Fuel cells

A spark of hope for future energy generation

In an innovative collaboration, Gräbener Maschinentechnik GmbH & Co. KG and RAYLASE GmbH are bringing reduced costs and improved efficiency to the manufacturing process

To understand the future, it pays to look to the past: Back in 1838, the principle of the fuel cell was first discovered by Christian Friedrich Schönbein. By submerging two platinum wires in dilute sulfuric acid, one in a flow with hydrogen the other with oxygen, an electrical voltage was created on the wires. This reverse electrolysis produced electricity.
"Water will be the coal of the future. Water that has been broken down by an electrical current will one day be the energy of tomorrow. The elements of water, hydrogen and oxygen constituted this way will secure the earth's energy supply for the future, even if it's unforeseeable."With his farsighted vision, Jules Verne later gave the new technology its place in history in his novel "The Mysterious Island" published in 1875.

But the story turned out differently. With Werner von Siemens' invention of the electrical generator, the promising "galvanic gas battery" was lost again to obscurity.

THE FUEL CELL: A CORE TECHNOLOGY FOR THE 21ST CENTURY

Today, over 100 years later, fuel cell technology is once again sparking hope for the future of energy generation in the 21st century. With the signing of the Paris Agreement in 2015, the global community committed to limiting global warming to a maximum increase of 2°C this century, in the hope of securing humankind's continued existence and averting an impending climate collapse on the planet.

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

However, only by completely restructuring our current energy system and moving away from the use of conventional energy sources toward renewable ones does this promise have a chance of succeeding. Consequently, the G8 countries agreed to reduce CO2 emissions by a total of 80% and by 95% in road traffic by 2050. Based on today's technological perspective, electric and fuel cell drive systems are the best alternatives we have.

Countries in Asia, notably South Korea, Japan and China, are already investing massively in fuel cell technology and bringing about a steep upturn in growth, especially in the transport sector. This is where we can expect to see the greatest technological advances. Hydrogen fuel cells, in particular, are being heavily promoted. Between 2020 and 2025, the global fuel cell market expects annual growth rates of around 15%, with individual studies even predicting more than 20%.

Demand is not only being generated by the transport and vehicle market, but also from energy generation - stationary and mobile - and from a growing energy market.
As a supplier of electricity and heat, fuel cell technology also makes a notable contribution to the climate-friendly heating of buildings in both the private and public sectors. "Even now, with the support of the Japanese government, around 305,000 building heating systems in the country are already being operated using fuel cells. Thousands of forklifts worldwide are powered by this technology, buses and soon even railways will also increasingly rely on fuel cells. Even the aviation industry is showing interest in the subject", says Wolfgang Lehmann, product manager at RAYLASE, in quoting the current figures.

Hydrogen technology funding
by the Federal Government

The topic of hydrogen is now also gaining momentum at a national level. Germany's Federal Research Minister Anja Karliczek's dictum is "out of the lab and into the real world in preparation for use on an industrial scale." On 10th June 2020, the German federal government passed a decision by the administration on a "national hydrogen strategy" with regulatory relief and specific production targets for "green" hydrogen from eco-power, in other words from wind and solar energy. To this end, the government is providing seven billion euros in funding for production facilities and infrastructure in Germany with the aim of becoming the world leader in "green" hydrogen technology. By 2030, generation plants are to be built that will replace the output of about 4 nuclear power plants.

