



# Laser Micromachining for Industrial Applications

Your service provider for application development  
and series production

**PULSAR**  
PHOTONICS

# State of the art laser technology & process competence for your industrial application

**Ladies and gentlemen, dear customers and business partners,**

We are pleased to present our current services and examples of typical applications in the field of laser micromachining with the application overview 2020/21.

Since the foundation of Pulsar Photonics GmbH, process competence has been a central component of our services. The business area of application development has steadily expanded and today comprises a machine park of self-developed Ultra-short pulse laser machines for micro drilling, surface structuring and fine cutting. The laser technology is complemented by state-of-the-art measuring technology for 2D and 3D surface measurement.



In addition to the latest software functions, we also have the most advanced beam shaping technologies on the market and special optics for 2.5D micromachining. Benefit from our wide range of services from technology consulting to series production.

At our place or on your own machines. We look forward to your industrial applications!

***Philip Oster, Head of Application Development  
&  
the management, Pulsar Photonics GmbH***



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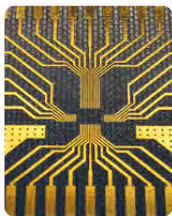
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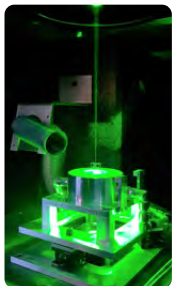
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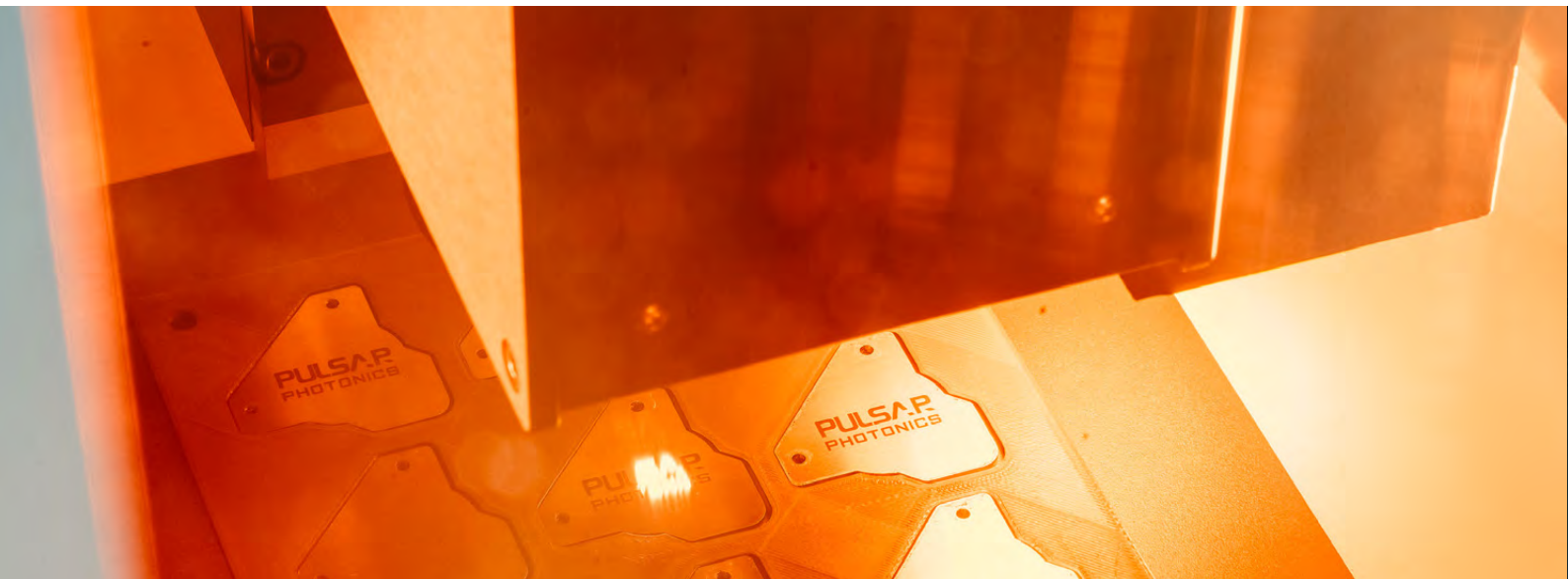
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## - 4 - Our tool: **Ultra-short pulse laser**

### Ultra-short pulse laser (USP laser)

Ultra-short pulse lasers are an established tool in laser technology for the micro-machining of components with highest precision.

The lasers emitted the laser radiation in the form of single ultrashort laser pulses. The pulse duration of these lasers is in the range of femtoseconds ( $10^{-15}$  s) to a few picoseconds ( $10^{-12}$  s).

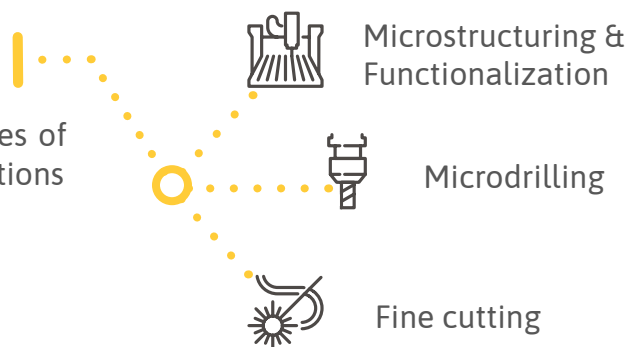
The resulting high light intensities when focusing the laser radiation on a workpiece enable ablation with strong localization of the introduced energy and absorption in any material.



