



# Editorial

Anniversaries are an occasion to look in the rear-view mirror where things may appear closer than they actually are. So it doesn't seem that long ago since a small team of just ten employees built the first 4JET machines. Prior to being shipped, the machines had to be rotated 90 degrees on two forklift trucks in order to fit through the narrow doors of the too small assembly hall. It was like playing Tetris, the old blockbuster video game.

Since then we have developed into a medium sized equipment manufacturer that has supplied several hundred machines to customers on five continents over the last ten years. Hundreds of millions of tires, automotive parts and solar cells have been processed using laser technology from Alsdorf – a reason for us to feel proud. In this edition of 4SURfaces we have included impressions from throughout the company's ten-year history.

However, looking towards the future is more important than looking to the past: We are continuing to work on a number of innovations for our key sectors. In this edition, read how 4JET enables the "Internet of Tires", learn more about our new spin-off company 4JET microtech, and how lasers help to functionalize surfaces.

We hope you enjoy reading this edition – here's to the next ten years!



Jörg Jetter  
CEO

PS: ... with regard to rear-view mirrors – thanks to our PearlCut™ laser process, they can be cut like butter. Read more about it in this magazine.

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# 4SURfaces



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# CLEANING WITH LASER TECHNOLOGY – An Overview

"Cleaning", "decoating", or "stripping" – there are numerous approaches to laser based surface processing. 4JET has industrialized touchless precision cleaning in a variety of different industrial applications.

## The basic technology – laser ablation

Pulsed solid-state lasers or fiber lasers are particularly suitable for economic surface processing. Pulsed CO<sub>2</sub> TEA or excimer lasers can also be used for more exotic applications. In addition, some cleaning tasks can be carried out using continual CO<sub>2</sub> lasers.

Short pulses are used for ablation with pulsed laser radiation (typically in the range of a few nanoseconds). The pulsed and focused light meets with energy densities of several J/cm<sup>2</sup> and peak powers in the MW range on the surface that is to be processed. The

instantaneous application means that the energy cannot dissipate, and it virtually blasts off the coating in a small area. The area of impact corresponds with the size of the laser beam spot on the surface. The penetration depth depends upon the application with just a few µm per pulse. By repeating this process several tenthousand times per second, the surface can be gradually cleaned pulse by pulse. Using optical scanning systems, the laser beam spots are placed side by side in order to process a larger continuous area.

Organic surface layers and metals can be removed. Due to the comparably poor absorption of short-wave light in organic surface layers, the removal sometimes does not happen by layer-wise ablation "from top to bottom", but by absorption of the laser radiation into the substrate and therefore underneath the layer that is to be removed.

The matter that is blasted off – generally fine dust and gas – is suctioned off locally

and piped to a filter. During the short duration of the pulses, the substrate – such as an aluminum vulcanization mold – absorbs virtually no laser light. As a result there is no thermal effect upon the substrate. Organic materials in particular are therefore easy to remove from surfaces. Furthermore, mineral layers such as oxides and ceramics can also be processed.

The speed is determined by the laser power used and the absorption behavior of the surface layer. When removing thin layers of lubricant for welding preparation, ablation rates of 10 cm<sup>2</sup>/s are reached per 100 W of laser power applied to the surface layer. Vulcanization molds with a tool surface of more than 1 m<sup>2</sup> can be cleaned in around 20 minutes. A 35 µm thick cathodic dip paint coating is removed at a rate of 8 cm<sup>2</sup>/s utilizing 750 W laser power.

