Mikrobohren mit gepulsten Faserlasern

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ROFIN-LASAG LASERS

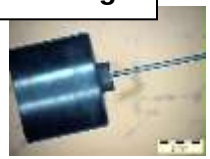
Content

- Market and applications overview
- Properties of lamp pumped pulsed laser technology
- Comparison to conventional cw fiber laser technology
- qcw diode pumped pulsed fiber laser technology
- Current application ranges and process limitations
- Application examples
- Comments and Conclusions

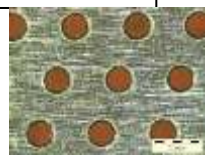
Markets for typical laser micro drilling applications

Medical Engineering

SP drilling



OTF drilling

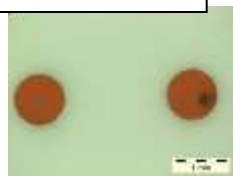


SP drilling

Trepanning

Electronics

Trepanning



OTF drilling

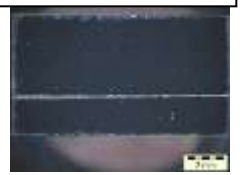
SP Drilling

Perc. Drilling

Tool

Shaped holes

Perc. drilling



Automotive

scribing

OTF drilling

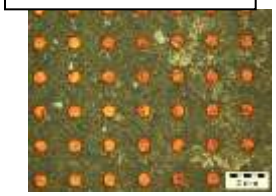
Perc. drilling

Turbine

Perc. drilling

Shaped holes

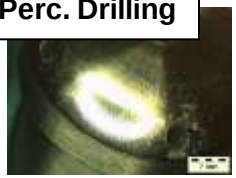
OTF drilling



Mechanical Devices

Trepanning

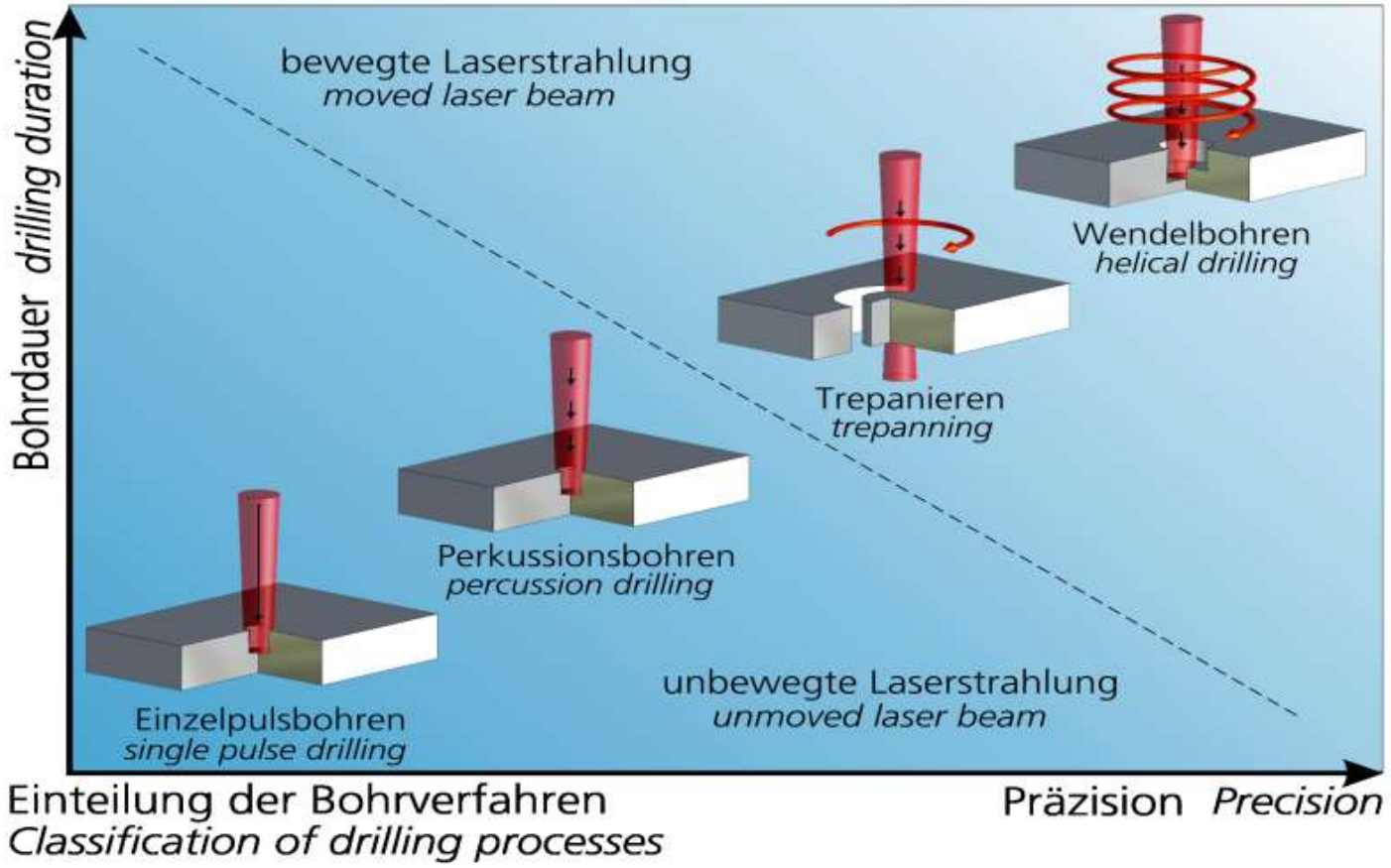
Perc. Drilling



OTF drilling

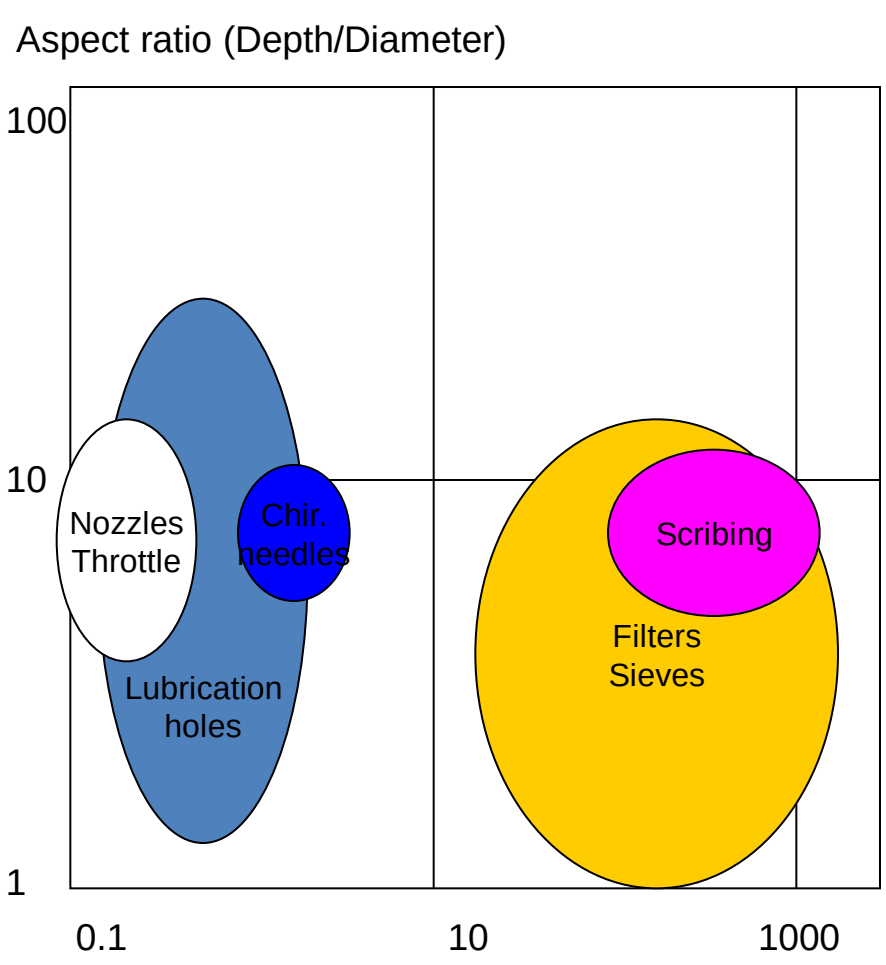
Perc. drilling

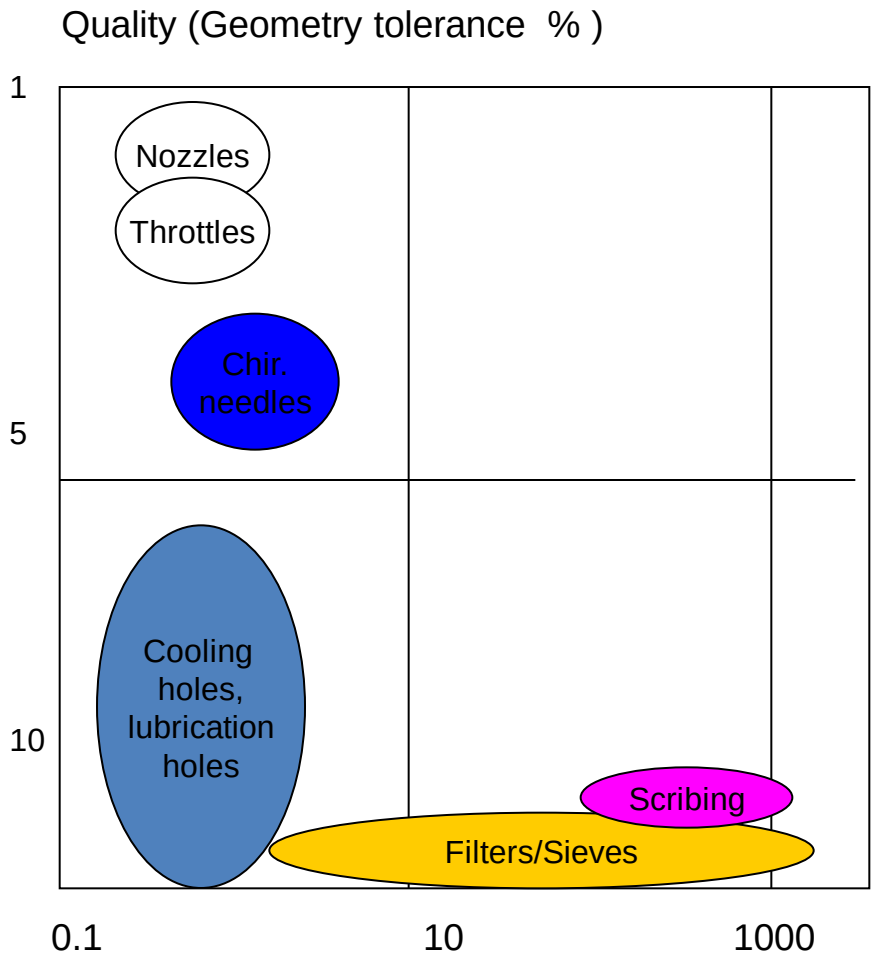
Micro drilling strategies



Source: ILT Aachen

