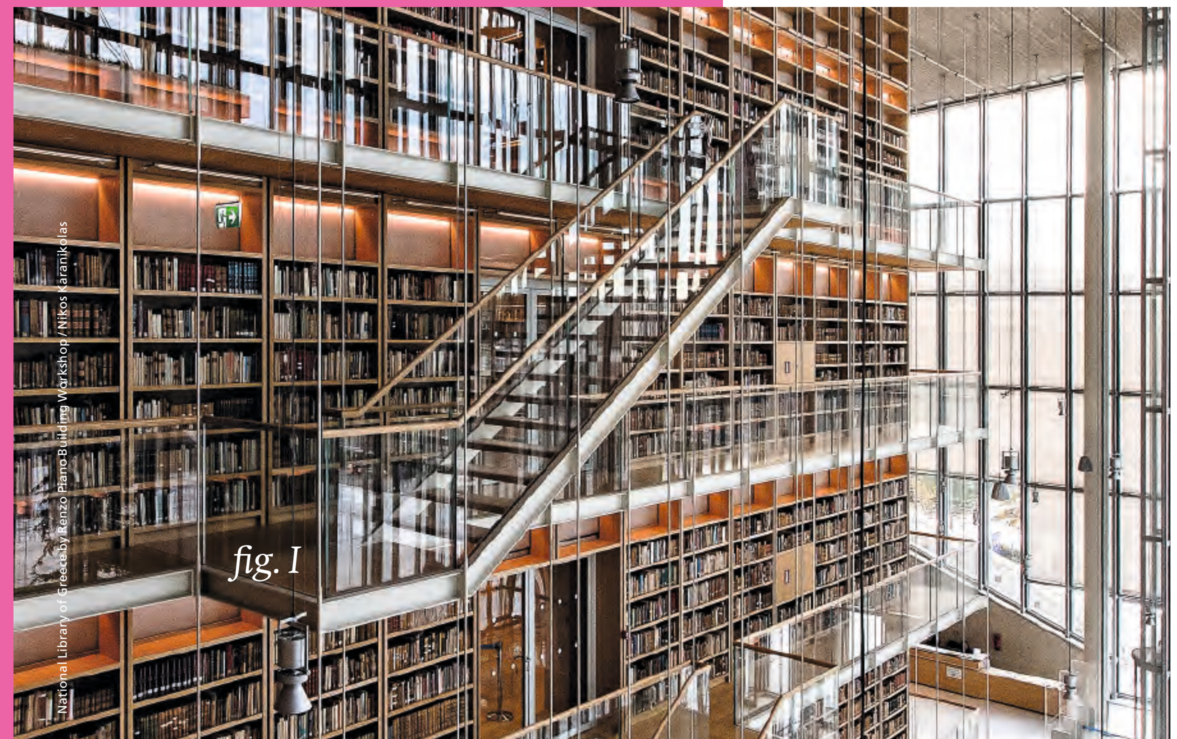


fig. I

National Library of Greece by Renzo Piano Building Workshop / Nikos Karanikolas

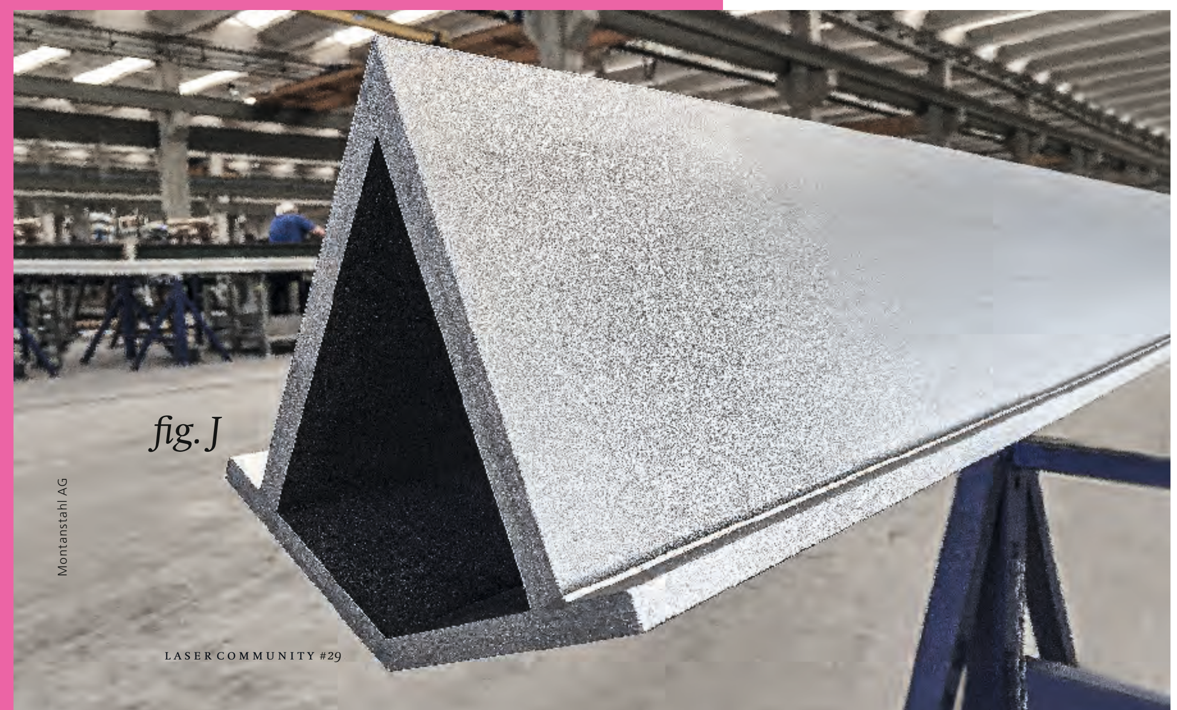
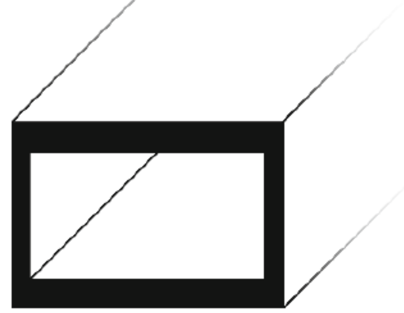