1

### Precise tool in material processing

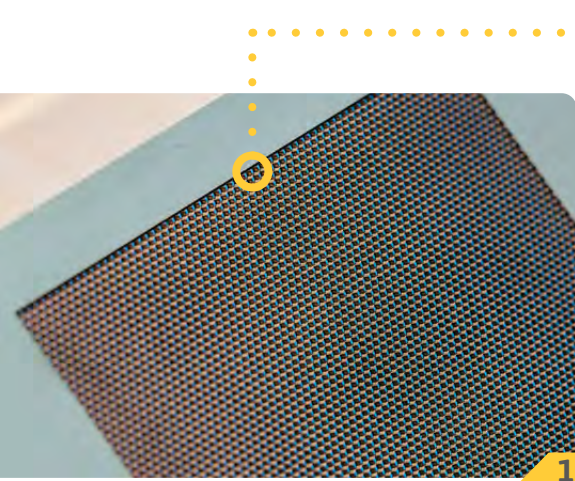
Due to the outstanding characteristic properties of these lasers, there are more and more applications in various fields of material processing - especially for **microstructuring, micro-drilling, fine cutting** and **functionalization of surfaces**.



1 Laser machine P1000-R2R for processing flexible substrates

# Why USP Laser?

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## Increase product quality: Tool for highest requirements

The mostly significant quality advantages of USP processing compared to established processing methods and also known laser processes are the main reason for a change to this technology.

Lateral resolutions of a few micrometers and a depth resolution of less than one micrometer basically enable a wide variety of applications.

## What are the advantages of USP machining?

- Any material can be processed.
- High lateral structure resolution up to  $1\text{ }\mu\text{m}$
- Depth resolution up to  $<1\text{ }\mu\text{m}$
- Lowest thermal influence zones
- High reproducibility
- No post-processing necessary

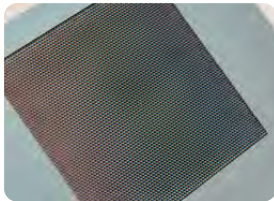


**1** Tool insert for micro injection molding and micro embossing

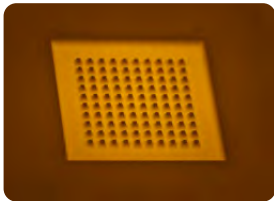
**2** Laser-cut glass gearwheel with marking



# Microstructuring at a glance



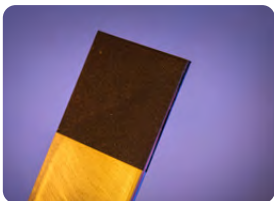
Mold inserts for micro injection molding and micro embossing



Micromachining of brittle hard materials and plastics



Microstructures for hydrodynamic pressure build-up in plain bearings



Roughening of surfaces



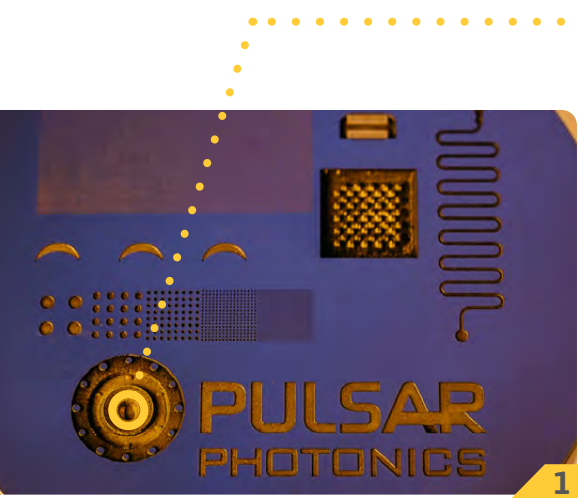
Hydrodynamically effective conveying structures



Functionalization of ceramic seal rings

# Mold inserts for **micro injection molding** and **micro embossing**

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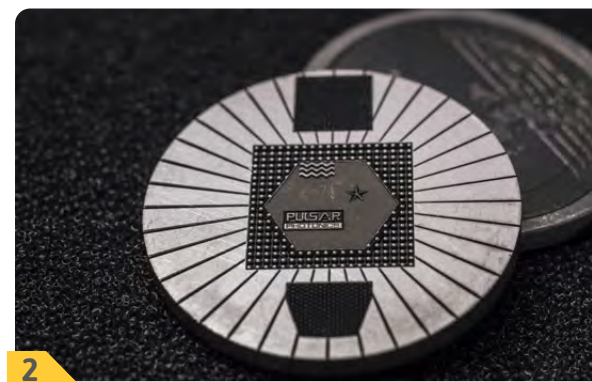
## Laser microstructuring of stainless steel and hard metal for the production of replicative tools

Laser microstructuring has increasingly established itself as an applied process for tool technology.

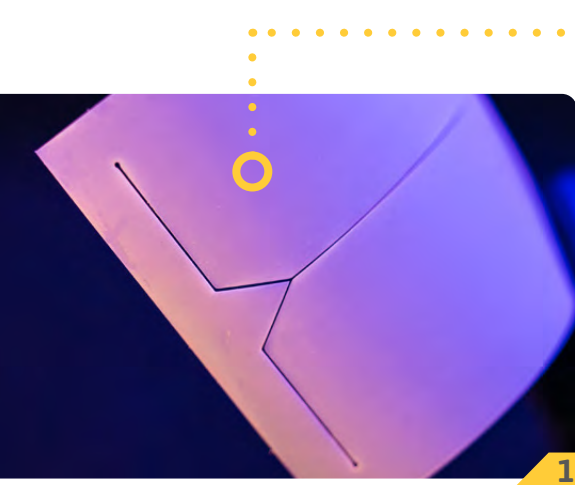
The main advantages of laser structuring are, in addition to a high degree of geometric and material flexibility, the small achievable structure sizes and surface roughness. In addition, the continuous digital process chains enable the fastest possible design changes with significant effects on production flexibility.