Laser drilling market: requirements and limits





Requirements of industry

Quality

Geometry

Shape
- Taper
- Diameter
- Aspect ratio
- Roughness
- Entrance geometry

Tolerances
- Roundness
- Conicity
- Flow

Metallurgy

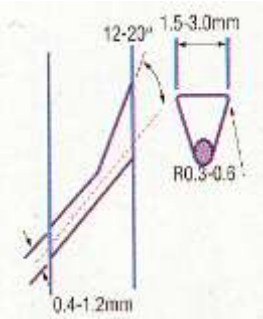
- HAZ
- Recast, oxide layer
- Micro cracks
- Delamination

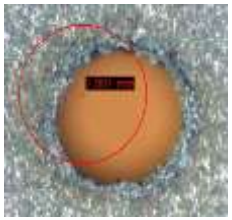
Side effects

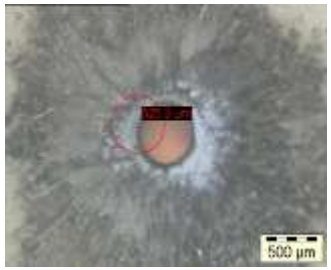
- debris
- burr
- delamination of coatings
- backwall strikes

Costs

- Investments
- Running costs
- process speed
- pre- and post process
- production steps







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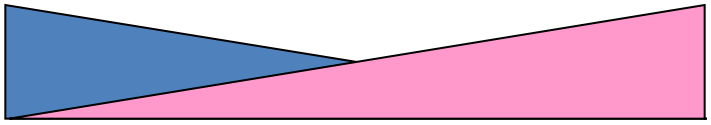
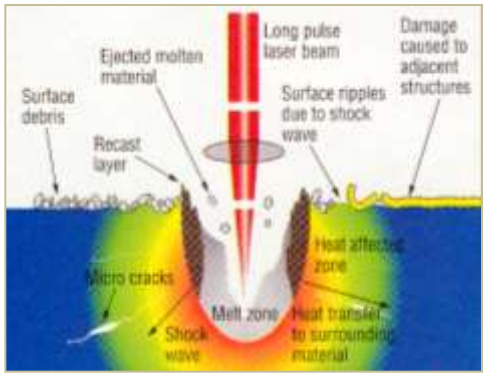
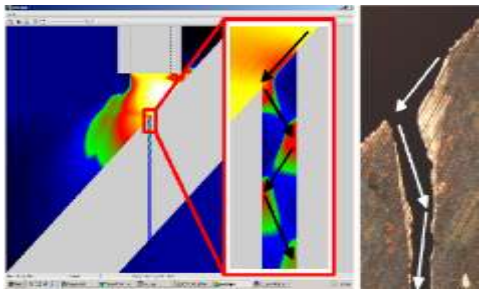


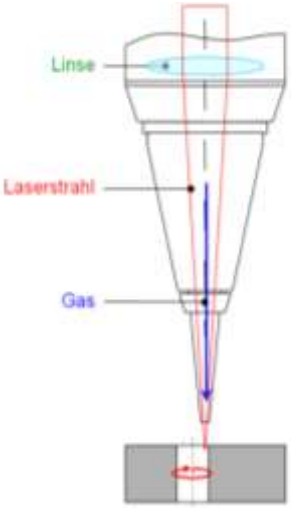
Efficiency Quality

Properties Nd:YAG (µs-Pulse): drilling process





Source: LLT Aachen



Laser beam
Wavelength (µm)
Power (W)
Irradiance (W/cm^2)
Energy (J)
Interaction time/ pulse duration (ms)
Polarisation
Beam quality (mm mrad)

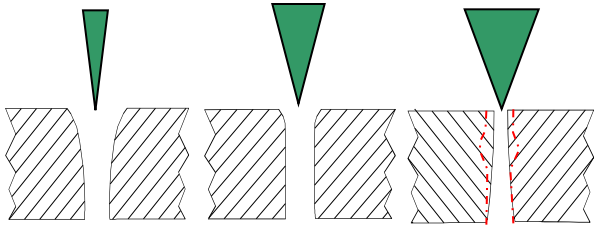
Optics
Focussing length/distance to surface
Aperture
Quality
Beam shaping

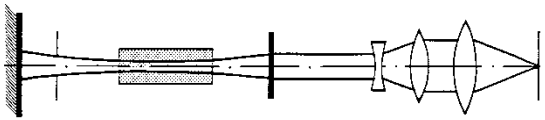
Gas
Type/mixture/purity
Velocity/distance nozzle - surface