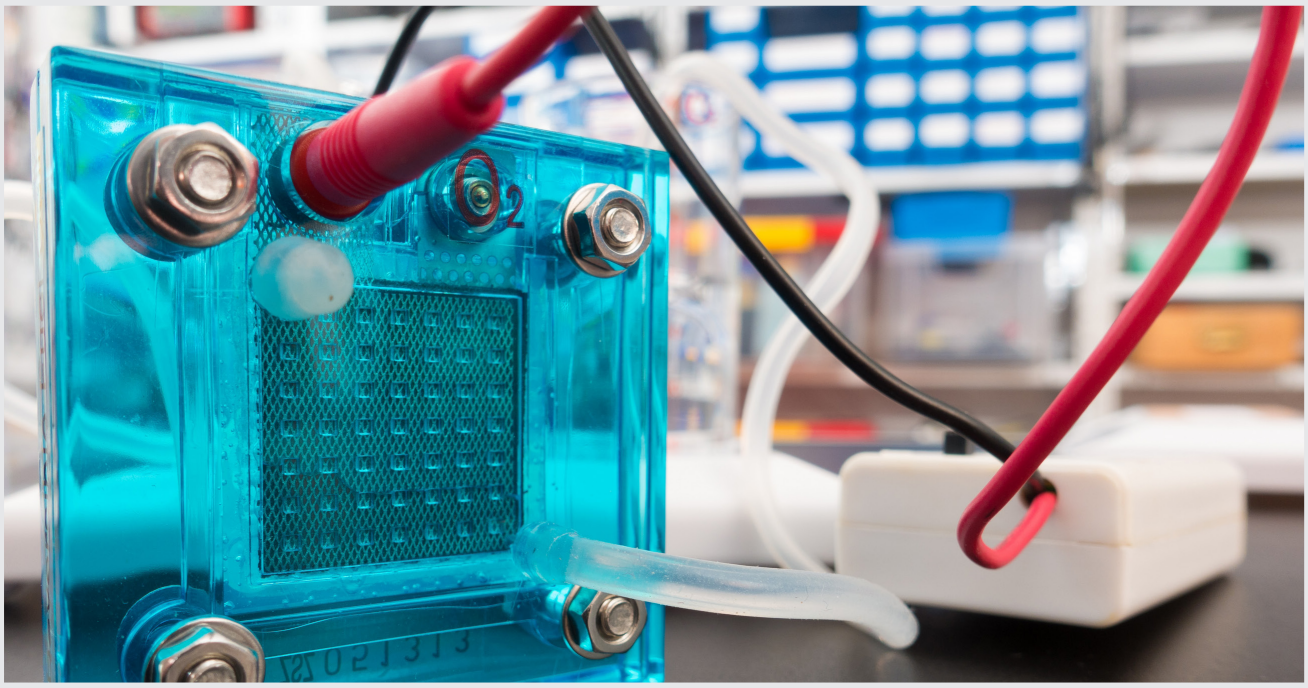
GROWTH MARKETS NEED INNOVATION DRIVERS

With this anticipated growth market, technology costs should also decrease. However, the cost-cutting potential has so far only been exploited to a limited extent.

Hydrogen is still simply too expensive to produce. Which is why it will be all the more crucial in the next two to five years for the industry to position itself as being as efficient and cost-reducing as possible along the entire value chain of hydrogen and fuel cell production. And, at the same time, make the right investments to compete internationally. Two innovation leaders are showing us how it works: Gräbener Maschinentechnik GmbH & Co. KG, a hidden champion in special machine construction as a partner for production systems for the manufacture of metallic bipolar plates, and RAYLASE GmbH, as a supplier of laser deflection units. With more than 14,000 units produced and delivered in 2019, they are one of the largest suppliers of deflection systems for laser applications worldwide.

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

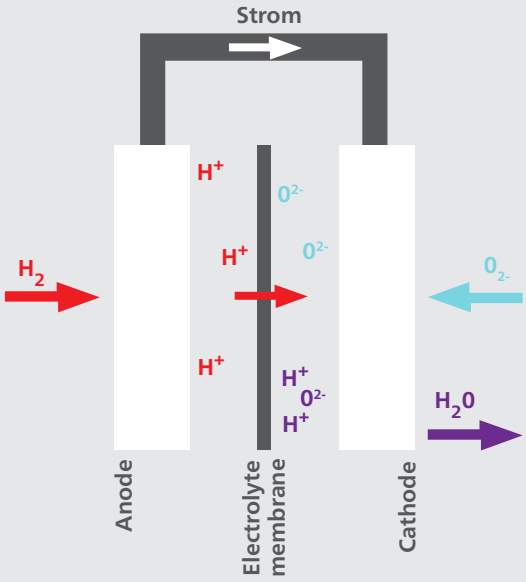
How does a fuel cell work?



In a fuel cell, a continuously supplied fuel, for example hydrogen, reacts with an oxidizing agent such as oxygen from the air. Each individual cell consists of two plates, each with a gas distribution structure, separated by a membrane. In a polymer electrolyte fuel cell (PEM), the hydrogen is separated into H+-ions and electrodes. The H+-ions migrate through the membrane and react with the oxygen in the air to form water. The electrons flow through an external contact and deliver the desired electrical current. The end products of this chemical reaction are water, electricity, and heat. The electrochemical reaction in the fuel cell is also known as "cold combustion" and is particularly efficient, clean and climate friendly.

