4SURfaces

Issue 3

The Laser Technology Magazine by 4JET

PROCESSES FOR TOMORROW

A look into the 4JET lab

FOUR IN ONE

Processing of CIGS modules

LASER | SYSTEME | SERVICES

4JET

Editorial

Here to stay

As a technology company, we are constantly finding new opportunities. The laser as a multi-functional tool and our expertise in the field of surface technology can be applied to almost every industry. But just as a laser beam only does its job when it is in focus, we are concentrating on specific sectors rather than dipping into all areas.

And while some companies enter and leave markets as if they were riding on a bus, we see our commitment to the tire industry, to solar technology and to each newly tapped market as a long-term one.

Part of that commitment is the readiness to remain loyal to a sector even in weaker years and to invest continuously in product development and service. In fact, since the end of the automotive crisis in 2009 we are seeing stronger and stronger demand from the tire industry, which we have been able to respond to with a number of successful new product launches.

And we are seeing the same development in the solar industry, which has been experiencing some serious bumps recently. As part of the needed market realignment, manufacturers will invest in new and more efficient production processes that are already being developed in our laboratories or on customer pilot lines.

You will find a preview of some of tomorrow's applications and products and a look behind the curtains of our development labs in this edition of 4SURfaces.

Yours sincerely

Dr. Stefan Bergfeld – Jörg Jetter – Dr. Armin Kraus – Dirk Teppe

Imprint

PUBLISHER	4JET Technologies GmbH, ViSdP Jörg Jetter
PHOTOGRAPHY	Calyxo GmbH
	Kira von Gradowski
	Projektbüro Deutscher Gründerpreis
	Olaf Rohl
	© Dark Vectorangel - fotolia.com
DESIGN	www.scribble-werbeagentur.de
PRINT	Printed on chlorine free paper.

4SURfaces

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Content

CIGS LINE

All inclusive

4JET provides manufacturers of CIGS solar cells with a complete integrated solution for all processes from structuring to contacting solar modules

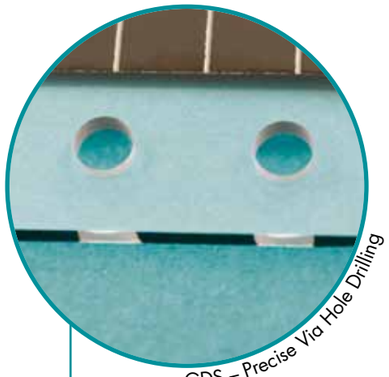
Customers have a tough choice to make when building new production facilities. Every customer wants the best available system technology for each production step, but, at the same time, would like to keep down the number of suppliers and work with as few, competent partners as possible.

The new CIGS line from 4JET provides a cluster of four backend production systems for laser drilling bus bar vias, laser edge deletion, bus bar exposure and cleaning module edges.

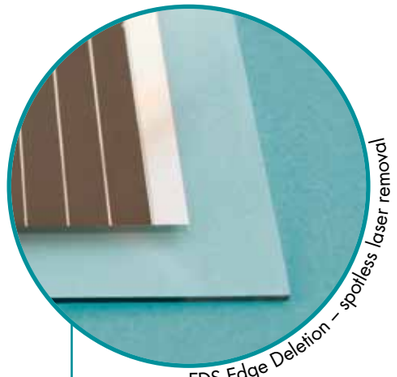
The system, typically designed for 50 MW lines, is fully interlinked and can be integrated into any factory via an MES interface. The modular system platforms can be adapted to suit all common substrate types and are fitted with process and system controls.

Tuning the different processes to each other significantly reduces the number of interfaces for the end customer.

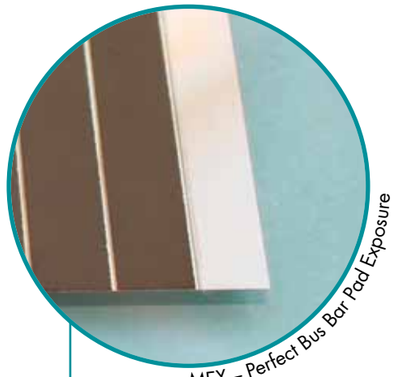
All the systems have been tried and tested in thin-film photovoltaics in numerous installations and can also function as a stand-alone tool.