## Achievable qualities

- Structure resolution: typ. from 10  $\mu\text{m}$
- Surface roughness: typ.  $R_a = 1 \mu\text{m}$ , smaller roughness through laser polishing



## Micromachining of **brittle hard materials** and **plastics**



1

### Ceramic, glass and plastic processing

The very high light intensities occurring during micromachining with USP lasers allow the processing of materials where mechanical or other laser processes reach their limits.

With the USP laser plastics can be cut cleanly and without carbonization. Ceramics and glasses can be drilled, structured and cut without thermal damage to the materials. This opens up new degrees of freedom in electronics and medical technology.

### Achievable qualities

- Materials: ceramics, glasses, polymers
- Material thicknesses: 5-300  $\mu\text{m}$
- Structure solution: typ. from 10  $\mu\text{m}$
- Bore diameter: < 10  $\mu\text{m}$  - 300  $\mu\text{m}$

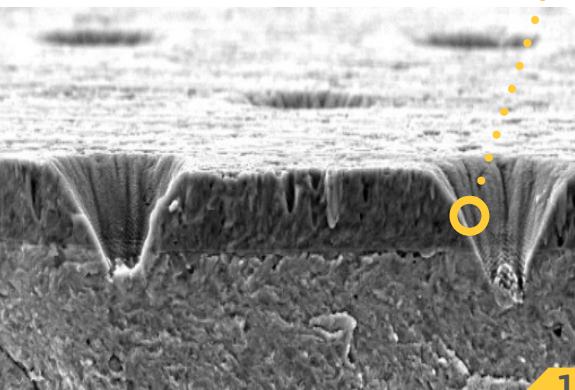


2



# Microstructures for hydrodynamic pressure build-up in plain bearings

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1

## Cell structures for targeted influencing the Stribeck curve in tribosystems

### Target:

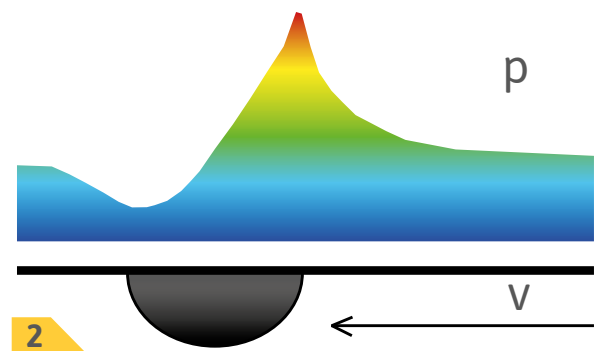
Reduction of friction and wear in surface friction contacts by reducing static friction and shifting the mixed friction range to lower sliding speeds.

### Functionalization:

Insertion of cell structures that cause a hydrodynamic pressure build-up and thus an enlargement of the lubrication gap. In combination with conveying structures, the sealing effect can be maintained.

## Advantage of USP laser processing

- High structure resolution: structure depths from 1  $\mu\text{m}$  depth and 3D topographies can be realized
- Freedom of post-processing: laser processing without throw-ups
- High design freedom in structural geometry
- Material freedom: Machining of sliding surfaces from metals, hard metals and ceramic

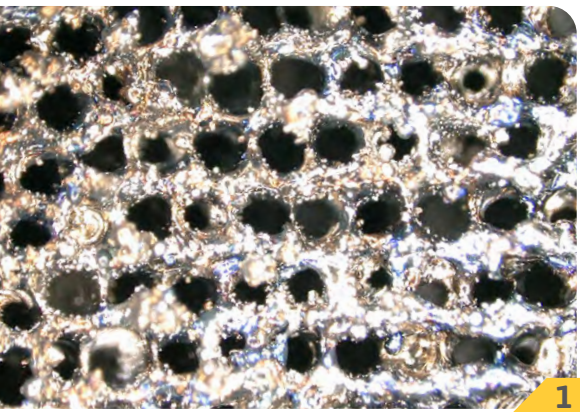


2

1 Cell structures in PVD coating (SEM image)

2 Functional diagram of hydrodynamic pressure build-up (pressure/ velocity)

## Roughening of surfaces



1

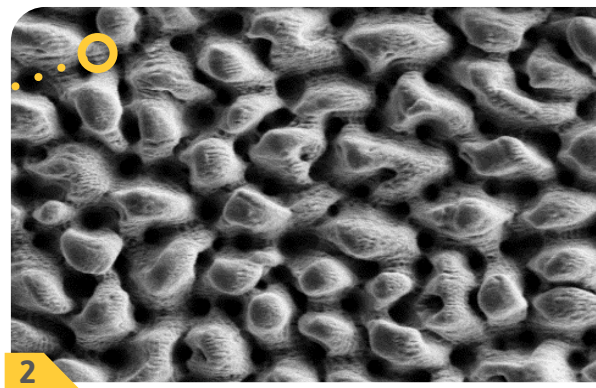
### Roughening by laser structuring

With the use of an ever-increasing variety of materials in e.g. electronic products, joining processes of dissimilar materials (such as metal-plastic connections) are becoming increasingly important.