Bipolar plates consist of a tightly welded metal anode and metal cathode (white in the picture) with gas distribution structures. Together with the membrane (MEA), they are the core components in fuel cells, which are layered in tightly compressed stacks and form the core of a fuel cell system.

A stack can contain several hundred bipolar plates. As an integrated component, the plates carry out the following tasks: electrical connection of the cells, gas distribution across the surface of the plate, gas separation between adjacent cells, outward sealing, and cooling.



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Interview

GRAEBENER Bipolar Plate Technologies

Graebener® Maschinentechnik – Managing Director Fabian Kapp and Project Manager Patrick Müller

With their production facilities for metallic bipolar plates and the involvement of RAYLASE GmbH, they are achieving a breakthrough in series production for fuel cells.

Fabian Kapp, you are Managing Director at Gräbener Maschinentechnik GmbH & Co. KG in Netphen-Werthenbach in North Rhine-Westphalia, one of the world's leading manufacturers of production systems for the manufacture of metallic bipolar plates, a core component of fuel cells.

HOW DO CUSTOMERS BENEFIT BY COMING TO YOU?

Simply put: they benefit from 66 years of accumulated development experience and world-class quality. At Graebener®, we differ from other companies in that we rely on the hydroforming process combined with state-of-the-art laser systems for cutting and welding, instead of mechanical forming.

This means that our company is more than the proverbial one step ahead of the competition, both in terms of development time and experience. And we are currently the only company worldwide to deliver metallic bipolar plates to this level of perfection.

HOW LONG HAS GRAEBENER® BEEN DEVELOPING THESE SOLUTIONS?

We have been developing hydroforming presses for sophisticated geometries in the industry for over 30 years now. At the beginning of 2000, we recognized the great potential this method has for the manufacture of metallic bipolar plates, which are one of the core components of fuel cells. A huge growth market.

In Germany, this market is still fairly insignificant, but in Asia it is already very dynamic. The Japanese, notably Toyota, are already presenting their second generation of vehicles based on fuel cell technology. Which is why, a number of years ago, we started developing laser cutting and welding systems as a complementary technology in the manufacturing process.

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

DOES GRAEBENER® OFFER DIFFERENT SOLUTIONS FOR METALLIC BIPOLAR PLATES?

We make it our business to understand our customers' processes. So we focus on our customers' requirements all along the line. Right now, the market is not ready and by that, I mean fuel cell production is still in its infancy, so it doesn't yet deliver large quantities. Initially, our customers have a first idea of the bipolar plate design of the fuel cell and we provide them with a corresponding design optimization based on our long-standing engineering expertise. In the next step, we test whether what we have developed will also work for series production in our application lab for prototyping & small batch production. And finally, we plan together for the future, for example, what might be necessary to scale up from 10,000 to 1,000,000 bipolar plates a year. In other words, we think in terms of each production system right up to the complete production line.

CAN YOU GIVE US AN IDEA OF THE INDIVIDUAL CUSTOMER REQUESTS YOU RECEIVE?

Well, all customers bring their own ideas, depending on the conditions in their manufacturing facility, their logistics, financial possibilities, and the vision of where they would like to be in one or five years. Here we see ourselves as a supportive, competent partner working side by side with our customers, both in the planning and the implementation of each detailed process step. As a result, our customer receives a production system or line for metallic bipolar plates that is completely tailored to their needs. Meaning, they get exactly what they really need, instead of an off-the-shelf solution.

WHAT CHALLENGES DO YOU SEE AHEAD FOR FUEL CELL DEVELOPMENT ON THE GLOBAL MARKET?

Well, it's a fact that fuel cell technology has been around longer than the combustion engine. But oil and gas development has simply been cheaper for a long time, and still is. That's why it's very important to us that our production technology helps to reduce costs in series production so that we can play our part towards an emission-free future.

MR MÜLLER, YOU ARE A PROJECT MANAGER AT GRAEBENER®, HOW DID THE COLLABORATION WITH RAYLASE GMBH COME ABOUT AND HOW IS IT GOING?