Material

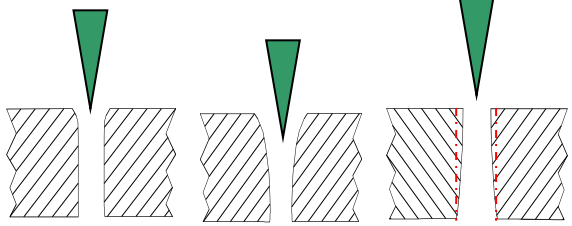
Surface	bulk properties
Absorption	material type
Roughness	thickness
Temperature	heat conduction
Dirt	heat capacity
Melt property	microstructure
-tension	
-chem. reactions	

Beam expansion





Focal position



Resonator:

changeable:
- M^2
- Power
- beam diameter

Optics:

- no Change of beam quality
- M^2 constant:
  change of spot size
  in relatioship to divergence

f = focal length of lens (mm)
also working distance
w_f = diameter of focal spot (mm)
F = speed of lens
(f/diameter on lens

Θ= beam divergence (mrad)

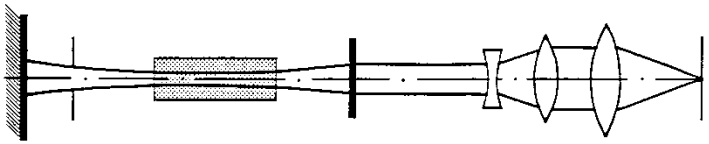
$\Theta w_0 = M^2 4\lambda/\pi$ = beam product

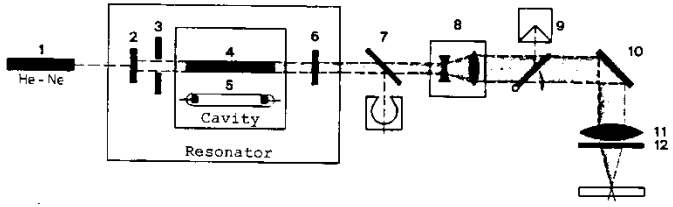
Achievable focal spot diameter: $w_f = (4\lambda/\pi) M^2 F$

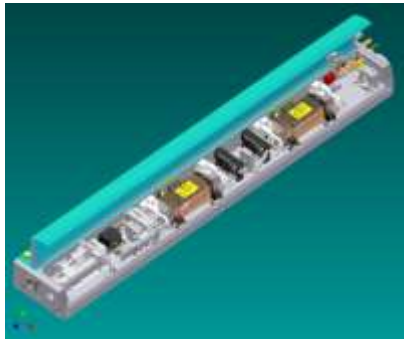
Rayleigh length (depth of focus) $z_R = (4\lambda/\pi) M^2 F^2$

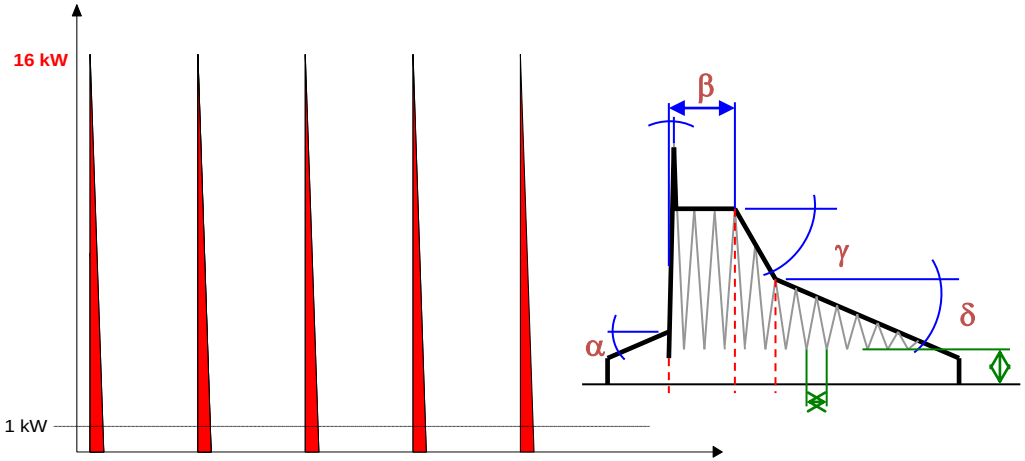
Important process parameters
Depending on w_0:
Threshold (pulse power/w_f)
Tolerances (Rayleigh length)
Productivity

Properties of lamp pumped pulsed laser technology









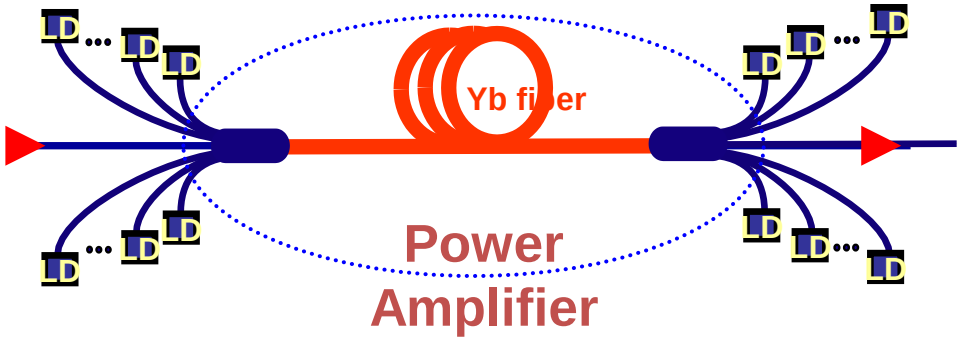
Advantages:

- High peak power
- Low average power
- Controllable heat transfer
- Pulse shaping
- Pulse modulation

Disadvantages:

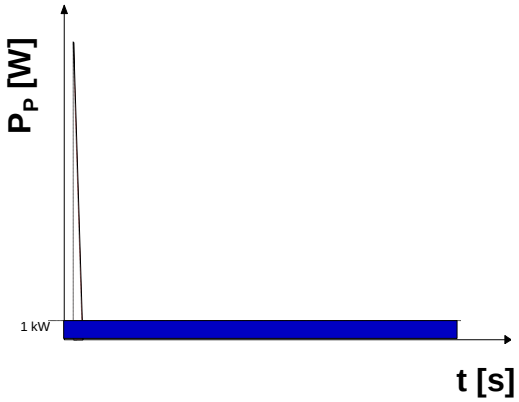
- Lamp pumped system
- Low power efficiency
- Low beam quality
- High maintance costs
- High running costs

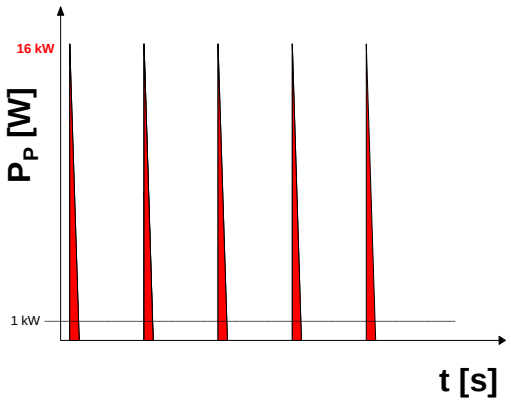
Comparison to conventional cw fiber laser technology



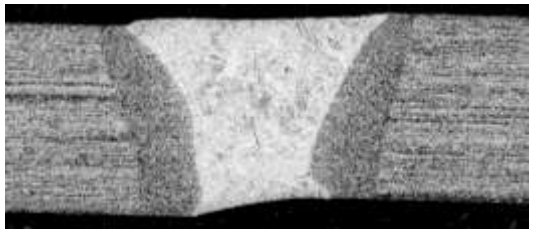
Advantages:
- High average power
- High beam quality
- Low maintanance costs
- Low running costs
- High power efficiency