Laser processing can be used to roughen or structure the surfaces of the partners. This leads to an optimization of hybrid joining processes.

### Optimization of joining processes

The laser can be used to provide metal surfaces with undercut structures. These enable a particularly strong metal-plastic bond with shear tensile strengths of up to 75% of the tensile strength of the plastic material. Depending on the requirements of the component, different surface topologies can be adjusted.



2

**1** Roughened metal surface with geometric undercuts

**2** Hierarchical structures in steel with undercuts (SEM image)



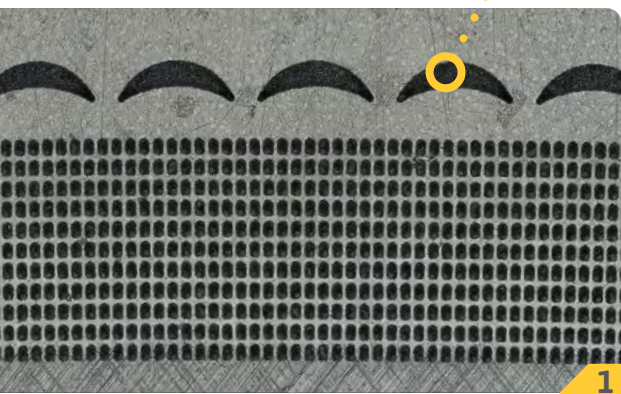
# Hydrodynamically effective conveying structures

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**Introduction of conveying structures to optimize the sealing properties of mechanical seals**

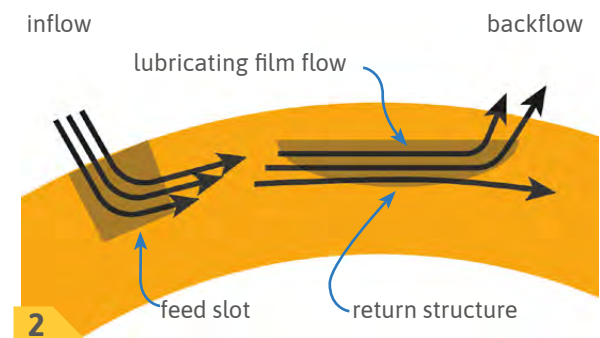
## Goals:

- Formation of a thermal wedge in highly loaded plain bearings through targeted lubricant cooling
- Return of lubricant to maintain the Sealing effect
- Delivery of sealing liquid in sealing area



## Functionalization:

- Insertion of grooves open radially to the outside, which drag liquid into the sealing gap and thus cause cooling of the sliding surfaces. The result is the setting of a wedge gap by the formation of a radial temperature field.
- Production of conveyor structures with geometric convergence (squeeze effect)
- Introduction of hydrodynamic conveying grooves

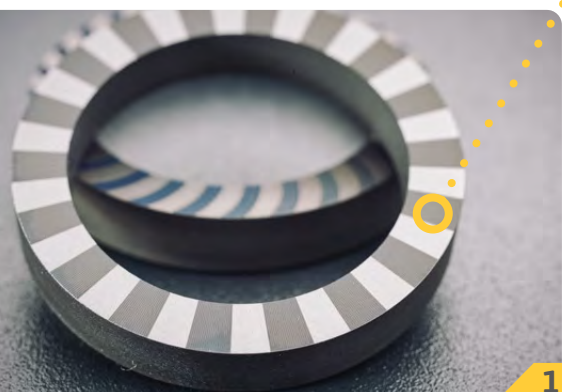


see Neumann et. al. in „Laufwerk dichtungen werden leistungsfähiger“, in: DICHT, 01-2015, p. 14 f.

**1** Combination of conveyor structure and cell structure in one plain bearing

**2** Functional diagram of the funding structure

## Functionalization of **ceramic seal rings**



1

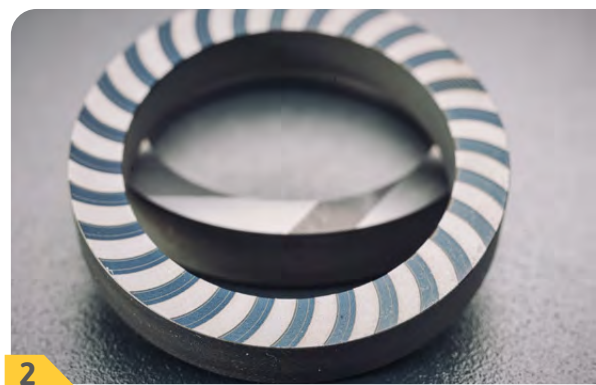
### Reduction of friction and wear in ceramic seal rings

In the context of the increase in environmental regulations, especially in the automotive sector, there is an need for further optimization of tribological systems. These include ceramic seal rings used in bearings and seals in pumps, for example.

By functionalizing the ceramic surface with microstructures, the tribological properties can be specifically adjusted. USP processing allows the ceramic materials to be processed with high structural resolution and without damaging the materials.