As special-purpose machine builders we offer, among other things, specialized manufacturing technology for the production of metallic bipolar plates. We are always searching for suitable technologies or components to help our customers move forward. And we quickly found the company RAYLASE in Weßling, Bavaria. What convinced us were their technical solutions and excellent consulting expertise. Our further cooperation was also collaborative and fair, both in terms of sales and support from the Technical Competence Center. It was an open and uncomplicated partnership. As users, we were able to incorporate all our suggestions and wishes regarding the production of bipolar plates. Starting with immediate optimization of the scan system right up to integration of new functions. A real WIN-WIN situation for both partners.

WHAT WAS IT THAT INSPIRED YOU ABOUT THE LASER SOLUTIONS RAYLASE OFFERED FOR FUEL CELL MANUFACTURE?

At Graebener® it is really important to us that we develop solutions that deliver excellent quality. And that's where the RAYLASE system, consisting of the laser deflection unit and control unit, really won us over. Because on the one hand, it can be easily integrated into a complete system solution and, on the other hand, it met all the requirements we had for suitability for series production.

WHICH CHALLENGES WAS THIS ABLE TO SOLVE IN THE MANUFACTURE OF METALLIC BIPOLAR PLATES?

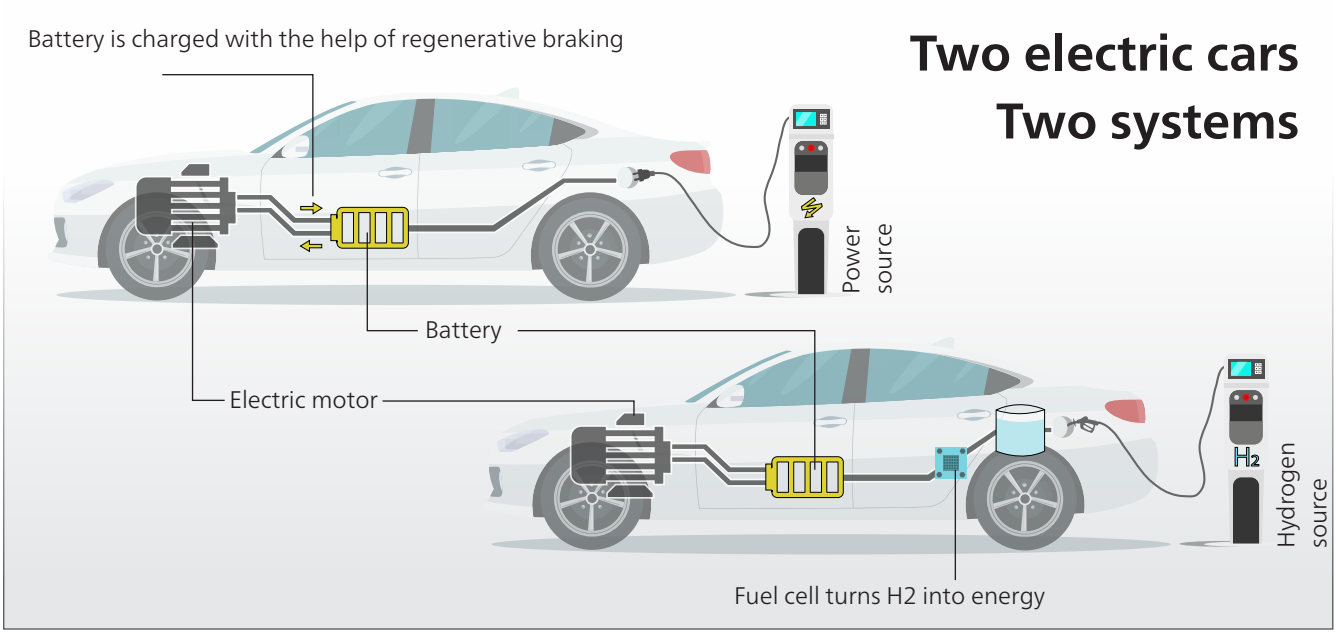
In the value chain for metallic bipolar plates, the welding process in series production is very time sensitive. When you use Cartesian systems, a high degree of parallelization is necessary to be able to produce the required quantities. With the help of the laser deflection system, we were able to shorten the cycle times in our systems and work in a way that significantly saves resources.