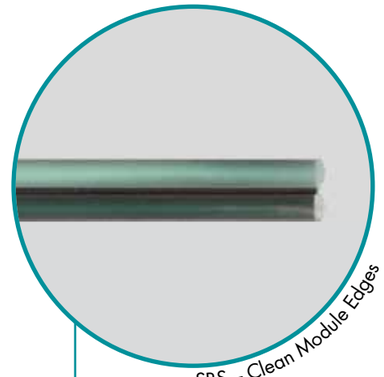
GDS – Precise Via Hole Drilling



EDS Edge Deletion – spotless laser removal



MEX – Perfect Bus Bar Pad Exposure



SBS – Clean Module Edges

An interlinked solution for CIGS modules

FLEX
on the roll!

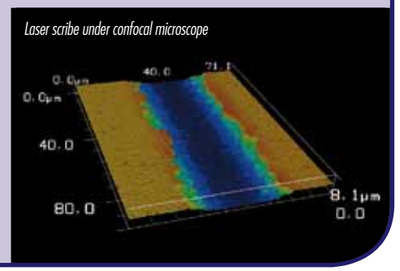
4FLEX System for Roll to Roll Laser Patterning

Flexible thin-film solar cells, OLEDs and other electronic foils can be structured on-the-fly with the new roll to roll system from 4JET.

The patented beam and foil guidance system guarantees a constant working distance between the laser optics and the foil surface. A vision system controls the positioning of up to 10 parallel laser beams with fast and highly accurate axes.

Optional add-on modules for marking, inspection and cleaning plus integrated printing technology make new production designs for flexible electronic components reality.

Laser scribe under confocal microscope



SHARP EDGES
for thin glasses

Chemically strengthened glass for smartphones, touchpads and other displays are marvels of technology. Less than a millimeter thick and feather-light, they are significantly more scratch-resistant and flexible than "normal" glass.

What is an advantage for day-to-day use is a major headache in production and processing. Conventional processing of strengthened glass is slow and has low yields with glass getting damaged in the process.

The new GDS process module from 4JET makes it possible to drill and separate thin glass layers in a multistage, controlled laser process, delivering sharp edges with minimal chipping and reproducible bending strength.

GDS Laser System by 4JET

Display for mobile with two drillings

PIONEERwork

More than 20 manufacturers of thin-film solar cells have opted for 4JET production technology. One of the very first customers was Calyxo GmbH in Bitterfeld-Wolfen.

Thin-film solar module with 4JET laser edge deletion

The company was founded in 2005 and produces thin-film solar modules based on cadmium telluride (CdTe) technology. The expert team in the appropriately named Solar Valley in Saxony-Anhalt is industrializing a highly innovative glass coating technology from the US company Solar Fields. The technology deposits thin layers of semiconductors using atmospheric deposition technology.

Calyxo initially set up a pilot line with a production capacity of 8 MWp in Bitterfeld-Wolfen/Thalheim (Germany) to show that the technology could be transferred to mass manufacturing and rapidly commercialized. The pilot line became operational in summer 2007 and shortly thereafter was stepped up to 25 MWp. Since then, 4JET has been Calyxo's partner for laser edge deletion.

The existing CX-3-series module from Calyxo has an average efficiency of 11.9 percent based on the aperture area. The current champion module has reached an output of 88.7 W, equivalent to an efficiency of 13.4 percent.

"The Calyxo development team rapidly reached another milestone on its efficiency road map, aiming for even higher efficiencies in the near future. High module efficiencies in combination with our low-cost atmospheric deposition technology are decisive factors for cost-competitive solar energy", explains Chief Technology Officer Michael Bauer.