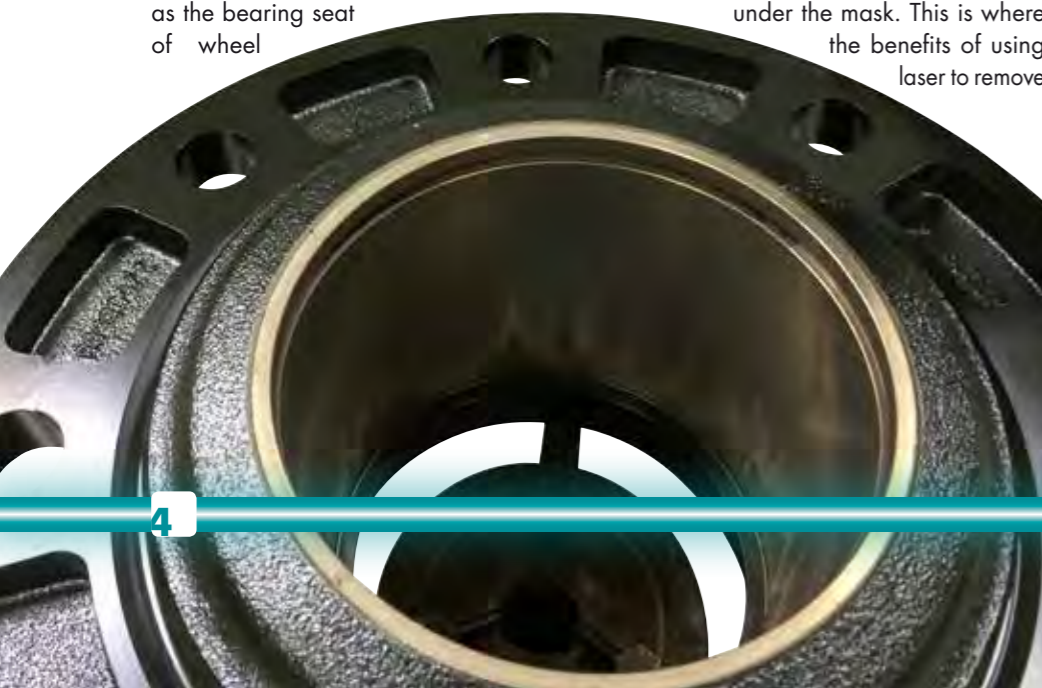
## Example I

### Cathodic dip paint removal

To provide components with high-quality corrosion protection, they are coated in cathodic dip paint. In certain areas, such as the bearing seat of wheel

hubs, it is not possible to apply a cathodic dip paint on the component. Usually, the components were masked accordingly prior to painting. However, this is very time consuming and there is no guarantee that the cathodic dip paint will not seep under the mask. This is where the benefits of using laser to remove

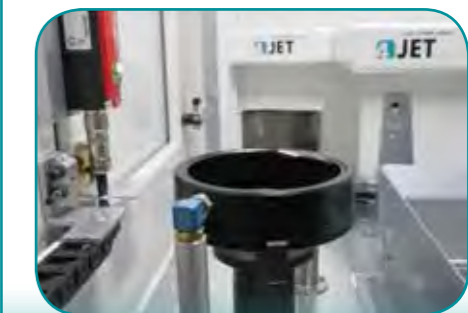
cathodic dip paint are apparent. The component is first coated fully with paint. A pulsed solid state laser then selectively removes the cathodic dip paint layer in the respective areas, leaving them exposed. The layers below the cathodic dip paint, such as zinc phosphate, are not affected.



## Example II

### Welding seam preparation of gear parts to prevent cracks and pores:

A pulsed solid state laser can be used to clean defined areas on gear parts that are free of corrosion protection, oils and fats, without leaving behind residues, in order to guarantee process safety for the subsequent welding process. The cleaning process is automated and monitored to make sure that each component meets the requirements. The quality of the cleaning process is ensured by a suitable in-process measurement.



## Materials that can be removed using laser ablation include, among others:

- Process residues (e.g. in mold tools) such as by-products from the vulcanization of "rubber" (soot, separating agent, rubber)
- Resin residues
- Plastic injection molding products
- Insulation layers (e.g. on CU conductor tracks) such as PU, PVC, PTFE, PP, PUR, PET and PI (Kapton®)
- Welding and corrosion protection (e.g. on piping) such as PA and PVF
- Coatings (e.g. on rollers or in molds) such as rubber and Teflon®
- Paint (on metal or composite materials)
- Powder coating and water-based paint
- Oxide, eloxal coating and hard coating
- Metals (e.g. molybdenum on glass, zinc on steel, CU conductor tracks on films)

## Essential benefits of laser processing:

- Dry process with no need for solvents or abrasive materials
- No consumable materials to be disposed of
- High process reliability and repeatability
- Compact footprint
- Selectivity of the process – the processing areas can be precisely defined unlike wet processes, and can be reduced to the areas that are to be cleaned
- No mechanical or chemical impact upon the substrate

# TOTAL TIRE TRACEABILITY COMPLETE SOLUTION

4JET adds new mobile app to SCANNECT™ solution



## Simple solution, speedy success

While the tire community is still looking for an "all-in-one solution" for intelligent tires in the Internet of Things, 4JET has created facts. Based upon the solution for laser engraving on tire sidewalls, which has been used for a number of years, the tire surface carries digital information about the tires. SCANNECT™ is the name given to the practical 2D matrix codes that are applied to tires in seconds at the end of their manufacturing process. Engraved into the surface of the tire where they are wear resistant, the codes and their information can be read easily throughout the service life of the tire.

## Quantum leap in safety and driving dynamics

Admittedly, this does not make tires more intelligent, and SCANNECT™ technology promises considerably less than tire-mounted sensors (TMS). TMS are not only designed to replace the tire pressure control system that sits on the tire rim, but the intelligent tires also provide constant feedback on the current driving situation. Anyone who

has walked a few steps with a sleeping foot can imagine the quantum leap in terms of safety and driving dynamics if constant feedback is sent from the tires to the vehicle. TMS systems that are used already in niche markets provide initial functions such as tire pressure control.

## Tire-Mounted Sensors (TMS) still have a way to go

However, car manufacturers say that TMS still do not yield enough advantages for the mass passenger car market over already TPMS (tire pressure monitoring systems) that are already tried and tested in numerous applications. Therefore, end users will still have to wait at least another couple of years for the sensor technology. The development hurdles are high, and include questions about energy supply and standardization among all vehicle and tire.