Disadvantages:
- Peak power limited to max. cw power
- Thermal drift of optics

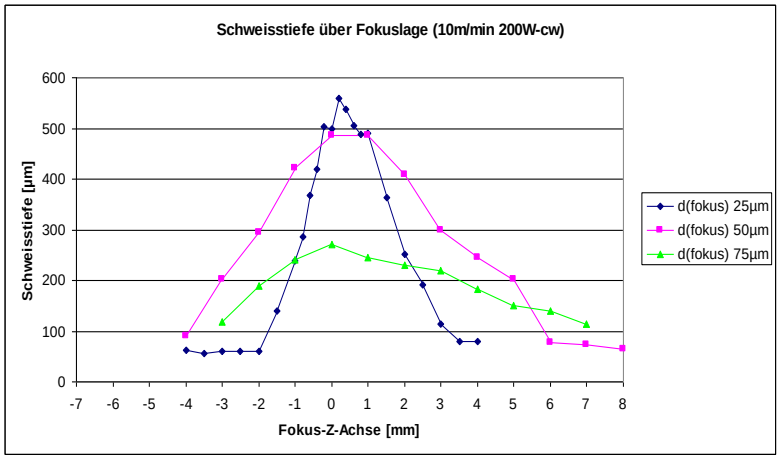




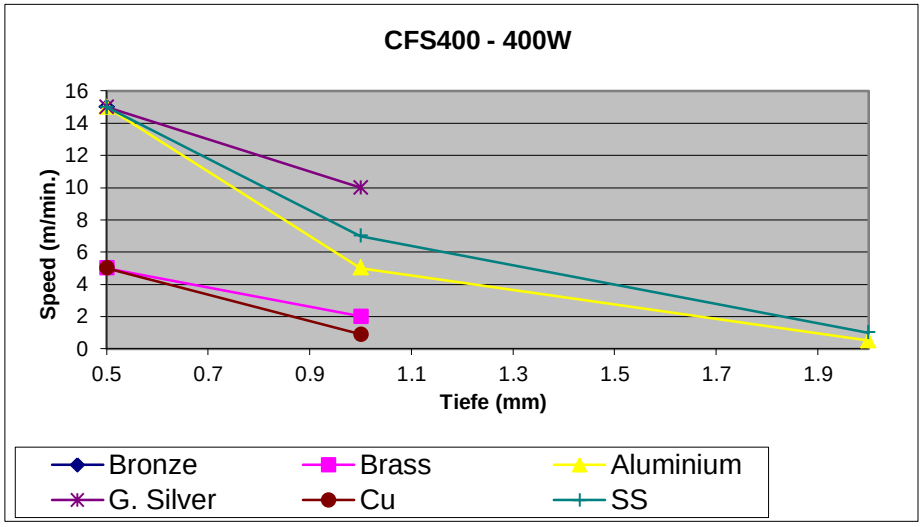
Comparison to conventional cw fiber laser technology



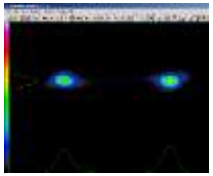
Cw FL vs. pulsed Nd:YAG laser



Welding penetration FL welding @ focal postion



Cutting performance of a 400 W cw fiber laser



d (Weld geometry) @ Spot distance bifocal optic

Comparison to conventional cw fiber laser technology

1999 – introduction of pulsed qcw diode pumped rod lasers

LASAG DLS

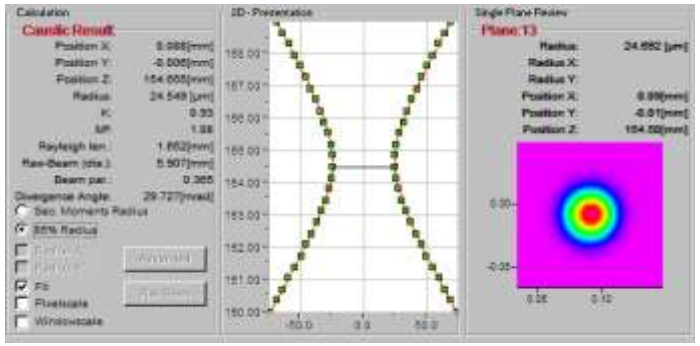
Technical Specifications

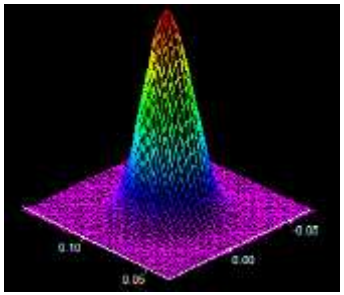
Average power:	max. 40 W
Pulse length:	0.02 – 0.4 W
Frequency:	0.1 – 4500 W
Energy:	0.5 J
Peak power:	1.5 kW
air-cooled	