### Functionalization:

- Introduction of hydrodynamic wedge gaps with angles of less than  $0.1^\circ$ .
- Insertion of cell structures for hydrodynamic pressure build-up without throw-ups and without damaging the edges
- Processing of all common ceramics: silicon nitride ( $\text{Si}_3\text{N}_4$ ), silicon carbide ( $\text{SiC}$ ), oxide ceramics



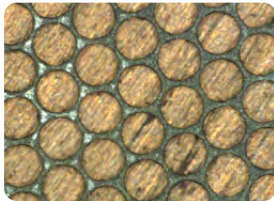
2

**1** Ceramic seal ring with functional cell structure

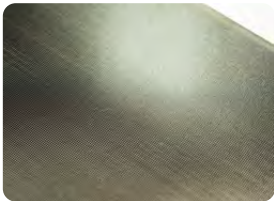
**2** Ceramic seal ring with functional guiding structure



# Microdrilling at a glance



Laser microdrilling



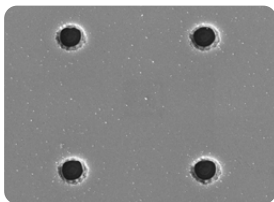
Laser drilling of micro sieves



High aspect ratio microdrilling



Deep hole drilling

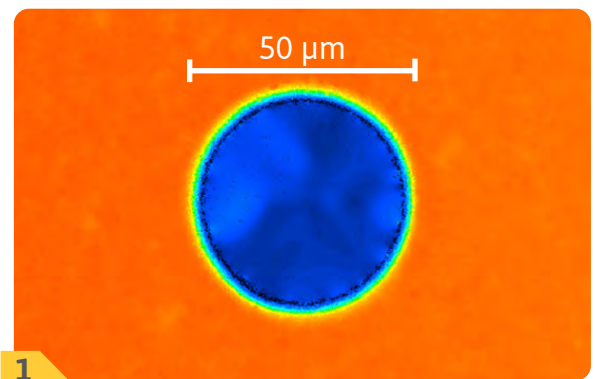


Micro drillings with diameter  $< 10\mu\text{m}$

## Laser microdrilling

### Precision drilling with the laser

Laser drilling is a non-contact and chipless drilling process that enables both fine bores of a few micrometers and precision bores up to several millimeters in diameter. Depending on the requirements, different laser drilling methods can be used.



Due to the fusion-free ablation process, USP laser drilling produces precision holes without the need for post-processing.

Possible applications include nozzle bores, screens and filters, and holes in pipes.

The advantages are high reproducibility and high roundness.



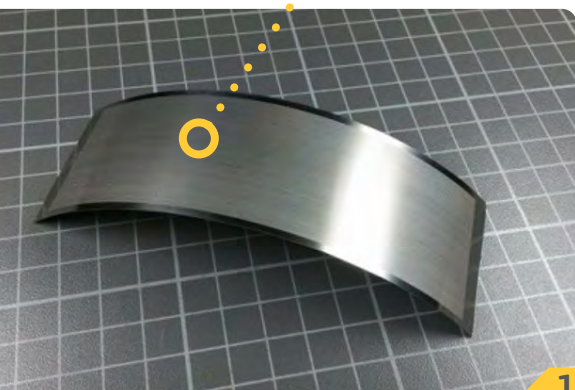
# Laser drilling of **micro sieves**

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## Laser-drilled microsieves as an alternative to etching and electroplating

Metallic microsieves with defined outlet geometries are nowadays produced by etching or electrochemical deposition processes. Laser-drilled microsieves offer an alternative here: Laser microdrilling allows microsieves to be produced from films or thin plates of almost any material and high density.

In selected processes, the use of laser-drilled stainless steel screens has increased throughput by up to a factor of 4 and significantly increased service life.



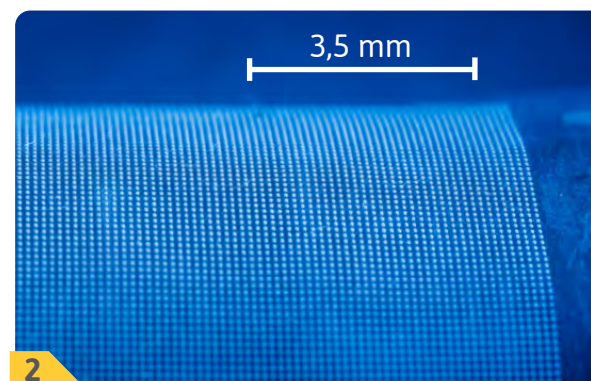
1

### Achievable qualities

- Materials: stainless steel, aluminum, titanium, ceramic
- Material thickness: 5-100  $\mu\text{m}$
- Bore diameter:  $<10\mu\text{m}$  -  $50\mu\text{m}$
- Number of holes per component: typically up to 2 million holes

### Applications

Microfiltration, analytical technology, microfluidics, Micro-Dispenser/ Low-Volume Dispenser



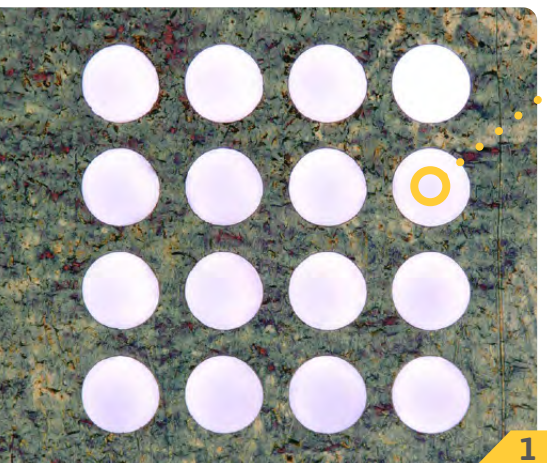
2

1 Microsieve for process engineering

2 Laser drilled PTFE membrane, bore diameter 25  $\mu\text{m}$



## - 16 - High aspect ratio microdrilling



### Precision bores with large aspect ratio

By using a special optic for spiral drilling, precise micro holes can be drilled in components with material thicknesses of up to several millimeters. In combination with an ultrashort pulse laser, holes of the highest quality can be produced in almost any material.