The interest in SCANNECT™ technology from 4JET within the automotive industry is correspondingly high. Even without tire intelligence, this system solves certain major problems for car manufacturers. For the first time, tires critical information about

their type, age and mounting direction in a machine-readable format, thus allowing reliable and correct assembly in the associated vehicle without the need for time-consuming manual quality control measures.

The code also allows the unique identification of each individual tire as well as its tracking throughout production, assembly and the entire service life of the tire. Compared to other automotive parts, tires still do not have individual traceability, which makes them a fossil among the important parts of a modern vehicle – in other words, the complete opposite of Industry 4.0.



## SCANNECT™ – the perfect addition to TMS

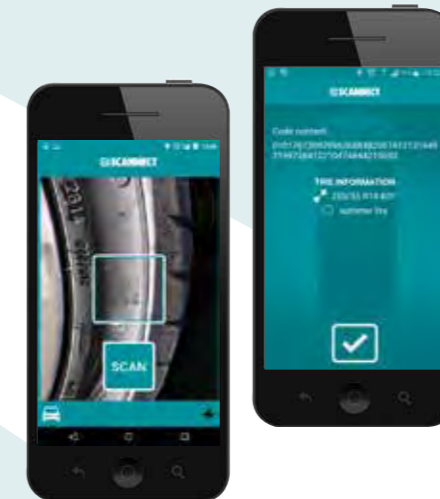
On the way to the Internet of Things, the Tire Industry 4.0 or the "Internet of Tires", the SCANNECT™ code is thus an initial milestone. Even more so, as it has a number of key complementary features compared with TMS networked via RFID, making it the perfect addition to radio chips. Thus the code that can also be read via smartphone provides a direct interface to the end customer or the commercial user which means it is also suitable for use cases that do not justify to invest in a special RFID reading device. Furthermore, the TMS requires the independent unique identification of the tire via this radio chip. SCANNECT™ technology enables the simultaneous application of a machine-readable code and a visible serial number that can be read manually for the purpose of redundancy. And finally, not only can the tire's rotation direction be automatically crosschecked using the SCANNECT™ code, but the line-of-sight scanning also eliminates the risk of misreads that can occur with RF technology when batches of tires require identification.

## Fully-industrialized complete solution

4JET has therefore developed a complete solution in collaboration with partners from the automotive industry and manufacturers of industrial image processing solutions. This includes engraving on tires, standardization of the code content and the corresponding quality requirements of the code, as well as reliable and fully-automated reading technology. In the near future, the first vehicle series will be equipped with SCANNECT™ codes.

## New SCANNECT™ reading app

4JET has rounded off its SCANNECT™ tire-marking solution with a reading app for mobile devices that has been optimized for SCANNECT™ codes. A demo version that is available as freeware from Google Playstore highlights the possibilities of SCANNECT™ for applications in the automobile plant after the wheels and tires have been fitted. A number of workflows can now be designed to be more efficient and effective, whereby the tires can be simply identified and traced, and important information about the tires can be provided automatically and digitally.



## SCANNECT™ and "Tire as a Service" business models

Tire manufacturers are excited about the opportunities the digitalization of tires yield. One of the most important trends in this respect is the possibility of enhancing the classic business model. The sale of mileage performance instead of selling

tires, opens up significant potential for manufacturers and commercial fleet customers alike. The lifetime of tires and casings can be extended and fuel consumption can be reduced through professional tire management. However, a basic prerequisite for this is the efficient and effective asset management of tires, which in turn is only possible on the basis of digitalized tires.

## Co-development with partners from the tire industry

In order to meet the special requirements for the reliable reading of SCANNECT™ codes for truck fleets, 4JET has developed a customized reading algorithm for "black-on-black" codes. Several million test kilometers using SCANNECT™ tires and the feedback from important partners within the tire industry were essential in order to find the optimal parameters. The result is a smartphone tool that provides the highest read rates for old or dirty codes, even in poor lighting conditions. The adaptive algorithm is self-learning, detects data matrix and QR codes and is being constantly enhanced. The app is designed to integrate into the existing or future applications of tire manufacturers, large fleet operators or solution providers, and already offers a WIFI interface that enables the read data to be easily extracted to third-party systems.

Watch the video:



# OPENING – THE FIRST ...

## New Assembly Hall

4JET has opened a second hall for the final assembly and commissioning of laser machines at its Alsdorf location, thereby more than doubling its production

area. The new hall provides space for the growing number of serial machines. The former assembly area in 4JET's main building will be used for manufacturing

of customized projects. Thanks to the short routes between production and the engineering specialists, an optimal project flow is ensured.