2012 – still in use for Nitinol cutting…

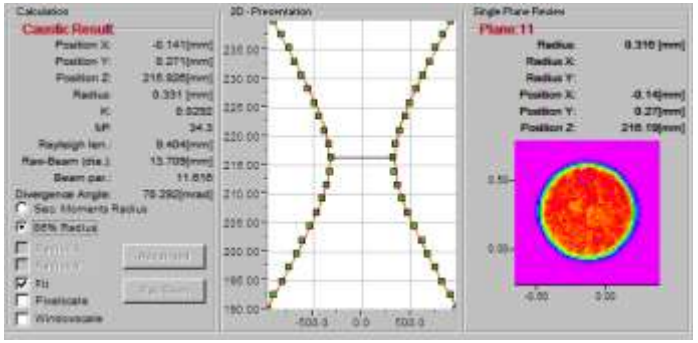
QCW fiber lasers – a silent revolution

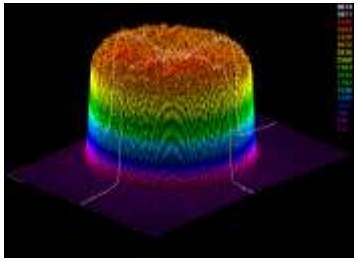
IPG YLR-150/1500-QCW-AC





IPG YLS-600/6000-QCW-AC





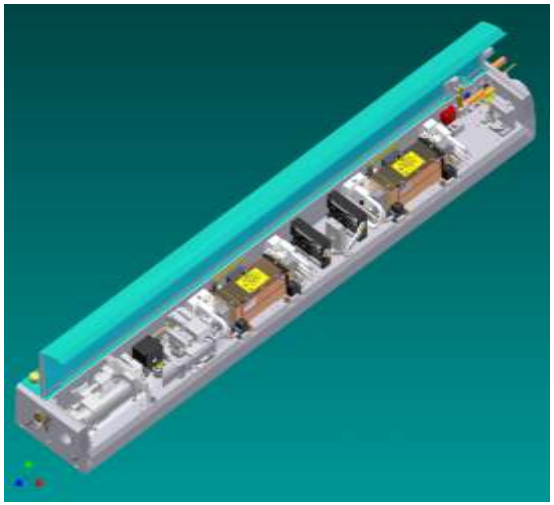
QCW fiber lasers – a silent revolution

Rofin-Lasag LFS 150

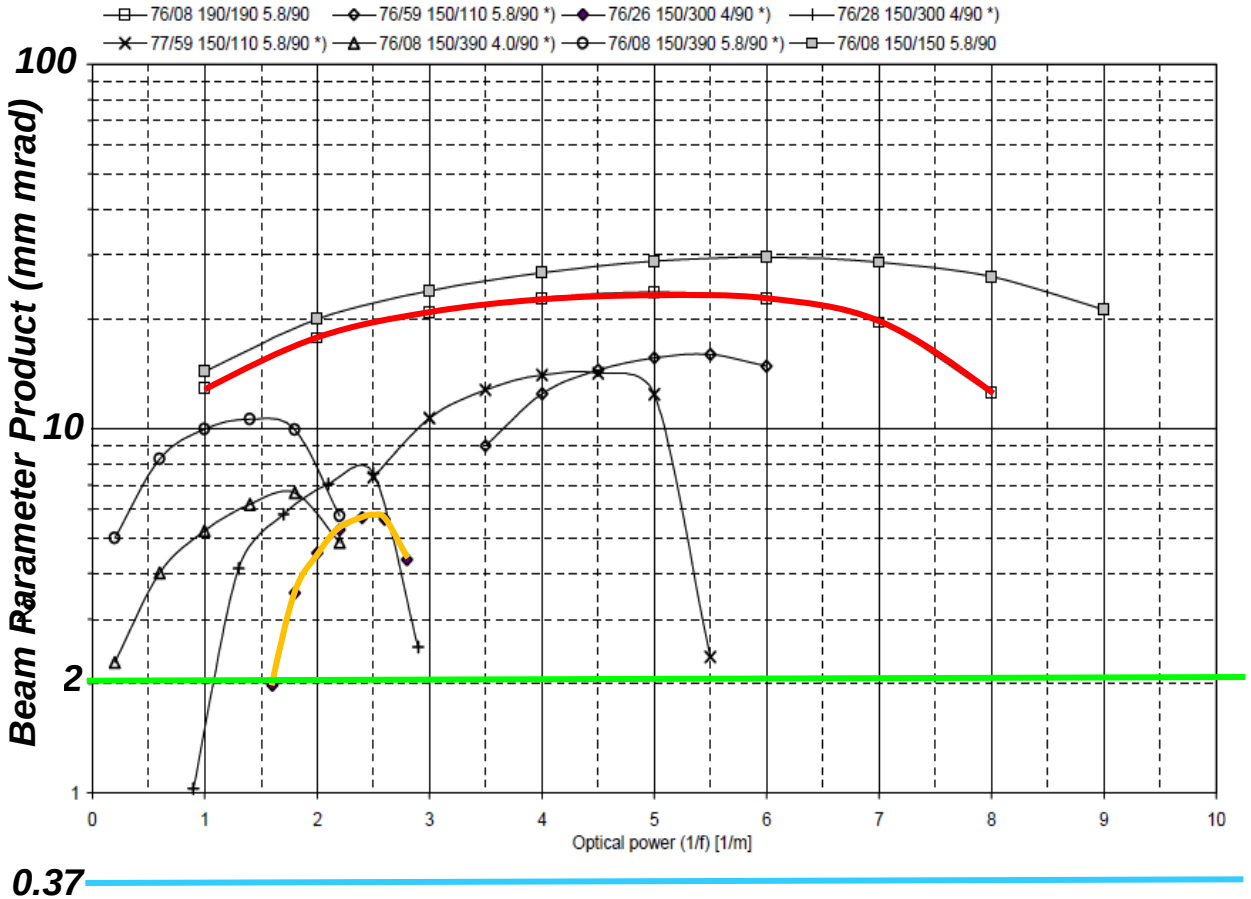
Properties:

- High peak power
- High beam quality
- Fiber output
- Air cooled
- 2 phase power interface
- Low maintenance
- High power efficiency

Behaviour of state of the art drilling lasers



Resonator setup FLS 652 RU 26 A



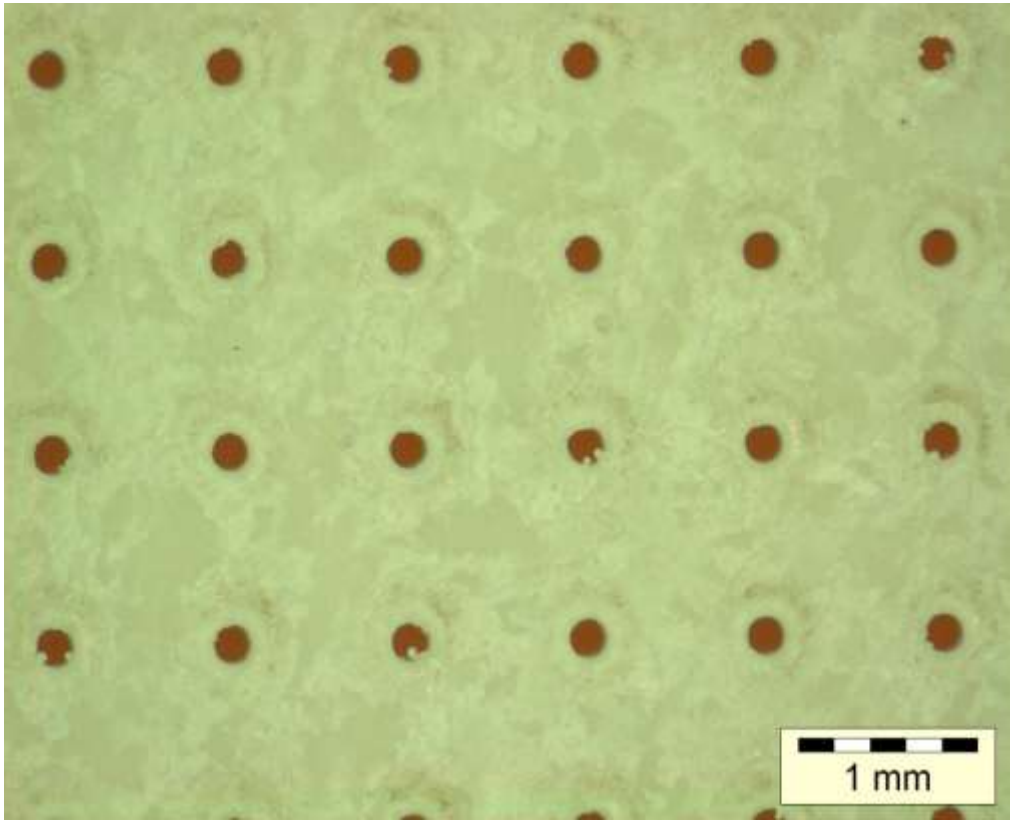
LFS SM

LFS MM 50µm

KLS / FLS stabile resonator

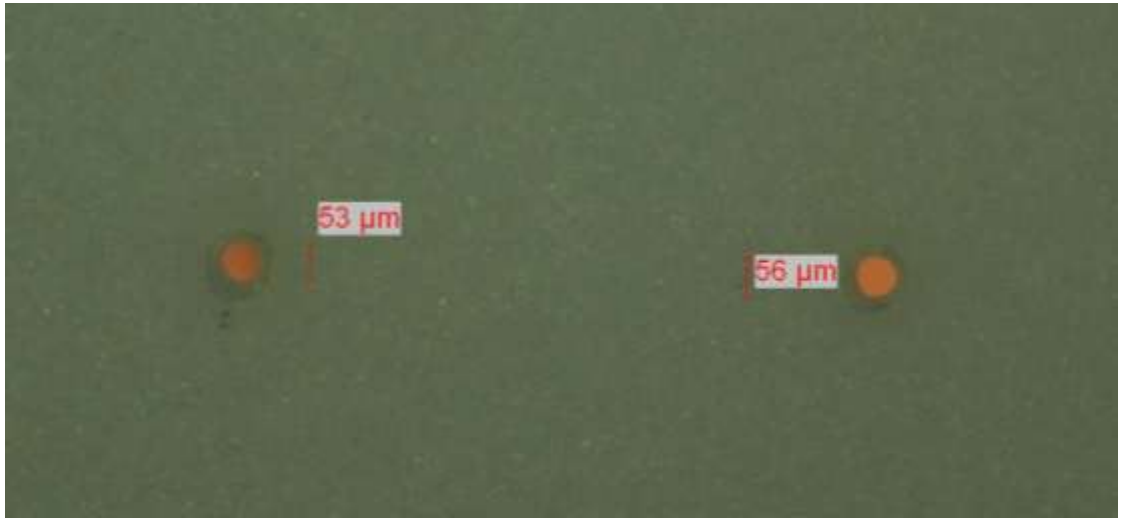
KLS / FLS dedicated instabile resonator

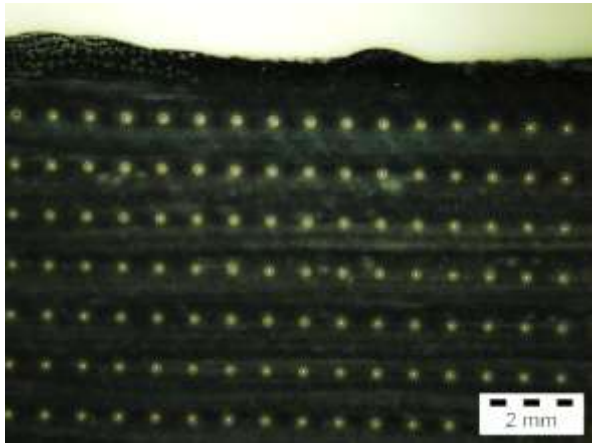
Applications – drilling of silicon nitride