Application examples are injection nozzles, spinnerets, vent holes and filter applications.

### Achievable qualities

- Vertical bore walls
- Controllable conicity:  $\pm 5^\circ$
- Material thickness: up to 3 mm
- Typical aspect ratio: up to 1:30
- Bore diameter from 0.025 mm



1 Matrix of precision holes in brass

2 Laser drilled injection nozzle



# Deep hole drilling

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## Laser drilling with water jet guidance

With short pulsed laser radiation, deep-hole drillings with extreme aspect ratios (structure width/ material thickness) can be achieved in the waterjet process. For this purpose, the laser radiation is coaxially coupled into a thin water jet in a nozzle. The laser radiation is guided through the workpiece via this light guide while maintaining its focus.



1

### Achievable qualities

- Vertical cut surfaces
- material thicknesses: > 5 mm
- Typical aspect ratio:
  - up to 1:20 (micro-drilling)
  - up to 1:400 (micro cutting of large material thicknesses)
- Bore diameter from 0.05 mm

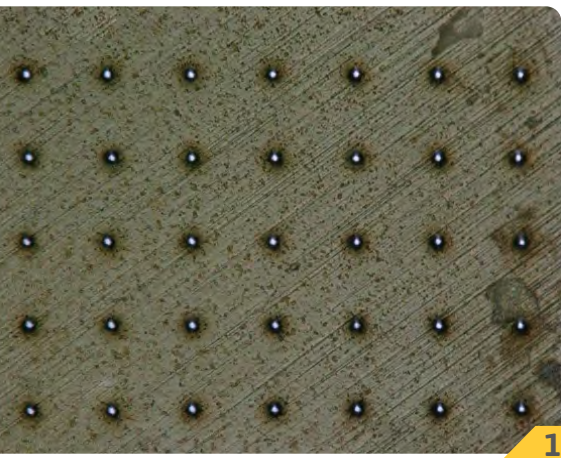


2

1 Angled drill holes in a turbine blade for stratified cooling

2 Honeycomb cut in 18 mm thick Aluminium (3 mm hexagon size)

## Micro drillings with **diameter < 10µm**



1

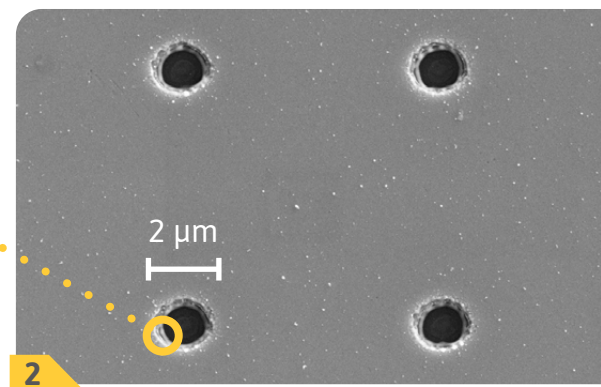
### Microdrilling at the limits of laser technology

There is an increasing demand for defined microbores in the single-digit micrometer range, especially in metrology and industrial separation. With the microscan technology developed by Pulsar Photonics bore diameters of up to less than 2 µm can be produced reproducibly, even with a higher number of bores.

By using USP lasers, high-quality holes can be produced in these size ranges as well.

### Achievable qualities

- Bore diameter up to < 2 µm
- Material thicknesses up to 50 µm
- Number of holes: 1-10,000
- Variation of bore diameter depending on application
  - » in the same processing step: up to < 5% SD
  - » between components: up to < 10% SD
- Materials: metals, ceramics, thin-film systems



2

**1** Micro drillings in stainless steel foil  
t = 30 µm with diameter < 4 µm

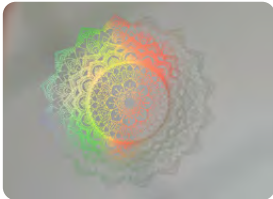
**2** Microbore in metallic thin film with a diameter  
of 1.6 µm (SEM image)



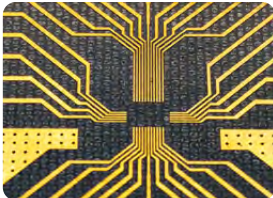
## Surface functionalizing at a glance



Resistant markings



Surface functionalization



Thin layer removal



## Resistant markings



### Markings for demanding environments

Ultra-short pulse lasers can be used to produce corrosion-resistant, high-contrast and abrasion-resistant markings in many metal components, especially stainless steel.

In contrast to conventional marking lasers, the marking is done by inserting a special microstructure.

The incorporated microstructure has broadband light absorption properties, resulting in high contrast and abrasion resistance.

The chemical resistance of the marking is mainly due to the topographically determined absorption mechanism used and, in the case of stainless steels, by maintaining the protective effect against corrosion through a chromium oxide layer.





# Surface functionalization

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## Nanostructuring of surfaces with the laser

By using so-called laser interference structuring, the laser can be used to introduce nanostructures with a high surface rate into metallic, ceramic and plastic surfaces.

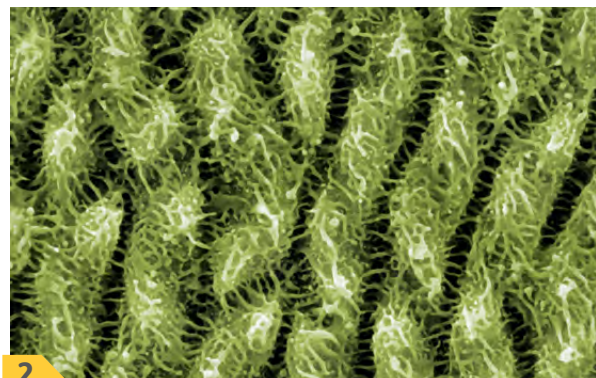
Thus, for example, optically effective grid structures can be created for product protection.