# ... AND – THE SECOND

## Demo Center for Tire Machines

4JET has created a new demonstration and development center for its portfolio of tire manufacturing solutions and in doing so has extended its application area. Fully-automated systems for mold cleaning as well as manual and automatic machines for tire marking are now permanently

installed in the demo center. Additionally, the demo center also houses solutions for handling and reading tires, as well as a flexible processing station for developing new laser processes. The demo center enables customers to qualify products and processes on series

systems and manufacture pilot series. CEO Jörg Jetter explains:

"We sell production-critical machines to some of the most high-profile companies in the sector. Our demo center enables our customers to carry out bulletproof feasibility tests prior to making purchase decisions. At the same time, we can continuously develop our systems and carry out extensive testing on new solutions prior to their release onto the market. Last but not least, the systems enable us to provide targeted training for customers and new employees on site."



# GET THE GRIP

## Optimization of the axle joint through an innovative laser process

BPW Bergische Achsen KG from Wiehl is one of the leading manufacturers of innovative chassis solutions for trucks and trailers. In order to offer the complete chassis from a single source, the company works with subsidiaries around the world that use ultra-modern processes such as gray and spheroidal casting technologies in their casting plants. A newly developed laser system from 4JET, which has already been successfully installed at the BPW factory in Hungary, will enhance these processes in the future.



By structuring the surface of the cast parts, a positive locking connection is created between the elements when fusing the chassis components. This optimizes the joint in order that the chassis can be used both on-road and off-road.

The smooth contact surfaces of components and axes are converted into a defined structured surface by the 4JET laser process. The 4JET process significantly increases the transferable torsion moment between the joint from the axis to the carrier.

By using this innovative laser technology from 4JET, BPW is able to produce high-quality yet cost-effective axis systems that withstand the extreme stress on dirt roads. "As one of the leading drivers of innovation in the sector, we need strong partners by our side, with whom we can move in new directions," says Heinrich Picker, Head of Industrial Engineering at BPW. "In process development testing, 4JET processed many components that were inspected, tested and simulated at our headquarters in Wiehl. Thanks to this successful collaboration, within just seven months we were able to install the new laser machine on schedule at our Hungarian subsidiary and begin production."



LASER ENGRAVING  
FOR FULL TRACEABILITY



STMCS – Laser Mold Cleaning



Tire Marking with  
T-Mark Compact

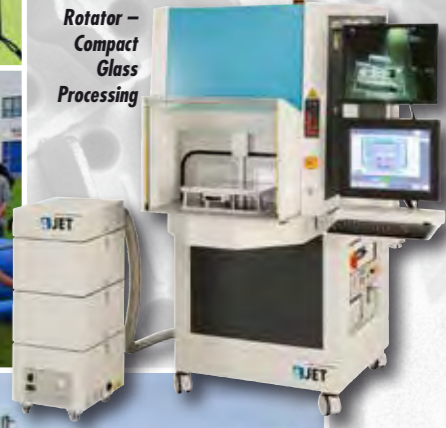


Deutscher Gründerpreis  
Award 2011



OLED Processing

Rotator –  
Compact  
Glass  
Processing



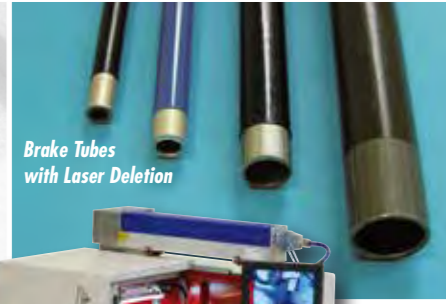
Relocation in 2009 from Hückelhoven ...



... to Alsdorf



SMART House on Approach ...



Brake Tubes  
with Laser Deletion



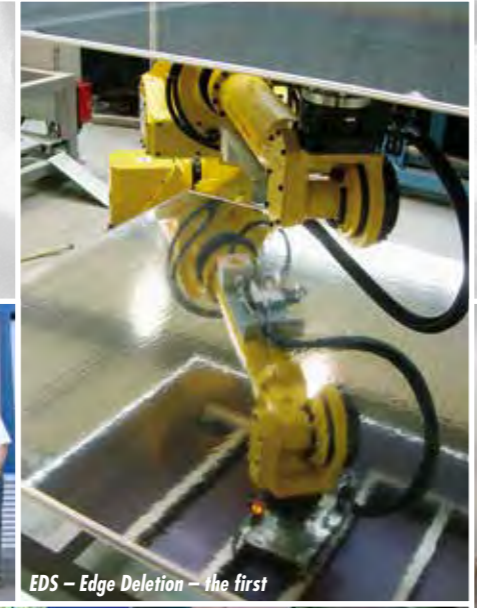
National start-up award winner "GründerChampions 2009"

# 10 YEARS 4JET

We would like to thank all  
our customers, suppliers  
and business partners for  
the trusting and excellent  
collaboration over the last  
10 years!