The specialists from Bitterfeld see the collapse in solar module prices and the turmoil in the solar industry as an opportunity: "With the financial contribution of our long-term shareholder Solar Fields, we will reduce our costs by the end of this year to less than 0.60 EUR per Wp, which corresponds to a cost reduction of nearly 30 percent from the recent level", says Michael Bauer.

Calyxo uses the latest technology for encapsulation. The edges of the substrate glass are deleted after coating and structuring. Calyxo was one of the first manufacturers globally to replace aggressive mechanical blasting and grinding processes with the less destructive laser cleaning process, setting a new industry standard.

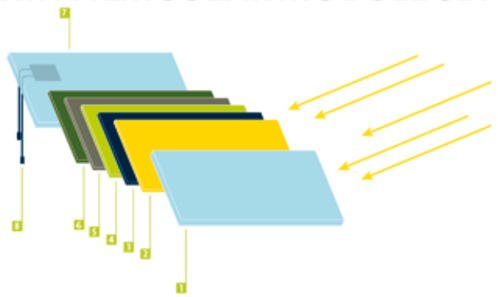
Sealing around the edges and cover glass protects the modules from the environment, acting as a barrier to humidity and vapor and thereby ensuring long service life. IEC 61646 and IEC 61730 certification with doubled inspection times and success in the noxious gas test are clear evidence of the strength of the modules. Calyxo offers a 10-year product warranty for CX3-series modules and a performance warranty of 90 percent in the first 10 years and 80 percent in the following 15 years.

In 2012, Calyxo will bring another production line into operation and will then have production capacity of 110 MWp. A 4JET edge deletion system will be installed as well.

Dr. Michael Bauer – chief technology officer at Calyxo

Calyxo	milestones at a glance
2004	Solar Fields researches CdTe technology
2005	Calyxo GmbH founded
2007	Calyxo USA Inc. founded, Solar Fields becomes share-holder
2008	Capacity ramp up to 25 MWp
2012	Champion module achieves 13.4% efficiency expansion of capacity to 110 MWp 150 employees

THIN FILM SOLAR MODULE SETUP



Cross section through a Calyxo CdTe module

1. FRONT GLASS
2. FRONT CONTACT: highly transparent layer with excellent electrical conductivity for maximum light permeability and practically zero-resistance electricity transport
3. CDS LAYER (0,1 µm)
4. CDTE LAYER (3,0 µm)
5. BACK CONTACT: highly stable, electrically conductive metal
6. GLASS LAMINATION FILM: water-insoluble seal, safe protection against escape of contents (e.g. in case of any damage), secure sealing of the module edges
7. BACK GLASS: specially hardened glass designed for long-term demands
8. JUNCTION BOX: including solar cable and connector