1

The technology also allows the production antibacterially effective surfaces. Cell growth, adhesion and wetting of surfaces can be specifically influenced by nanostructuring.

With the machine type RDX500 Pulsar Photonics offers laser machines for industrialization of this technology.

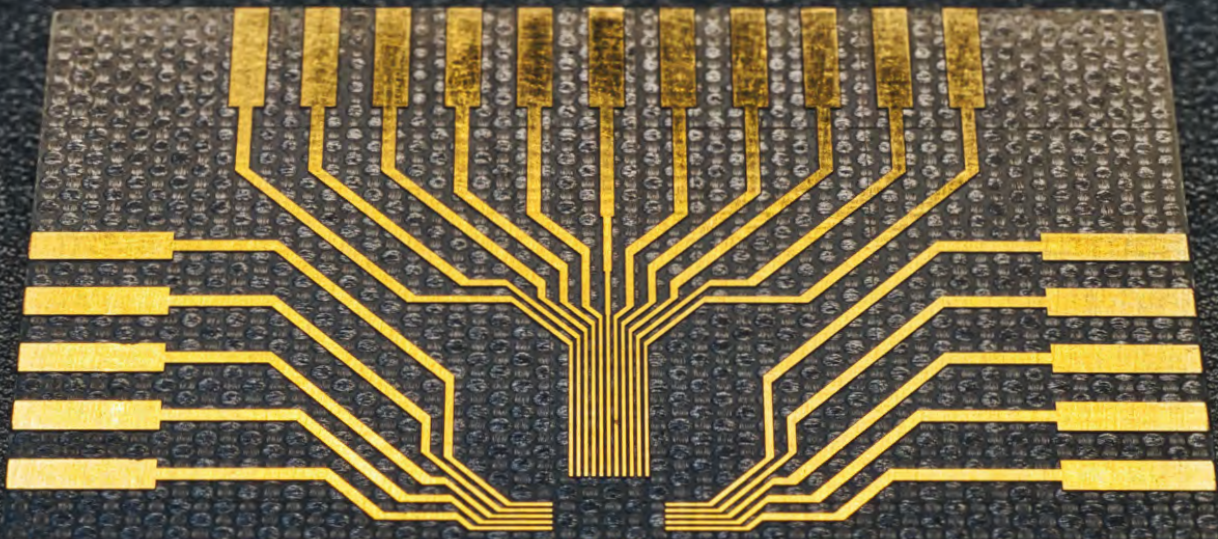


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1 Nanostructured steel surface with optically effective structure

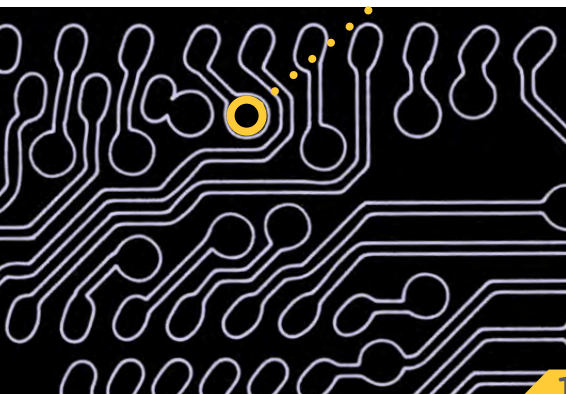
2 Biomimetic surface achieved by laser structuring





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## Thin layer removal



1

### Selective processing of thin layers

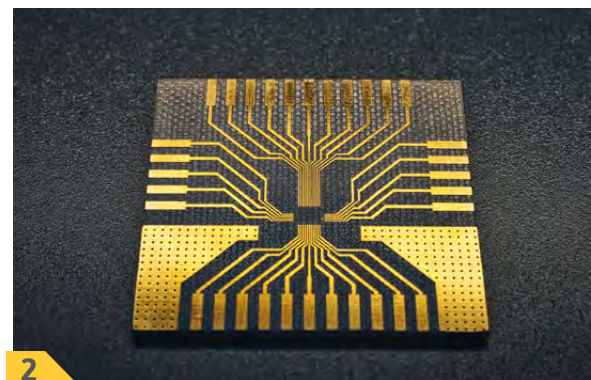
With ultra-short pulse lasers, thin-film systems can be processed highly selectively in all three spatial dimensions.

For example, metallized surfaces on a dielectric base substrate can be provided with isolation trenches with micrometer precision by laser ablation and thus functionalized for applications in electronics and sensor technology.

By suitable selection of the laser parameters it is possible to remove the metallic surface without removing or substantially damaging the underlying base substrate.