LABLATOR –  
R+D System



EDS – Edge Deletion – the first



International Sales Meeting



CIGS Solar Cell



Christmas Sledding



4FLEX – Laser  
Patterning on the Roll



Assembly hall in Hückelhoven 2007



Dr. Heinz Jetter –  
the Spiritus Rector



Winter Pleasure in Austria



4JET is a place in the "Land of Ideas"



CIGS Line – 4-in-1 Processing of Solar Cells





"NRW – Wirtschaft im Wandel" Award



Office Dogs!



Ice Ice, Baby!



IT Disruption!



TCS – Cleaning of Tire Innerliners



SCANNECT™ Launch at Tire Tech



4JET Management



How the T-Marks looked in 2009 ...



... and what they look like today.



REIFEN Innovation Award for SCANNECT™



2011 ...



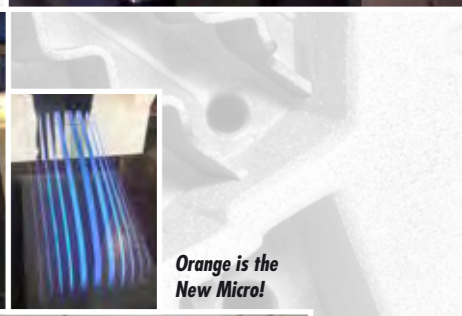
... 2014



Full House at Tire Tech



Done Deal!



Orange is the New Micro!



Mrs. Marketing



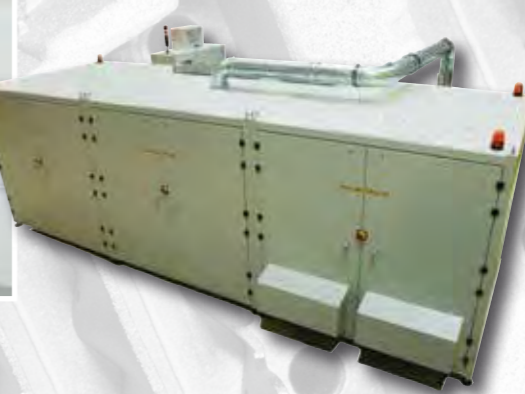
Lablator HP – a flexible System Platform for Micro-Processing



The Boss



Around the Rur Lake



MPCT – the fastest edge deletion in the world



*Another year of sportive challenges at 4JET in pictures*

High up and ways to go for the 4JET "Speed of Light" road cycling team: During the Tannheimer Bicycle Marathon the team had to go for 240 km and 3300 elevation meters – on a single day. Project manager Thomas set a team record in 8 hours and 24 minutes.



# ... AND ACTION!

As a warm up to the annual Christmas party the 4JET team had a kart racing tournament. The winning team showed little Christmas sentiment but put the pedal to the metal.



... and like every year the 4JET runners participated in Aachens company run event.

# SPIN-OFF 4JET MICROTECH

## Focused Growth

4JET has been developing new technologies, products and markets for ten years. The high development dynamics of laser technology and its markets require to be close to the customer, lean organizations and flexibility. In order to sustain focused growth, 4JET Technologies GmbH has established an independent company for its micromachining business – 4JET microtech GmbH & Co. KG.

4JET microtech develops solutions for the laser processing of technical glass and solar cells for international customers. Both

companies will continue to work under one roof at the Alsdorf location. Founder and shareholder Jörg Jetter is CEO of both companies. 4JET microtech uses the production and service organization of its sister company and can therefore ensure the usual delivery reliability and customer support from day one.

In future, 4JET Technologies wants to focus upon the considerable potential of laser-based cleaning and marking within the tire and automotive supply industry.



# GETTING STARTED as a trainee at 4JET

In cooperation with the training workshop at AQUUS GmbH, 4JET is currently training five people to become electronics engineers for industrial engineering (m/f).



Philipp began his training a couple of months ago. He explains why he chose this profession:

"It's important for me to have a diverse job. Whether assembling components, wiring switching devices or analyzing and rectifying errors – as an electronics engineer there is always exciting work to be done. As electronics is becoming increasingly important, I believe I can put the knowledge to good use in everyday life."

Andrea is already in her 2nd year of training. She tells us enthusiastically:

"A major highlight in the 1st year of

training was of course the first circuit that I completed independently and without any help. In the training workshop, we were also able to solder a dice that can display a number of points using LEDs. In machine assembly at 4JET, I can now build two flippers for a T-Mark Twin Station together with fellow trainee Christian. We are both delighted to be given so much responsibility. Overall I am extremely happy at 4JET and I feel supported at all times. I am already looking forward to my first service assignment where I can accompany an experienced colleague."