LaText

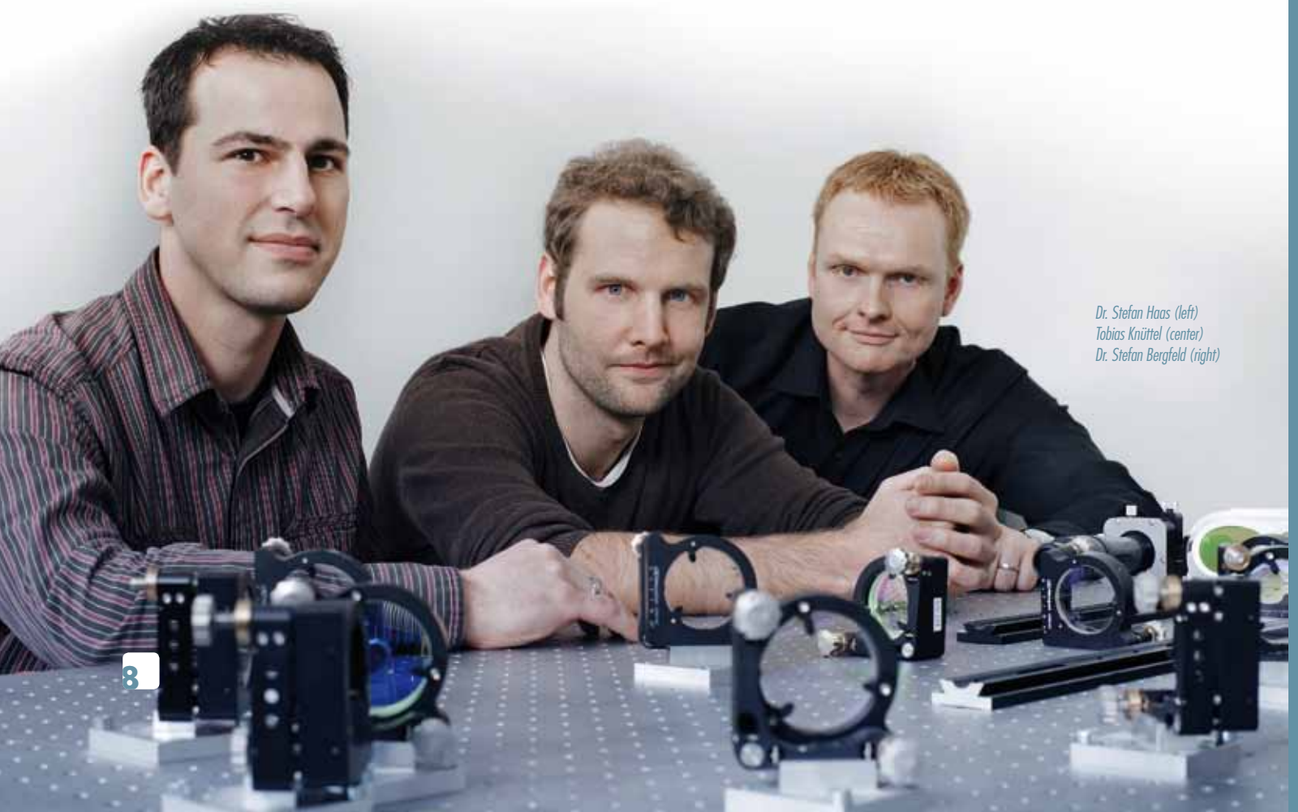
Trapping Light

A promising research cooperation

Solar cells have to become more efficient! 4JET and the Institute of Energy Research (IEK-5) – Photovoltaics at the Research Center Jülich, are working to achieve this goal, as photovoltaic modules will only survive on the market in the long term without subsidies if their efficiency can be increased.

Collaboration between the two partners has enormous potential, bringing together an industrial enterprise supplying production machines to the solar industry and the scientific expertise of IEK-5, an institute that generates world-leading research in the field of silicon thin-film solar cells.

Both the Ministry of Economy, Energy, Construction, Housing and Transport of North Rhine-Westphalia and the European Union (the European Regional Development Fund) are also convinced of the benefits and are supporting the project for a period of 3 years. Under the project name "**LaText**" (short for **La**ser Processes for Front-contact **Text**uring Silicon Thin-film Solar Cells), permanent employees of both partners, as well as a dedicated doctoral student specially appointed for the project, will undertake research and development. Physics graduate Tobias Knüttel is delighted by the opportunity to bridge academic research and the needs and applications of industry in his doctorate.



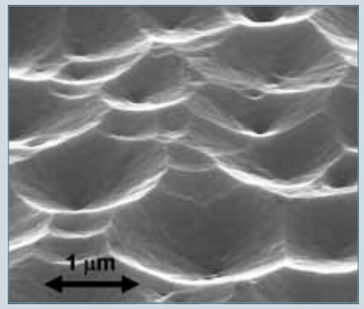
Dr. Stefan Haas (left)
Tobias Knüttel (center)
Dr. Stefan Bergfeld (right)

What is it actually about?