Material:	***Silicon nitride 0.2 mm***
Laser:	***LASAG LFS 150 SM***
Parameter:	***1.5 kW Peak power,***
	0.06 ms Pulse length
Comments:	***O2, 200 holes/s***
	Diameter: 0.1 mm

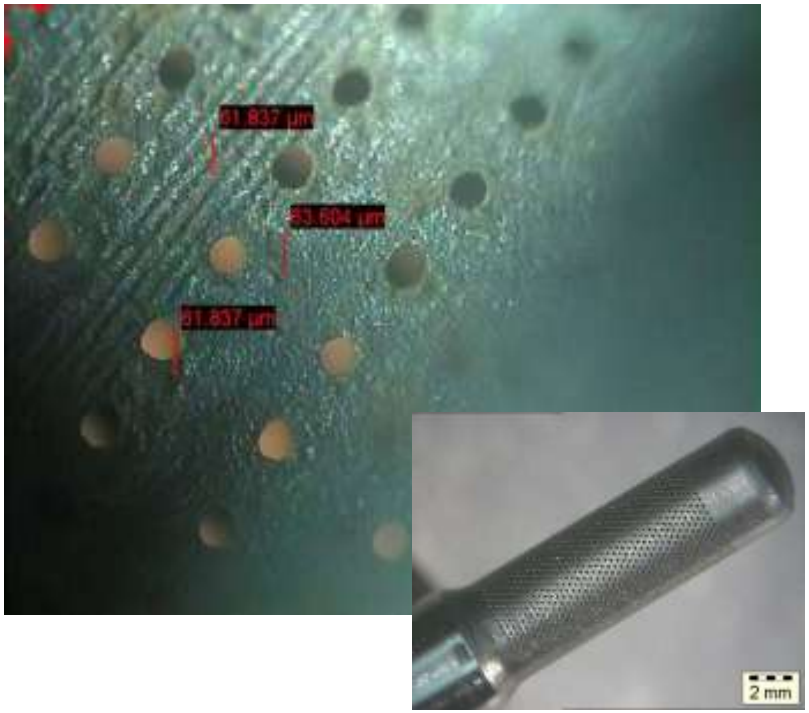
Applications – drilling of oxide ceramics

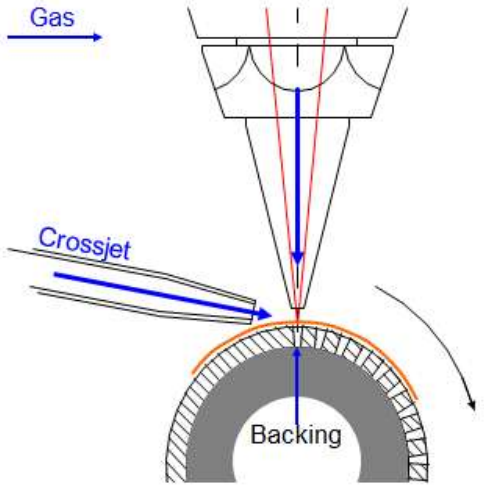




Material:	***Al2O3 0.4 mm***
Laser:	**LASAG LFS SM**
Parameter:	***1.5 kW Peak power,***
	0.08 ms Pulse length
	4 W Average Power
Comments:	***Air***

Applications – drilling of filters

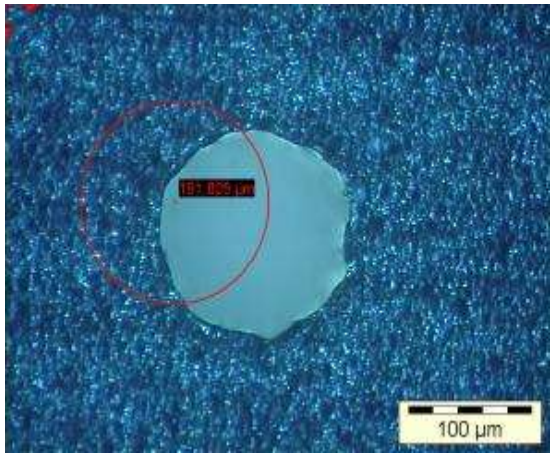


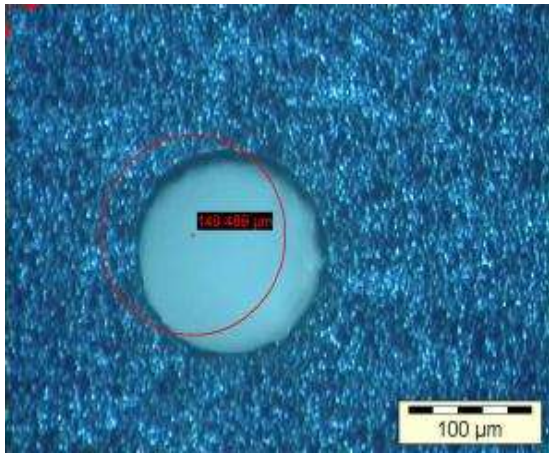


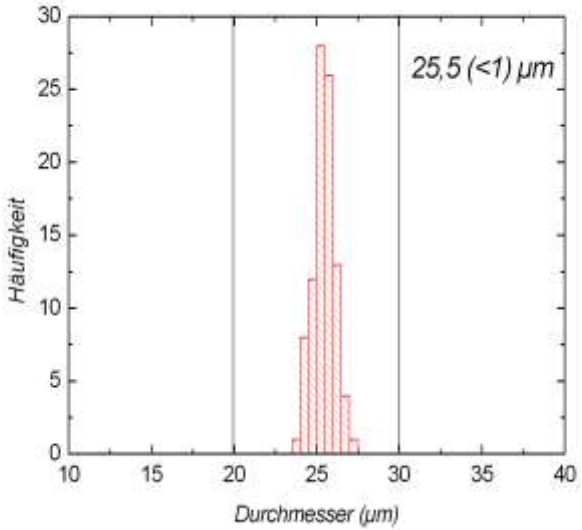
Material:	***1.4301 0.5 mm***
Laser:	**LASAG LFS 150 SM**
Parameter:	***0.8 kW Peak power,***
	0.1 ms Pulse length
Comments:	***Air, 1800 holes/s***
	Diameter: 0.05 mm

Limitation of conventional lamp pumped pulsed Lasers is 400 holes/s.