MIXEDzone

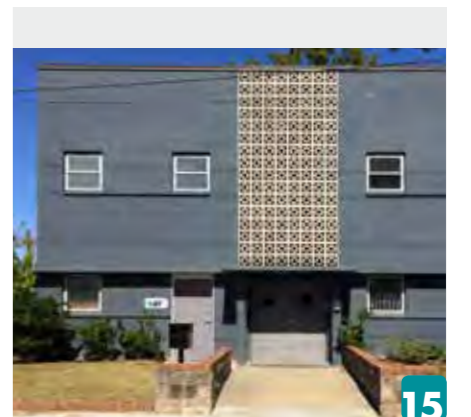
# ON COURSE FOR GROWTH

## More service power for the US-Team



4JET US-Serviceteam: Robert and Martin

In order to locally support our North American customers with the increasing number of machine installations, as well as maintenance and service work, 4JET has reinforced its US-Serviceteam and hired an additional field service technician. In addition to the sales office in Los Angeles, 4JET has also opened an office in Atlanta, from where the service assignments are coordinated. 4JET Americas LLC works for 4JET Technologies as well as 4JET microtech.





The multi-tool for laser micromachining

# TWIN

## Precision, dynamics and flexibility

4JET microtech has developed a flexible high-precision system for processing high-quality technical glass and film substrates as well as sensitive layers – the new TWIN laser micromachining system.

The modular design allows the integration of up to two parallel or alternating processing units, thus enabling increased throughput, or the combination of different processes in one machine.

Take a look for yourself:



Typical applications are the cutting of technical glass using the PearlCut™ process, glass drilling and the precise patterning of thin conductive films for the manufacturing of opto-electronic components such as touch panels, LEDs, OLEDs or Smart Windows, as well as in automotive and life sciences applications.

The TWIN system with innovative PearlCut™ technology produces glass parts in any shape – including undercuts – with high-quality edges and in just one process step. The smooth edges result in the high bending strength of the cut parts.

The substrates are positioned on a vacuum table ready for processing and are precisely recorded by a CCD camera. The processing layouts can be imported for recipe creation in common CAD formats without detours in the machine software. Individual loading and unloading systems are available for integrating into automated production environments.



# 4JET MICROFAB

Laser microprocessing in the job shop – from prototype to series production

4JET microtech offers a job shop for precision processing of glass, thin-films and electronic components, where it uses its own portfolio of precision laser systems for cutting, drilling, thin-film patterning and part marking. Customers may therefore benefit from the use of high-tech systems without having to invest.

MicroFab is the first dedicated job shop provider for free-form glass cutting using the kerf-free PearlCut™ process.

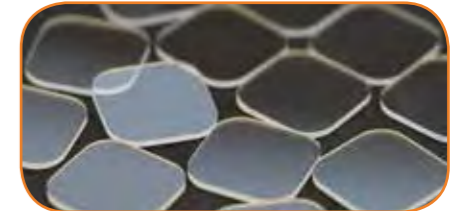
Other services include the individualization and modification of OLEDs after encapsulation using the SLAM process (Selective Layer Modification) developed together with NOVALED.

4JET also offers a service for the large-format patterning of ITO layers, thus

dispensing of expensive processes with lithography masks and long lead times.

Substrates up to a size of around 1 m<sup>2</sup> can be processed with precision in the micrometer range, whether for cutting, thin-film patterning or positioning drill holes. The bandwidth of laser sources includes wavelengths of 355 nm, 532 nm, 1064 nm up to 10.6 μm and pulse durations of fs, ps and ns to cw.

Processed components can be qualified in the in-house measurement room using light and surface microscopy and breakage testers. 4JET also offers the option for 100% final inspection, subsequent cleaning, packaging and logistics.



The fast link to 4JET MicroFab

## NEW G-MARK COMPACT SYSTEM

Flexible, handheld laser marking of glass

The G-Mark Compact from 4JET microtech offers a flexible way of marking glass surfaces with forgery-proof, permanent and unique codes. Glass sheets as well as tubes and other glass parts can be marked with graphics, text information as well as machine-readable QR and data matrix codes. The system consists of a mobile base unit and the processing unit that is clamped to a balancer.

Lettering recipes are managed via the PC controller. Interfaces to manufacturing execution systems (MES) and barcode readers are supported. The integrated evacuation removes dust efficiently.

Watch the video:



The Class 1 laser system does not require any special protective equipment.



# NANODIRECT™

2µm

## Functional Surfaces by Laser Interference

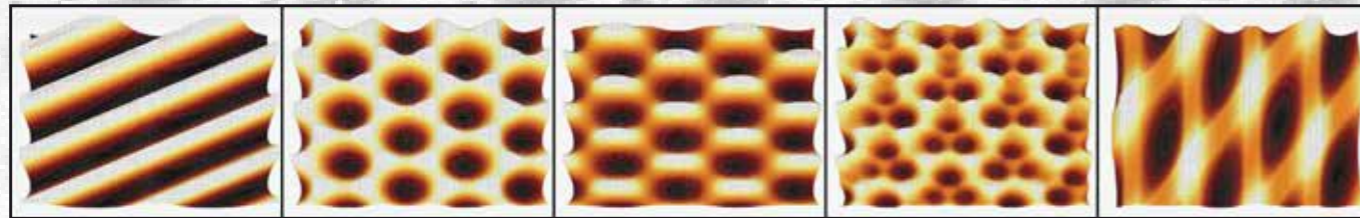


Fig. 2: Simulated textures: Different textures can be created by changing the number of interfering beams, their beam properties as well as multi-pulse processing.