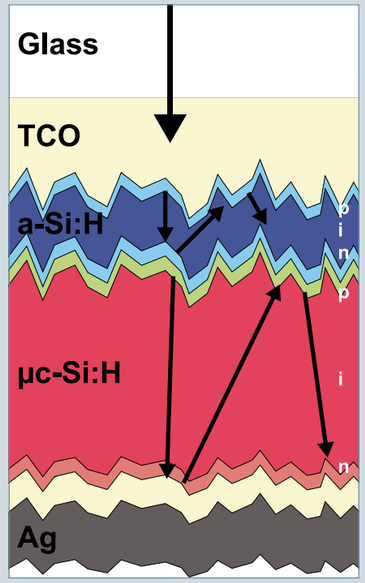
The most promising possible means of reducing costs is to increase the efficiency of solar modules using methods that entail no or only limited additional costs.

The structure of a thin-film solar cell made from amorphous or microcrystalline silicon is as follows: The base is a glass substrate to which various layers are applied. First, a layer of transparent conductive oxide (TCO) is applied as the front contact, then the actual photovoltaic absorber batch of silicon layers and finally a layer of silver as back contact.

The incidental light is scattered into the silicon absorber layers by texturing the TCO front contact. The aim is to scatter the light so that it is reflected as many times and as powerfully as possible within the cell with minimal loss of light. This is referred to as light injection or light trapping.



SEM image of texturing with the latest technology (etching technique)



Schematic structure of a thin-film solar cell made from amorphous or microcrystalline silicon

The texture of the front contact is therefore a key component in the manufacture of highly efficient silicon thin-film solar cells. It must be possible to define the structural dimensions and the shapes of the texture accurately and in a targeted way to optimize front contact textures and thereby maximize the efficiency of the cells. Texturing methods to date – chemical vapor deposition or etching – have not been able to do this, but a laser process provides just this possibility. Laser texturing can generate structural dimensions in the micro- and nanometer range in a reproducible and targeted manner.

4JET will purchase a scanning electron microscope (SEM) in order to organize the application experiments as purposeful as possible. It will be utilized to inspect the structures on-site following any laboratory trial and define possible improvements, if necessary.

Once the partners have defined the optimum texturing, they will develop a machine design in the following stage to implement laser texturing on an industrial scale. The cost factor will play a very significant role alongside all the technical aspects of the project. Ultimately, the project is all about reducing the costs of photovoltaic to a level at which photovoltaic can become established on the power generation market.

4JET's experience of laser processing thin-film solar modules will have a key role to play. System designs that have already been developed can be modified and applied to texturing TCO front contacts.

If the aim of the project is achieved, the door will be open to further potential industrial applications of laser processing, as structured TCO layers are not just used in silicon thin-film photovoltaics, but in numerous other solar cells, display technology and in organic LEDs (OLEDs).

If the laser process provides optimum light injection into solar cells, it is only a small step to reverse the process and optimize light emission from OLEDs.

GREAT STEPS *thanks to short pulses*

Even after 40 years of industrial application, laser technology is still developing in great strides. Beam sources are becoming more and more powerful, opening up new applications, and making established laser processes even faster and more economical.
That is why 4JET is completely redesigning its S/TMCS product family for cleaning tire molds.

This is what technical progress looks like – same price, performance doubled, operating costs halved!

The system platforms for mobile in-press (tire mold cleaning system/TMCS) and stationary offline (stationary tire mold cleaning system/STMCS) mold cleaning, tried and tested worldwide in industrial applications, now come with even greater cleaning performance at the same level of perfect quality. The complexity of the systems and the installation size have both been reduced as well.

New high-performance beam sources have been used to reduce cleaning times to less than 20 minutes in some cases for a car tire mold. The exact processing time is dependent on the mold geometry, the degree of contamination and the mixtures and release agents that are used.

4JET uses laser sources that emit some ten thousand very short light impulses per second for cleaning. Each individual pulse is just a few nanoseconds long – just a few billionths of a second. During the brief exposure time, contamination in an area the size of a pinhead is blown off without affecting the mold surface beneath. The rapid sequencing of individual laser pulses allows large surfaces to be cleaned extremely quickly.