AND WHAT'S THE BENEFIT FOR YOUR CUSTOMERS?

Quite simply: Thanks to the laser deflection units, processes are better integrated into the production line, allowing for easier scaling, and leading to a greater output in less time. In this way, we can reduce production costs. As an innovation leader in our field, we not only want to contribute to better quality fuel cell production, we also want to make it more attractive in terms of price. When we achieve that, we gain advantages not only in efficiency and sustainability, but also in terms of cost compared to conventional energy sources. RAYLASE technology helps move us forward.

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

Driving forces of the future: battery vs. fuel cell



"The global community's gigantic need for new, clean forms of energy cannot be met by battery-powered technology alone. A closer look at the currently favored propulsion systems electric battery and fuel cells, it becomes clear that a "clash of cultures" could be avoided if the different propulsion technologies are able to co-exist harmoniously in future depending on their use. Managing Director Fabian Kapp from Graebener® is optimistic.

He explains why: "while the automobile industry in Germany has been relying on the combustion engine for a long time, it is only now aiming to make the turnaround to becoming the e-mobility provider of the future. Meanwhile, the Asians are 10 years ahead of us in the development of electric drive systems and are now increasingly relying on fuel cell technology."

EVERY TECHNOLOGY HAS ITS LIMITS

"Of course, battery technology also has its limits. Among other things, the uncertain future of natural resources and their availability as raw materials for use as components in battery technology has recently brought about a change in thinking", remarks Patrick Müller of Graebener®. "That explains why China is currently focusing on fuel cell technology whose raw material "hydrogen" is practically infinitely available from the resource water". Several thousand hydrogen-powered vehicles are already on the road in China and establishing a suitable infrastructure is part of the government's five-year plan.

FROM ENERGY STORE TO ENERGY CONVERTER

In contrast to the battery, a fuel cell does not store energy, it converts it, having energy supplied to it in a chemically bound form with the fuel. "In other words, without an additional battery in the system it wouldn't work here either. Because the energy of the fuel cell has to be temporarily stored to be able to cover sudden peaks in demand and to enable a balanced system configuration" explains Fabian Kapp and continues: "however, this small battery requires a considerably lower charge capacity than, for example, is the case for vehicles that are purely electric. That means it is continuously fed by the fuel cell and does not have to be charged externally."

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

FURTHER ADVANTAGES OF THE FUEL CELL:

Fuel cells are not made of raw materials that have to be laboriously recycled or even disposed of after their service life. Nevertheless, the way hydrogen is generated needs to be looked at closely. It is usually produced by electrolysis. In this process, the hydrogen is dissolved and separated from the water using electrical energy in a virtually reversed process. "But if it takes place using regenerative energy, such as solar photovoltaic, you could say it's a very clean and emission-free energy source. RAYLASE also provides breakthrough technology for solar cell production which underpins our vision to make the energy transition possible," emphasizes RAYLASE product manager Wolfgang Lehmann.

In contrast to e-batteries, fuel cells also achieve a greater range, which makes them particularly interesting for long distances and for moving large volumes by ship or in the heavy-duty sector; all this is made easier with fuel cell technology. The necessary energy can be stored better, and hydrogen tanks are smaller and lighter. By contrast, it would take huge e-batteries to store the same amount of energy.

A great partnership:

Fuel cell and laser technology

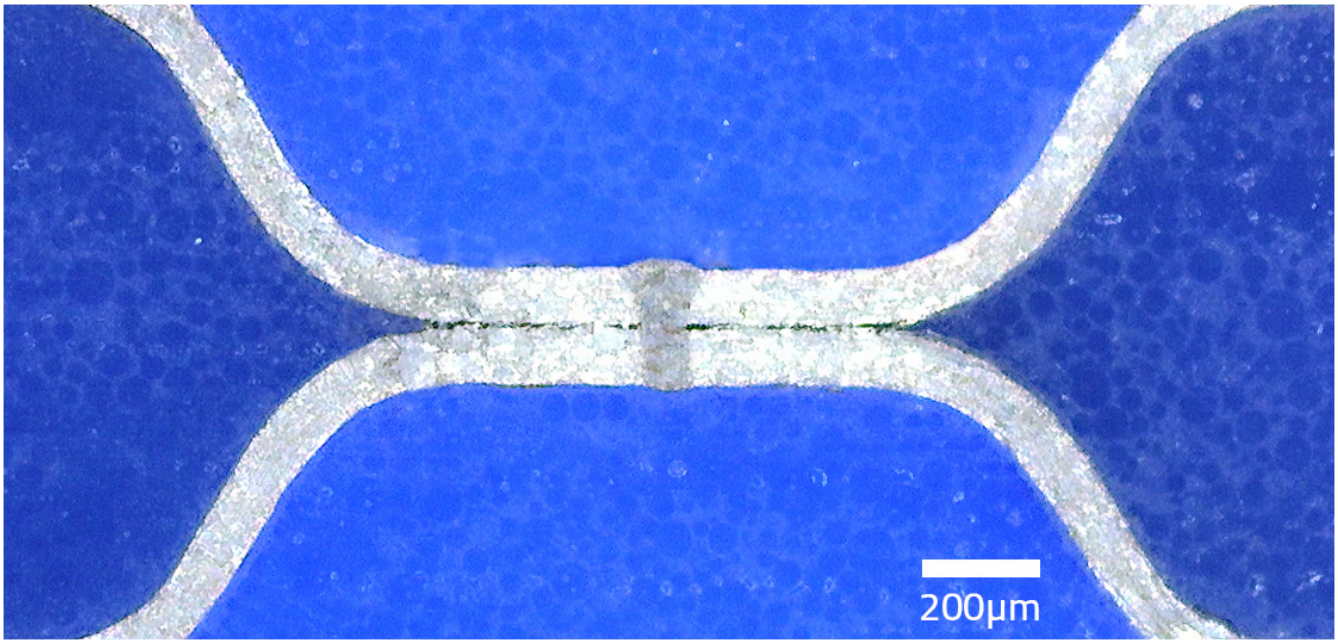


Photo Welding seam: shows a macrosection of the welding seam of a bipolar plate. Copyright by Graebener®

The use of modern laser deflection units in fuel cell technology makes sense not only because of its speed, accuracy, and effectiveness in industrial production, it also brings with it a major competitive advantage. Lasers cut and weld the bipolar plates with extreme precision without contact, force, or wear. Laser deflection units act as true drivers of innovation in the manufacturing process because they help to bring fuel cells into series production.

LASER TECHNOLOGY AT ITS FINEST

At RAYLASE GmbH, the vision is to make the special properties of their laser devices as effective and easy to use as possible for manufacturers of fuel cells, and machine and system builders. The company also offers high precision components for the rapid deflection and modulation of laser beams, as well as functional modules and solutions for laser material processing. One of the latest innovations, which is also used in the construction of fuel cells, is the combination of laser deflection units, industrial cameras, and welding monitoring systems.

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

LASER APPLICATIONS IN FUEL CELL MANUFACTURE: CUTTING, CLEANING, WELDING

In detail, three areas are particularly relevant for fuel cell manufacture: cutting, cleaning and welding. The process of laser cutting gives the formed metallic half-plates of a bi-polar plate their final contour. This includes an external cut, but also complex contours within the plate, for example, the openings for the gases. The laser with its very small spot diameters enables burr-free trimming of even the most difficult geometries at material thicknesses of up to 50 µm.

The welding process represents an important production step in bipolar plate manufacture, in which very thin stamped metal foils with delicate contours must be welded gas-tight (see graphic above). Compared to other methods, this can be realized much more efficiently and economically with a laser deflection unit. So-called single-mode lasers with corresponding beam quality can perform a heat conduction process or a deep welding process together with deflection units to produce the desired narrow weld bead.

Alternatively, the fine laser beam can be shaped into a spiral shape with dynamic and fast deflection units or, with the aid of the software and control electronics, into any lissajous figure to achieve the desired welding result. "The latest laser welding facility from Graebener® with technology by RAYLASE ensures that the bipolar plates are welded completely gastight. A tight welding of the bipolar plates ensures that the gases cannot mix. Since one single defect in a stack of hundreds of plates would make the entire fuel cell unusable," explains Wolfgang Lehmann product manager at RAYLASE GmbH, in describing the individual process steps.

Innovative laser solutions:

Sensors, camera, software!