Various laser processes are used in industrial applications today to ablate, clean and pre-treat surfaces for contacting, coating or bonding. Usually, layers with a thickness of several 100µm are removed, or microscopic changes are made to the surfaces for improved bonding properties of paints or adhesives.

tively, completely new applications are opened up for surface functionalization.

The NanoDirect™ method is based upon the principle of laser interference processing. Two or more coherent laser beams are overlapped at a defined angle. Due to interference effects, there is a periodic intensity distribution in the overlapping area (Fig. 1). If a workpiece is brought into this overlapping area, this periodic intensity distribution is transferred to a surface texture and/or surface modification of the workpiece.

By using laser interference, much smaller feature sizes can be achieved than with traditional laser processing. Using one laser pulse, not only one feature is created, but up to several hundred thousand features, making NanoDirect™ also suitable for large-area processing with feed rates in square meters per minute. By adapting the beam properties of the interfering laser, a variety of different textures can be created (Fig. 2). Another benefit is the possibility to deliberately adjust the feature size so that the texture

can be precisely adapted to the needs of a specific application (Fig. 3).

As the resulting texture is based upon the wave character of the laser beam, it is always well defined, homogeneous and

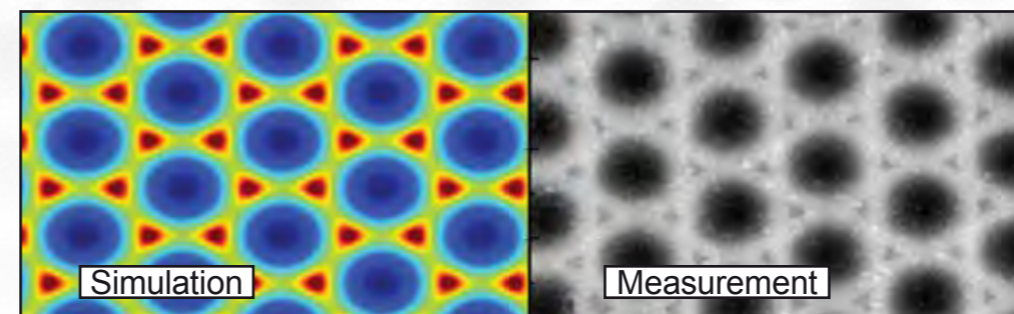


Fig. 4: SEM picture of a surface processed using just one laser pulse: The textures created by NanoDirect™ are well defined, homogeneous and strictly periodic, and in terms of size are smaller than the actual laser beam.

Fig. 5: Left simulation, right AFM measurement of a processed surface: A simulation tool developed in-house by 4JET enables the forecasting of the anticipated texture and opens up opportunities for fast texture optimization.

strictly period on the one hand (Fig. 4 and background), and on the other hand it can be determined by simulation prior to the actual processing. 4JET has developed a simulation tool that not only calculates the anticipated laser intensity distribution, but also simulates the actual material removal and thus predicts the anticipated texture for the material used (Fig. 5).

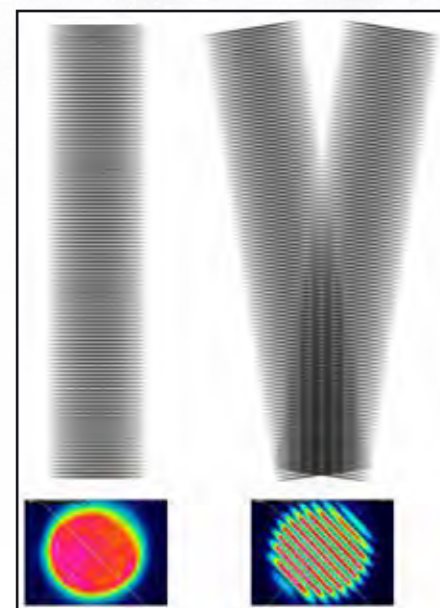


Fig. 1: Illustration of the laser interference principle and measured intensity profiles of the laser beam: Layering two coherent laser beams results in periodic amplifications and extinctions of the laser intensity within the beam diameter.