The lasers used by 4JET also function for some ten thousand hours without requiring significant spare parts and without costly maintenance. Besides electrical energy, the laser systems do not require any other media such as compressed air, gases or abrasive material. At around 1 €/h, the variable operating costs are just a fraction of the cost of conventional cleaning with CO_2 dry ice.

The exceptional beam delivery system of the multi-axis process head allows to clean even unusually complex tread patterns with perfect results.

LASER CLEANING *in profile*

- Perfect cleaning quality thanks to multi-axis 4JET heads
- Automated process with reproducible quality and consistent safety
- Low operating costs – no dry ice, no compressed air, no abrasive material and minimal energy consumption
- Clean molds at any temperature without preheating for long periods
- No mold wear and no damage to valve systems thanks to contactless cleaning

TWENTY-FOUR *SEVEN!*

Complex laser systems in 25 countries are serviced by the 4JET service team. Downtimes of systems installed in interlinked production facilities costs real money, so the 4JET service team is at work twenty-four-seven. A diary of one day …


Michael and Torsten


Janine and Udo


Julia and Bernhard


André and Marcel

02:12: It is morning in Japan and service technician Torsten is starting his shift. The systems for a number of Japanese customers are up for annual maintenance. "The laser systems have to be checked and serviced regularly to ensure they run smoothly", says Torsten, who has got to know Japan very well during more than 40 tours of duty.

04:15: The on-call service technician this week is Marcel. And, straight away, he gets a call on his standby mobile from a German tire factory – a laser system is reporting a sensor error. The system status is identified over a secure VPN connection and the possible causes of the error are narrowed down. A maintenance worker employed by the customer identifies a defect that can be corrected immediately.

05:27: While Germany still sleeps (except for Marcel at his computer ...), service technician Ben is working in Hsinchu in a solar cell factory at 4JET's partner company DKSH Taiwan. He is setting up a new processing recipe for a via drilling system. He received the software update by email from specialists in Alsdorf the previous evening.

8:21: Julia is processing queries that have come in from international customers overnight. A classic request – a spare part query with a photo and no part number. "Identifying parts is sometimes a bit like detective work", explains the after sales agent, who joined the 4JET service team after completing her studies and living in Japan for a number of years.

9:05: In Spain, service technician and SPS specialist André is setting up new software functions at a plant. "The customer commissioned us to upgrade his software. I could do the programming at 4JET, but setting up and testing are best done on site."

10:09: Service manager Bernhard welcomes 4JET partners from Hungary at the front desk. There are regular meetings with distribution partners from all over the world. "Our local partners do not just handle distribution, but customer after sales support as well. They are an important interface between the customer and 4JET", explains Bernhard.

10:30: Janine not only manages the front desk at 4JET, but arranges a large number of business trips as well. She is currently organizing a flight, hotel and rental car for a trip from China to the USA. "International reservations are part of the daily routine. A US customer wants to move a system. A service call in China is just finishing, so our colleague can take on the job and fly straight to the US."

13:00: It is 20:00 local time in Shanghai. Service technician Michael is finishing his shift. "I frequently do overtime in Asia, as the working hours are just longer. Technicians have to adapt to the local conditions to a certain extent. Tomorrow, I'll be leaving here and traveling on to the US", explains the cosmopolitan frequent flier, who worked, among other things, as a gravestone designer before joining 4JET.

14:20: Telephone conference between Julia and service technician Torsten, calling from his maintenance job in Japan. Torsten gives a brief summary of the status and passes on a spare parts list to be offered to the client.

16:50: Internal discussion on working processes with quality manager Thomas and the service department. "We are always striving to improve our processes. In terms of service, the installed base is growing every month with every delivery of machines. Processes help us to be able to react more quickly by giving us a best practice approach for recurring tasks".

21:05: Lunch break for Udo, currently overseeing the commissioning of a system in the Silicon Valley. "Service technicians get to know the machines right from final installation and commissioning. That increases our understanding of the system technology, the software and the laser process".