Applications – air bearings

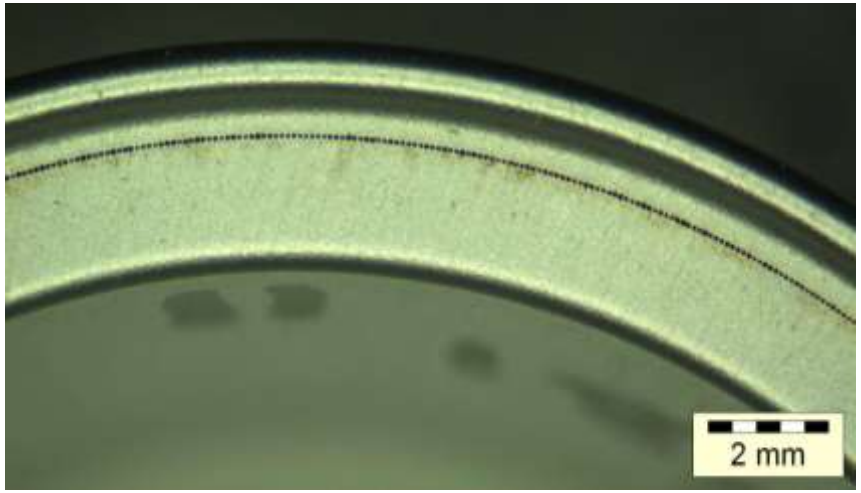


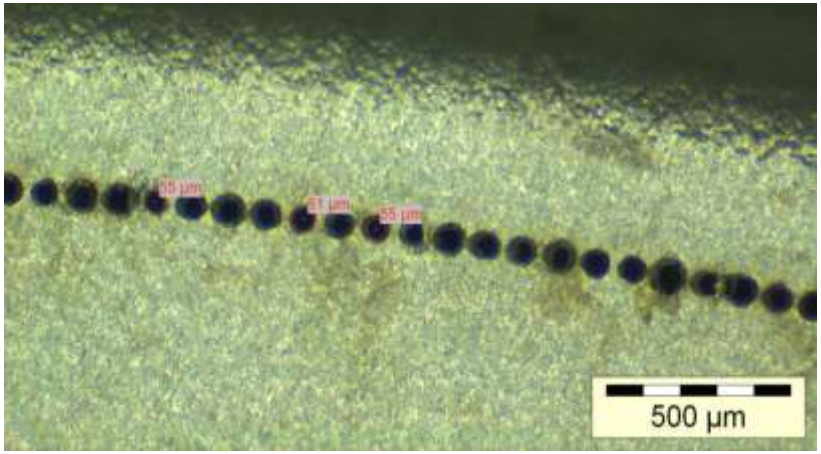




Material:	***Stainless steel 0.8 mm***
Laser:	***LASAG LFS 150 SM***
Parameter:	***1.0 kW Peak power,***
	0.05 ms Pulse length
Comments:	***O2***
	Diameter: 0.15 mm

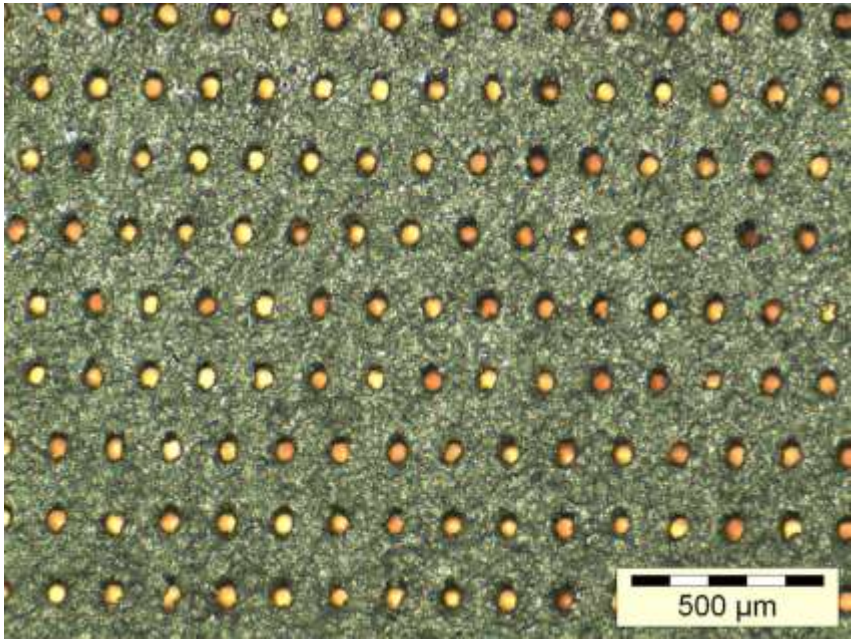
Applications – drilling of perforation holes





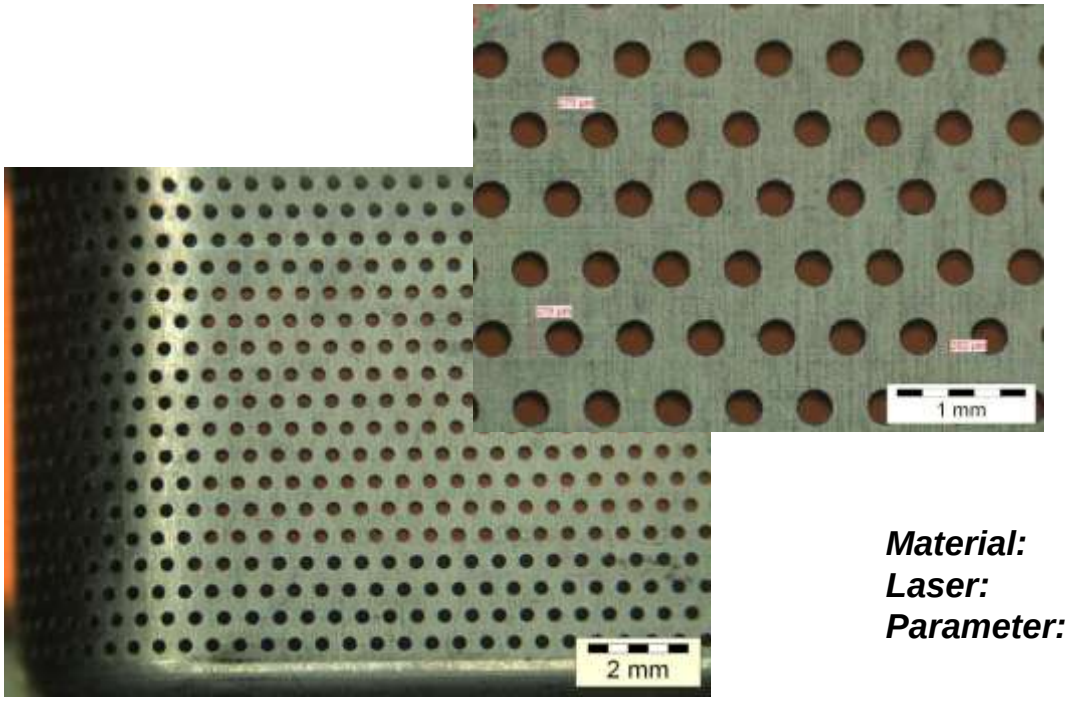
Material:	***Al 0.15 mm***
Laser:	**LASAG LFS 150 SM**
Parameter:	***1.0 kW Peak power,***
	0.05 ms Pulse length
Comments:	***O2***
	Diameter: 0.15 mm

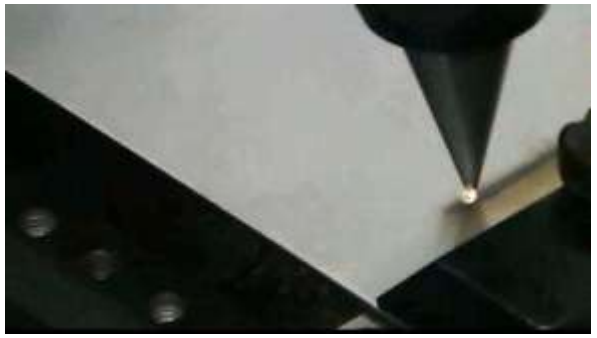
Applications – drilling of titanium



Material:	***Titanium 0.8 mm***
Laser:	**LASAG LFS 150/ 50 µm**
Parameter:	***1.5 kW Peak power,***
	0.08 ms Pulse length
	4 W Average Power
Comments:	***Ar, 100 holes/s, 4 m/min***