Entirely new areas of application can be opened by innovative methods for creating much smaller structures: 4JET has developed NanoDirect™ – a method for producing periodic textures in the micrometer and sub-micrometer range. By NanoDirect™, perspec-

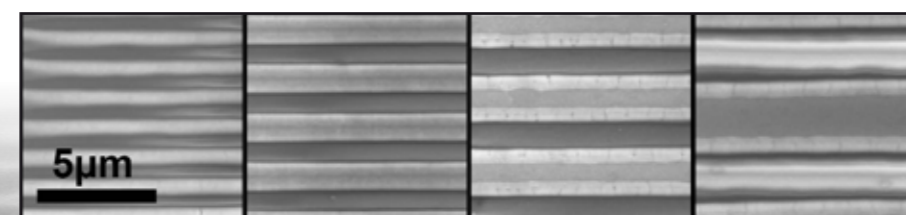
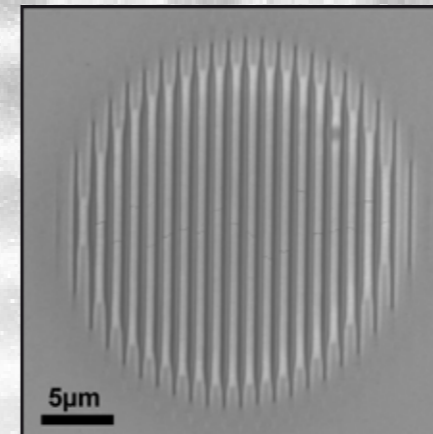


Fig. 3: SEM pictures of processed surfaces: By changing the angle of the interfering laser beams, the periodicity of the texture can be adjusted arbitrarily.



management in thin layers, such as in photovoltaics or organic LEDs.

4JET set itself the task to lift laser interference patterning from the laboratory scale to large area industrial production. Different commercial laser systems were already qualified for the use with NanoDirect™. A prototype system was built for initial tests in an industrial environment. With this system, 4JET already now is capable of functionalizing surfaces on flat and cylindrical workpieces on large areas. As part of the “High-Speed-f” project and in cooperation with the Fraunhofer IWS in Dresden, processing speeds of up to one square meter per minute are aimed at by the end of the year, thereby setting a new world record.

The first series production runs for systems with speeds in the range of several tens of square meters per hour at a cost of a few euros per square meter are planned for the next few years.

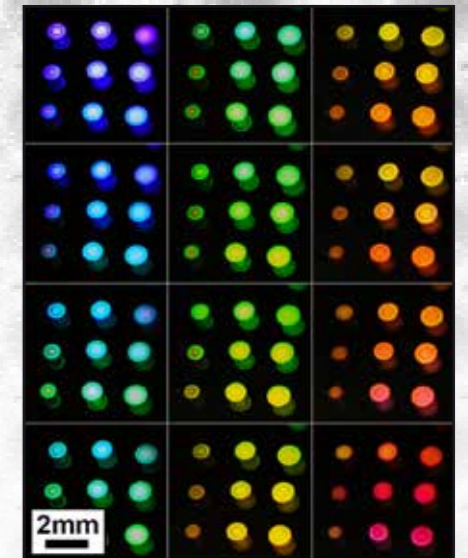


Fig. 6: 12 photographs of the same nine laser spots processed with NanoDirect™ at different illumination angles: Due to the highly-periodic micro-structure, the processed areas appear in different colors in dependence of the angle of illumination.



Fig. 7: Photograph of a processed workpiece: The micro-texturing results in a macroscopic shimmering effect of the processed areas.

There are many potential fields of application for NanoDirect™ technology, as the different properties of workpiece surfaces can be specifically changed and adapted by highly flexible micro texturing (Fig. 2 and 8). For example, the light diffracting properties of a surface can be changed so that it appears shimmering to the human eye (Fig. 6). The creation of shimmering surfaces is interesting not only for decorative purposes, but also for product protection (Fig. 7). Furthermore, the tribological, adhesive and contact properties of surfaces as well as the formation and flow of a lubricant film can be optimized. A further application in optoelectronics is engineer able light

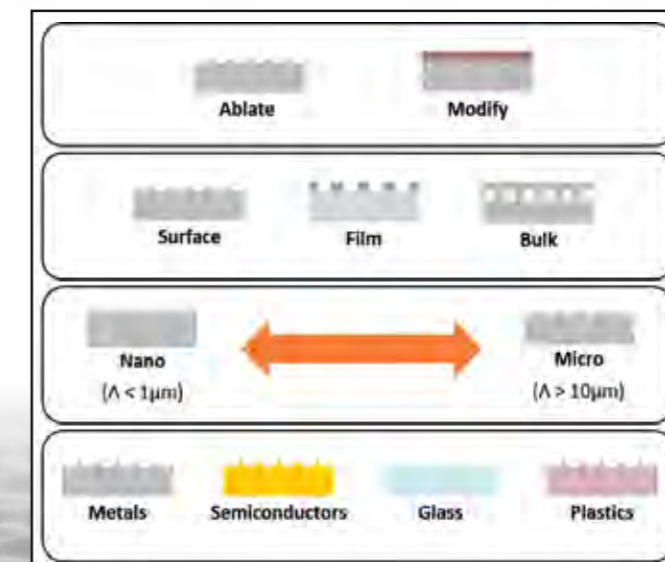


Fig. 8: Illustration of possible applications for NanoDirect™: The functionalization due to micro texturing is highly flexible and thus, can be of interest in many fields of application.