01:00: Evening in the US, a night's rest in Germany and a new day in Asia. Let's do it again – twenty-four-seven!

DEUTSCHER GRÜNDER PREIS *for 4JET*

The 4JET team has been celebrating a sensational success. The company was awarded the highly regarded Deutscher Gründerpreis Award 2011 in the Climber category at a ceremony in Berlin.

The jury handed the prize to 4JET "because of the unusual approach behind the company's success. The company combines laser technology, optics, design and software in flawless system solutions, demonstrating excellent intuition for growth markets. The company plays a leading role among competitors and has the potential to continue achieving enormous sales growth", stated the jury.

4JET was nominated for the prize by Sparkasse Aachen and was chosen as one of the three finalists from among hundreds of companies during the selection process. 4JET secured first place during a final presentation in front of a jury that included top representatives from industry, business media and the banking sector.

Founder and CEO Jörg Jetter had the honor of accepting the award from the President of the German Savings Banks Association Heinrich Haasis and the presenter of ZDF heute-journal Marietta Slomka at a ceremony attended by around 500 invited guests.

Alongside 4JET, the winners of the Life's Work (Dr. Martin Viessmann), Start-up (CEGAT GmbH, Tübingen) and Special Prize (Dialog im Dunkeln project, Hamburg) categories were also announced at the event attended by prominent political, business and media personalities.

INVENTUX AG, based in Berlin and a technology leader in the field of micromorph thin-film solar cells, was also among the finalists. It was a particular pleasure to see one of 4JET's first customers receive such recognition.

B. BRAUN as mentor

4JET has also attracted a leading entrepreneur as a mentor by winning the Gründerpreis. Prof. Ludwig Braun, Chairman of the Supervisory Board of B. BRAUN Melsungen AG, will support the 4JET management team in the coming years with his experience and network. B. BRAUN is a global healthcare supplier with 41,000 employees and annual turnover of 4.4 billion Euros.

Jörg Jetter and ZDF-Anchorwoman Marietta Slomka

DEUTSCHER GRÜNDER PREIS

Eine Initiative von

stern | Sparkasse

ZDF | PORSCHE

Leaner with PORSCHE

As winner of the Gründerpreis Award, 4JET has won a consultancy project with Porsche Consulting AG. The sport car manufacturer's in-house consultancy specializes in introducing "lean management" principles to companies. Porsche advises automotive, aerospace and engineering companies on how to develop efficient working processes under its claim "100% performance, 0% fat".

The consultancy project for 4JET involved two teams each working for five weeks to optimize project management and assembly. Tangible results were achieved.

Material supply, progress monitoring and resource planning in final assembly were optimized jointly with specialists from Porsche. Visible results include the newly introduced Kanban storage system for assembly materials and a picking system alongside wall charts and redefined assembly bays.

4JET project management was further optimized in the second part of the consultancy project. All projects now follow a standardized system of milestones by which defined work content has to be achieved and approved by the project board. The new system, supported by the in-house ProJET software, provides project participants with maximum transparency in terms of progress, scheduling and cost planning and is an important component for the successful completion of any project.

Porsche Consulting
Einfach. Schnell. Erfolg erfahren.

The Porsche Consulting and 4JET project team at the final presentation

The Award

Deutscher Gründerpreis Award is the most important award for outstanding entrepreneurs in Germany. The aim of the initiative is to create a positive climate for start-ups in Germany and to give people the courage to establish new businesses.

The Gründerpreis is awarded each year in the Schools, Start-up, Climber and Life's Work categories. Outstanding entrepreneurial achievements can be honored with a Special Prize.