fig. J

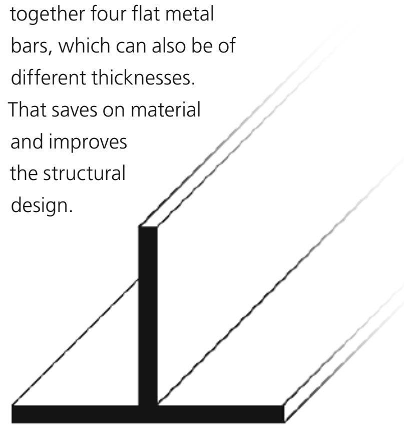
Montanstahl AG

PROFILING STEEL CONSTRUCTION



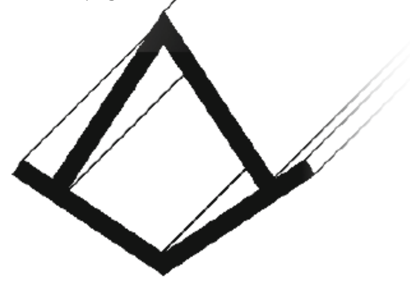
RECTANGULAR HOLLOW SECTIONS

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



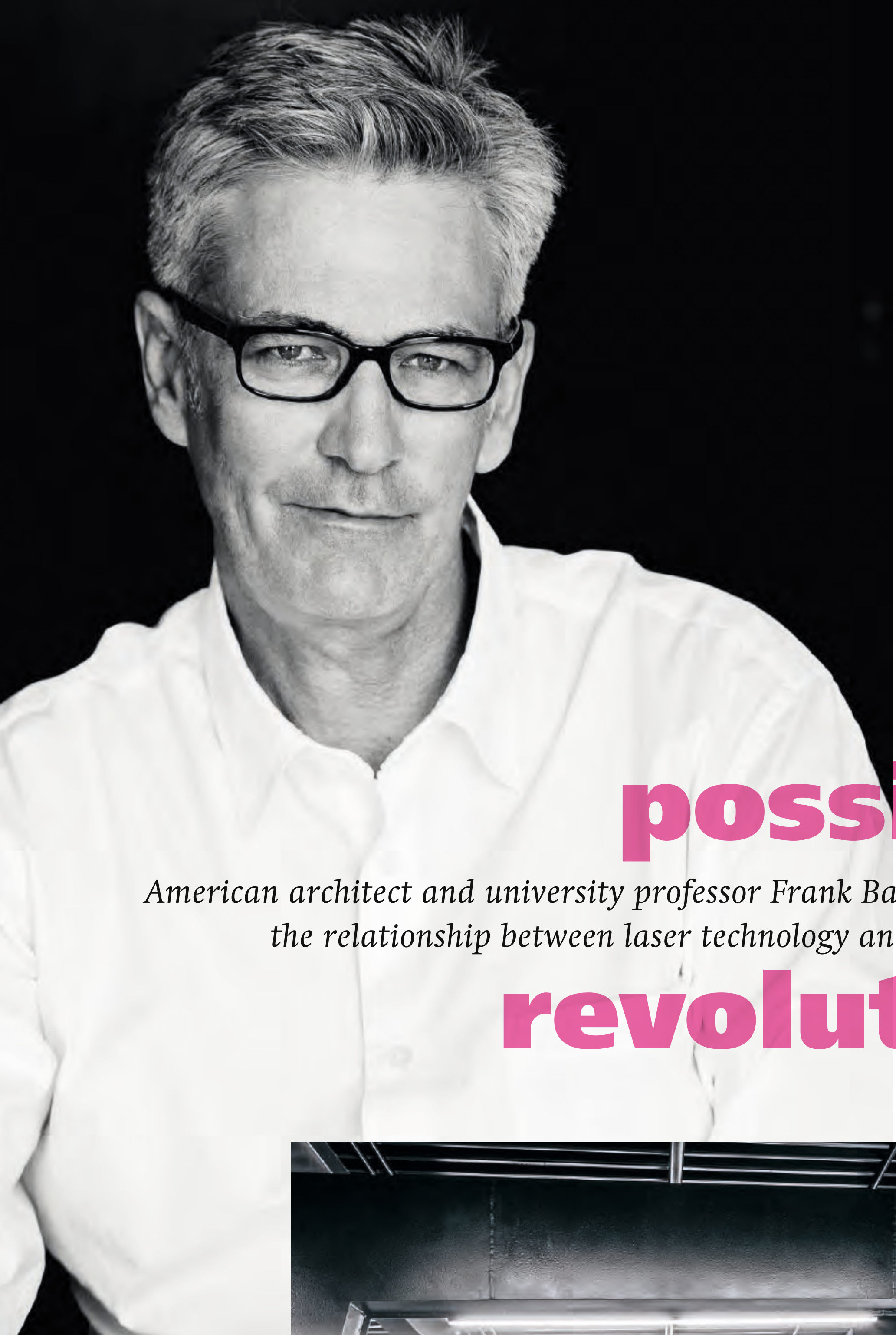
SHARP-EDGED T SECTIONS

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



FREE-FORM SECTIONS

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



“The possibilities are revolutionary”

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

Simon Menges, Corinne Rose

Mr Barkow, the architects’ firm Barkow Leibinger has been designing buildings for the past 20 years – and one of its clients is the machine maker and laser manufacturer TRUMPF. What impact has this collaboration had on your work as an architect?
I have often found myself thinking “Wow! These machines offer amazing potential for architecture—and that potential hasn’t really been properly explored”. When my partner Regine Leibinger and I were studying at Harvard in the 1980s, architecture was undergoing a transition toward digital technology—so making digital drawings and then producing them on the shop floor. When we started working with TRUMPF at the end of the 1990s and I took a proper look at machine tables that a laser had cut and welded, I thought to myself, if we can put these applications into practice on the scale of a building, we can use them to produce completely new kinds of structures and facades.

So you were breaking new ground in architecture?
What was new was the opportunity offered by digitalization, because even back then it was already fairly standard to use products from the mechanical engineering industry for facades and furniture. But we were interested in where the digital era was going to take us. And then, almost 15 years ago, we began developing buildings like the main gate and the staff restaurant at TRUMPF in Ditzingen—buildings that would simply have been impossible without digital and laser technologies.

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

How does that affect the way you plan a new project? Does it mean you always consult with technicians first nowadays?
It used to work like this: we designed something, then a few months later we called in the structural engineer and, a few months after that, we brought on board a facade company that fabricated sheet metal, for example. Now, we try to hold a workshop with the fabricators as early in the process as possible to discover whether our ideas can actually be realized in practice. That knowledge then influences the design process.

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

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

When you’re working with your students at Harvard, Princeton and the Architectural Association in London, do you specifically discuss the benefits lasers offer in bringing architectural concepts to life?
Yes, absolutely. In our lectures, we talk about the opportunities offered by modern technologies such as lasers, and we also involve the students in our research work. We show them a machine and ask them how they would make use of it in their work. The ideas they come up with are amazing.

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

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

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