### Achievable qualities

- Lateral resolution: typ. 20  $\mu\text{m}$ , up to 1  $\mu\text{m}$
- depth resolution: typ. 100  $\mu\text{m}$ , selective layer separation possible
- applications: sensors, electronics, solar cells



2

**1** Isolation trenches on a metallized ceramic substrate

**2** Interposer for high-frequency applications produced by laser ablation of a thin gold layer



## Laser fine cutting at a glance

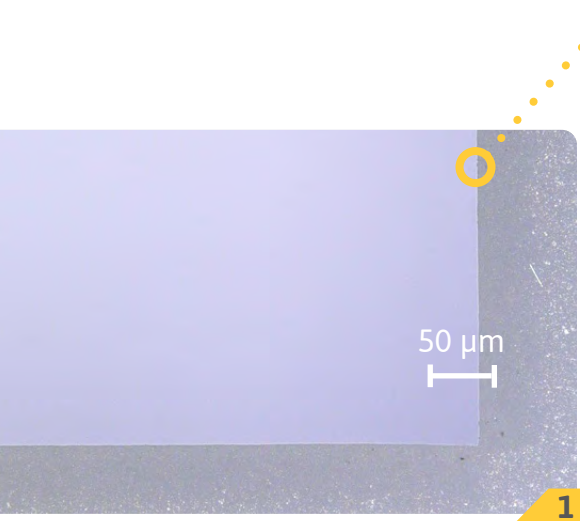


Laser fine cutting of ceramics and semiconductor materials



Precision cuts with vertical cutting edges

## Laser fine cutting of ceramics and semiconductor materials



### High freedom of geometry through scanner-based fine cutting

For the classical laser dicing of thin ceramic substrates and semiconductor wafers, wafer saws or laser-based solid optics systems are usually used. Both methods allow either only straight cutting or cutting with comparably large edge radii.

Scanner-based fine cutting with the USP Laser allows laser fine cutting with high precision, small edge radii and without microcracks in the workpiece. Thus, even small bores or micro-apertures can be inserted.

### Achievable qualities

- Ablative laser fine cutting of ceramics and semiconductor materials in free geometries
- Material thicknesses: typ. < 700 µm
- Edge radius: up to < 10 µm
- Aspect ratio kerf width to material thickness; typically up to 1:5
- Wall angle: typ. < 10°, spiral cutting < 1°



**1** Square contour cut in  $\text{Al}_2\text{O}_3$  with edge radius < 10 µm

**2** Ceramic plate cut by spiral cutting process with vertical cutting edges



# Precision cuts with **vertical cutting edges**

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1

## **Burr-free precision cuts of highest quality**

This production technology can also be used to produce precision cuts. Due to the relative movement of the component to the process head, any web geometry can be processed in two dimensions.

Hereby sapphire glass and comparable chemically hardened glasses can be separated without cracks.

## **Achievable qualities**

- Ablative laser fine cutting of ceramics and semiconductor materials in free geometries
- Material thicknesses: typ.  $< 700 \mu\text{m}$
- Edge radius: up to  $< 10 \mu\text{m}$
- Aspect ratio kerf width to material thickness; typically up to 1:5
- Wall angle: typ.  $< 10^\circ$ , spiral cutting  $< 1^\circ$



2

**1** Laser-cut micro gear made of stainless steel

**2** Demo part with burr-free precision cuts

# Pulsar Photonics at a glance



We develop your application  
and then manufacture for you in series



Our products



Your partner for professional laser micro processing



Contact





## We develop **your application** and then manufacture for you **in series**

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### Application development with ultrashort pulse lasers

Pulsar Photonics is your competent partner and service provider for precision machining in the micrometer range. Our many years of experience in working with ultrashort pulse

lasers and our access to all machine functions enable us to solve even complex problems of laser material processing and surface functionalization for almost any material.

#### Your application

Your application requires precise laser manufacturing in the micrometer range?

#### Application development

We develop step by step the best parameters for the production of your component.

#### Manufacturing at your site!

Let us support you from the first feasibility study up to your own plant.

#### Task

We discuss the requirements and possibilities for a production that is true to the original concept.

#### Manufacturing at our site?

You need more than one prototype? Move the complete production to us conveniently.

#### Service

Our service goes far beyond the delivery of your system. Benefit from our service offer in case of problems.



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## Our products



1

### Laser machine engineering

Pulsar Photonics develops machines for laser material processing, especially with USP lasers.

The systems for structuring, drilling and cutting can be configured flexibly and are suitable for manual operation as well as for fully automatic process sequences.

Our own machine control software allows easy adaptation to the respective requirements.

### Laser system technology

The Pulsar Photonics system technology enables the efficient use of USP technology for industrial production.

New optical concepts reduce process times many times over and thus increase the economic efficiency of the technology.



2

**1** Laser machine RDX1000 for USP laser micro processing

**2** MBS-G4 for massive process acceleration in laser micromachining





## Your partner for professional laser micro processing

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**Pulsar Photonics GmbH** develops and produces system and machine technology for micro material processing with USP lasers. The machines are adapted to the process and the customer's requirements with regard to the components they contain and are equipped with an individualized software solution.

In our application laboratories, **application-specific solutions** are developed for our customers and, if required, produced in (pre-)series on our own machines.

Due to many years of experience there is a very broad and well-founded expertise in the field of USP machining.

We have our own machine capacities, extensive and high-resolution measuring technology and can look back on a large number of completed projects with a team of dedicated process experts and software developers.

Pulsar Photonics GmbH was founded in 2013 and currently employs about 35 people.



### Contact us now!

**M.Sc. Philip Oster**  
Head of Application Development

+49 2407 / 55555-24  
[applications@pulsar-photonics.de](mailto:applications@pulsar-photonics.de)



**WE ARE LASER MICROMACHINING.**

**PULSAR**  
PHOTONICS

**CONTACT**

Pulsar Photonics GmbH  
Kaiserstraße 100  
52134 Herzogenrath  
Germany

☎ +49 2407 555-55-0

info@pulsar-photonics.de  
www.pulsar-photonics.de