And the winner is … Laudator Heinrich Haasis proclaims the winner

The Deutscher Gründerpreis is awarded by four partners: Stern magazine, the savings banks (the Sparkassen), the German public TV channel ZDF and Porsche. The partners have been promoting entrepreneurship and an entrepreneurial culture since 1997. In addition, the Deutscher Gründerpreis Award's Board of Trustees undertakes to mentor the nominees and prize winners. Patrons of the Deutscher Gründerpreis include Bertelsmann AG, Gruner + Jahr AG, the Süddeutsche Zeitung and the Sparkassen Versicherung. The Federal Ministry of Economics and Technology is also a cooperation partner of the Deutscher Gründerpreis.

Aachener Nachrichten report on their front page

Aachener Nachrichten

ÜBERPARTEILICH · UNABHÄNGIG

Alsdorfer Hightech-Firma freut sich: „4Jet" erhält Gründerpreis

MORE THAN *“Trial and Error“*

Visitors to 4JET have a real eureka moment when they are shown round the in-house laboratories. Whilst the offices and assembly areas look like at “any other” engineering company, the effort put into developing new laser processes only becomes obvious when you see the areas devoted to applications and analysis. A look behind the scenes ...

“We use pulsed laser radiation to remove thin films from surfaces”, says CTO Dr. Stefan Bergfeld, describing one of 4JET’s most frequently used technologies.

What sounds abstract is demonstrated very clearly in the laboratory. A sheet of glass covered in a matt black, thin layer is under the laser lens. A lightning-like line of points of light dances for a few seconds over the substrate, leaving the edges as clear as glass. There is nothing left of the coating where the sheet of glass has been processed.

“The laser pulses bring a high density of energy into the thin film, which blasts off the coating. One trick is that we use laser radiation with a wavelength that is absorbed by the coating but not by the glass, so we can avoid damaging the underlying glass. However, a short pulse duration is also important to prevent the neighboring layers to be affected by the process. In this example, we are using a laser with pulse durations of just a few picoseconds – that is, just a few trillionths of a second”.

The underlying process - termed “laser ablation” in physics - has been mastered by 4JET application engineers in all conceivable variations. The challenge is that, depending on the application and layer system, completely different wavelength ranges and pulse parameters have to be used. The equipment in the 4JET laboratory is suitably extensive. The inventory includes 20 W to 1,000 W solid-state and fiber lasers with pulse widths from femto- to nanoseconds, pulsed and continuous CO_2 lasers as well as excimer lasers. 4JET is always keen to test new laser sources in terms of suitability for industrial applications and has an excellent general overview of the devices available.

The work is complicated by the completely different components that are sampled, ranging from a stamp-sized organic LED over window glass panels measuring several m^2, to truck tires weighing 100 kg. Flexible scanners, µm-accurate axes with linear actuators and rotation and clamping devices are used for processing. The test stands in the laboratory have to be reconfigured frequently as a result.

Actually processing samples make little sense without interpretation and analysis. ”It is not just a case of ‘trial and error’ – we want to understand the processes occurring on the surface as far as possible”, says Stefan Bergfeld.

To do so, 4JET has not only developed in-house software models to calculate temperature profiles in layer systems, but has also invested heavily in analytics. A 3D laser microscope with a resolution of below 10 nanometers, a spectrometer and (in the near future) a scanning electron microscope are all available in the laboratories, alongside a range of optical microscopes.

For special applications, the 4JET specialists also develop custom test procedures, such as a measuring station for electroluminescence, or a test frame for high voltage testing of solar modules.

The applications laboratory does not just test for feasibility at the start of each project – it also guarantees exceptional service quality thanks to seamless adjustment of laser processes when products change. “Customers change input materials or product designs. Any adjustment to the processing parameters in systems that have already been installed can be prepared in the laboratory and then installed in the system. In many cases, we can simulate the processing conditions in the field. A change to a product can then be implemented without risk and more quickly than directly on a production system that has already been installed”, says Stefan Bergfeld.

The company also uses its excellent range of equipment to process small pilot series, however typical job-shop work such as laser marking is not offered, as 4JET stays true to the principle of only specializing in applications that (almost) no one else can do.

LASER | SYSTEME | SERVICES

4JET

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