In addition to high-quality 2-axis systems that work with so-called f-theta optics for flat process fields, RAYLASE also offers pre-focusing deflection units that do not require f-theta optics. The great advantage of a pre-focusing unit lies in the large process fields, as well as very good and small spot diameters. While systems based on f-theta optics can generate process field sizes of up to approx. 250 x 250 mm² with good homogeneity, fields of up to 800 x 800 mm² are no problem for pre-focusing systems. Another huge advantage is that the process light in pre-focusing systems can be decoupled directly behind the mirrors, unaffected by f-theta optics. In this way, process observation and control of the workpiece are possible without disturbing aberrations caused by different light refraction in the f-theta optics.

RAYLASE MAKES KNOWLEDGE SHARING A PRIORITY

RAYLASE provides training in the handling of laser technology, especially the many possibilities for creating the processing layout and setting the ideal process parameters in the software. "The brain of every laser system is in the control electronics and software of our deflection units. Only when these are in place, can all the benefits provided by laser material processing take full effect," stresses Harnesh Singh Director of Sales & Marketing at RAYLASE. Particularly for the benefit of first-time users, the company provides customers with on-site support for the installation, set-up, and calibration of its laser systems. Machine setters and operators receive not only a comprehensive range of training courses in-house, but also hands-on from highly qualified experts on their own premises.

Sources: Federal Government/Agora Energiewende; Figures: Aktien Check, Roland Berger "Potential of the hydrogen an fuel cell industry"

It is their task to support the specialists on-site with advice and resources during process implementation. It is always a matter of comparing how the machine builder envisages the process with the possibilities offered by the hardware and software. Lehmann underscores the various integration options "we also offer support with programming for customers who only want to use our software as a software development kit (SDK) and integrate the functionalities into their own machine software, for example through "code-check-support" programming examples."

Even though RAYLASE has officially committed to providing advice, support and training, the installation of its laser systems is pretty self-explanatory. A wide variety of mounting options facilitate mechanical integration into the system. Electrical connections and the laser fiber simply need to be plugged in. Here too, RAYLASE provides tools for creating the best possible process parameters, as well as for calibrating the process field.

Leading-edge laser suppliers

RAYLASE GmbH differs from pure suppliers of laser deflection units. The Bavarian company sees itself as an innovative solution provider for everything related to lasers, with customers receiving a special quality of supporting technology for their chosen lasers:

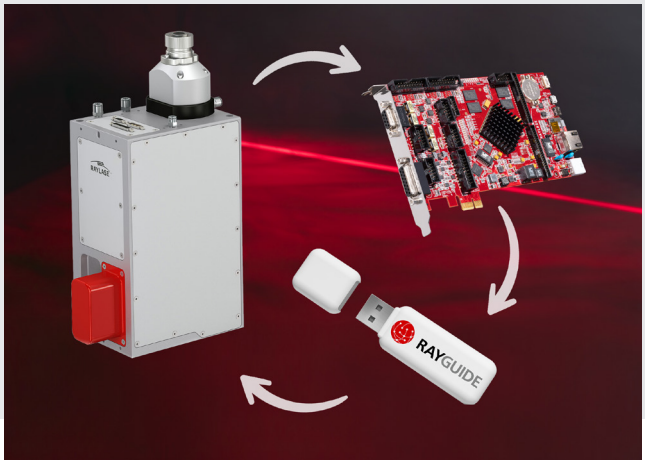
- **Deflecting process optics, some with integrated collimation for fiber lasers**
- **Control electronics and software that offer process-specific functions**
- **An optical platform for adapting process sensors**

Another highlight: Image processing software solutions for production equipment and position detection using camera technology enable "just in time" tracking of the manufacturing steps. This not only helps to immediately detect if a workpiece is incorrectly positioned, but also to correct it immediately.

Bottom line:

Using deflection units in conjunction with laser technology eliminates the need for prefabricated tools such as cutting blades and stamps, which wear out very quickly and slow down productivity. In addition, these tools are not particularly versatile, as is the case for lasers and deflection units with control cards and software.

Fuel cell manufacturers benefit from consistently good quality, more productivity in terms of higher quantities with extremely low maintenance times, and savings in personnel costs and waste; all the time maintaining maximum process stability. The biggest plus, however, is flexibility as the software can be used to adapt the laser components to literally ALL applications.



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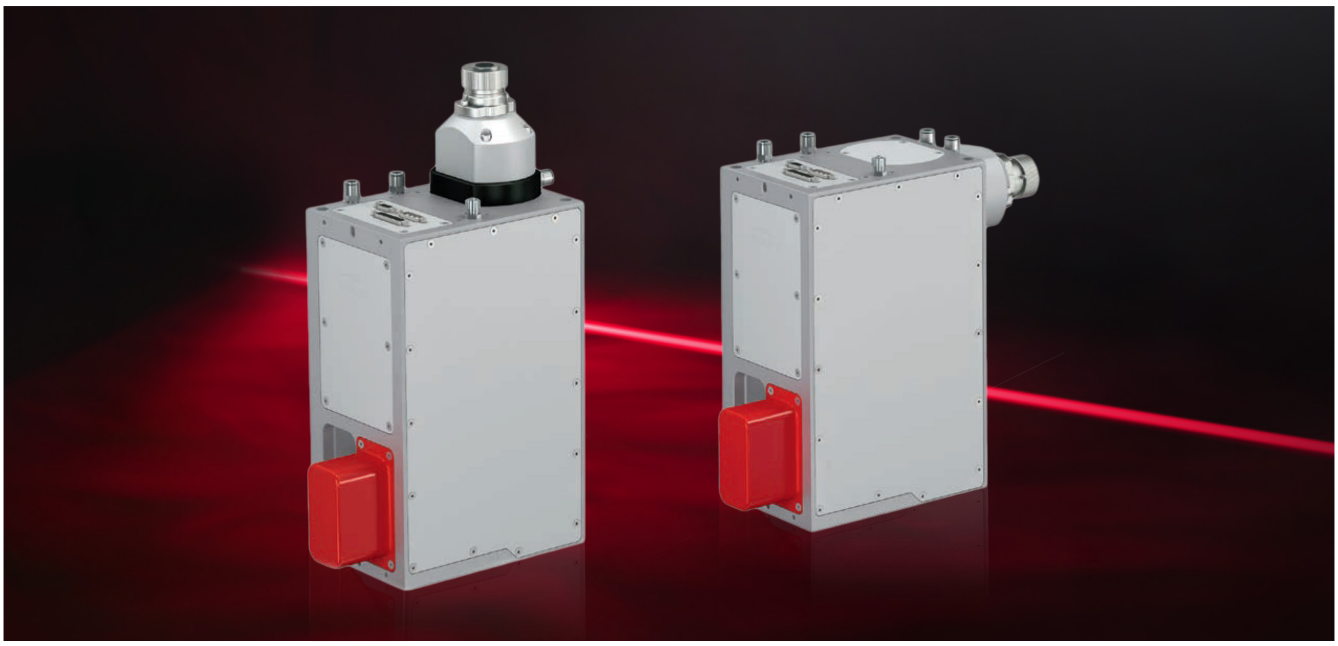
Unique on the laser market:

AXIALSCAN FIBER-30 BY RAYLASE



The pre-focusing deflection laser system for pre-settable process field sizes between 250 x 250 mm² and 850 x 850 mm² is to date the only one of its kind on the market and also very well suited for producing fuel cells. An optional monitoring module is also available. This offers camera monitoring with autofocusing, as well as a second channel for adapting welding monitoring systems. The automatic focus tracking of the camera, in particular, represents a unique selling point of the product in the market. Welding is supported by the software functionalities of the latest RAYGUIDE software. It includes welding ramp functions that ensure the material to be processed is heated, helping to avoid fracture, and provides different lissajous figures for a range of laser beam modulations.

- **IP64 completely dust-proof industrial design**
- **Integrated collimator for direct laser fiber connection**
- **Collimator can be mounted either vertically or horizontally, depending on conditions in the customer's machine**
- **Largely aberration-free (refractive index) process light output**
- **Protective glass quick-change system**
- **Preset process fields in a wide range from 250 x 250 mm² to 850 x 850 mm²**

The holistic approach offered by this RAYLASE solution involves providing customers with the tools and procedures that enable them to calibrate and easily recalibrate process fields as needed. The company supplies the software tool "multipoint editor" for this purpose as an integral part of every laser software package.

Before the year is out, they plan to make an automated solution available to customers that allows them to calibrate process fields and automatically align several fields to one another.

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