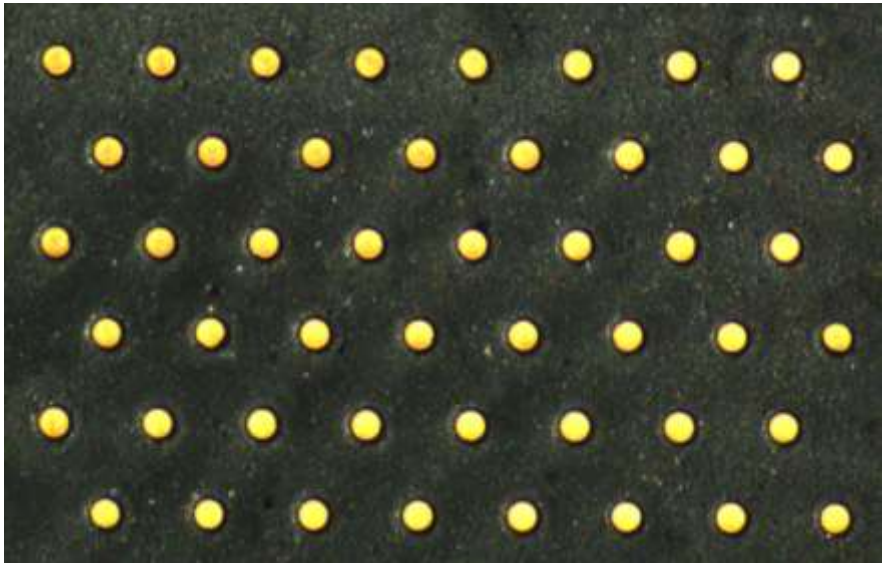
Applications – high speed hole cutting

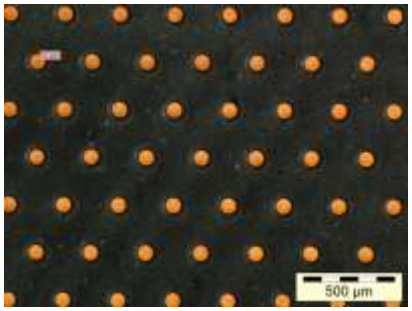


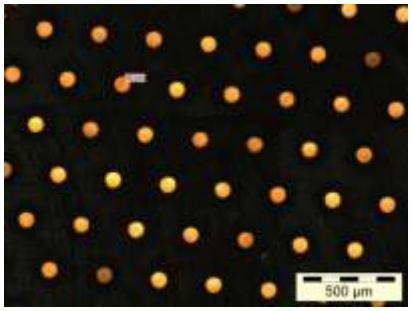


Material:	***1.4301***
Laser:	***LASAG LFS 150/ 50 µm***
Parameter:	***0.6 kW Peak power,***
	2 ms Pulse length
	50 W Average Power
Comments:	***O2, 12 bar, 200 m/min***

Applications – percussion drilling

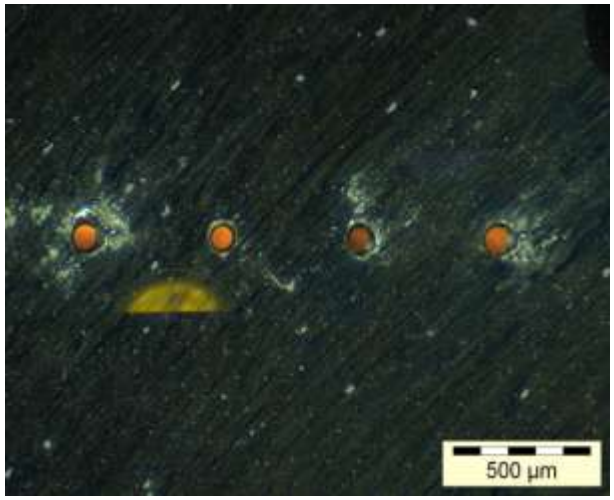


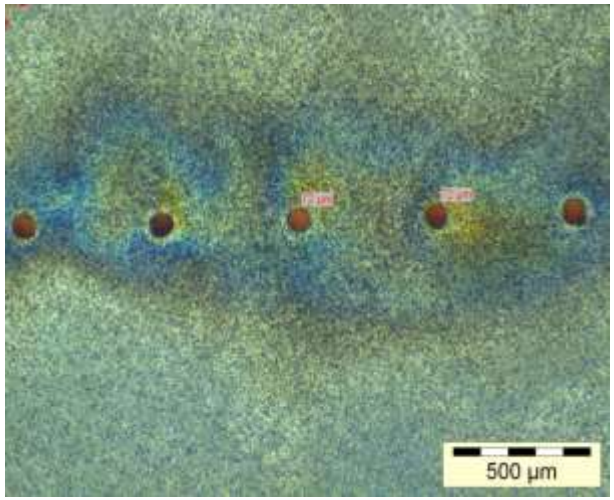




Material:	***Graphite 2 mm***
Laser:	***LASAG LFS 150 SM***
Parameter:	***0.75 kW Peak power,***
	0.2 ms Pulse length
Comments:	***O2, 0.5 s***
	Diameter: 0.085 mm

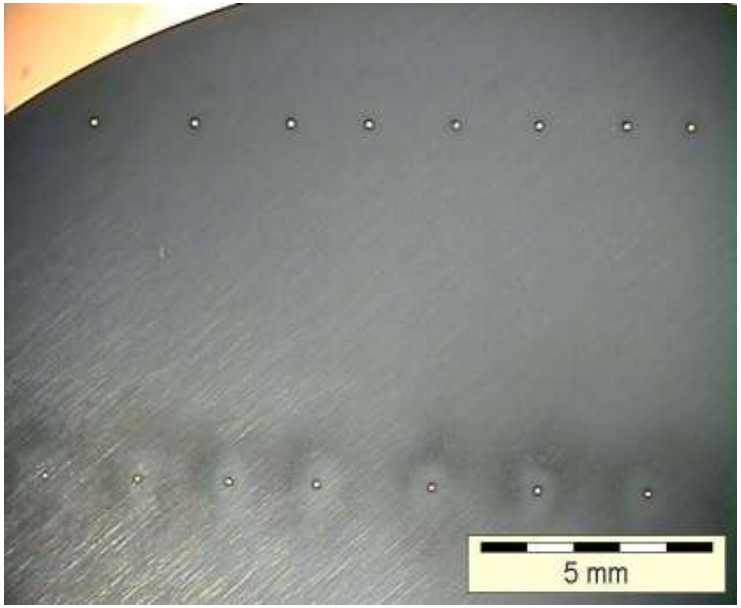
Applications – silicon wafers



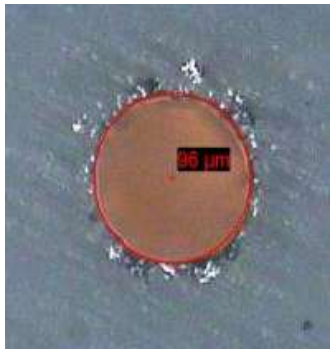


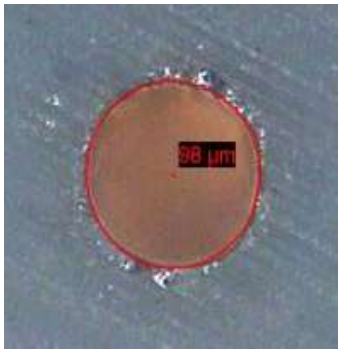
Material:	***Silicon wafer 0.7 mm***
Laser:	**LASAG LFS 150/ 50 µm**
Parameter:	***0.78 kW Peak power,***
	0.1 ms Pulse length
Comments:	***N2, 0.25 s***
	Diameter: 0.072 mm

Applications – silicon nitride ceramics

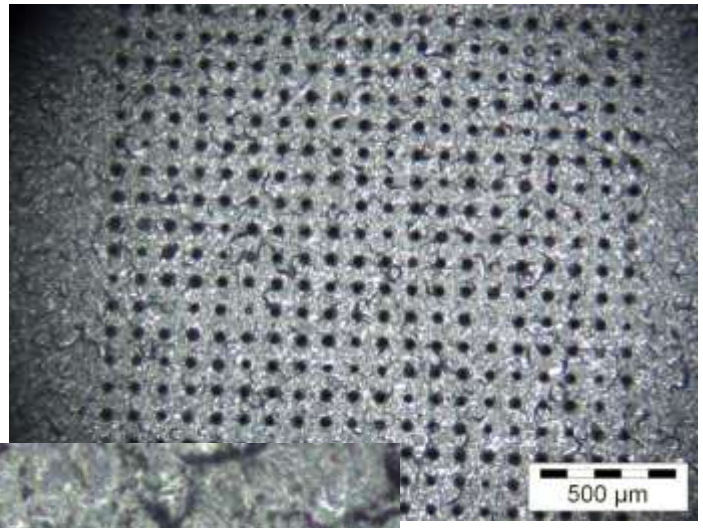


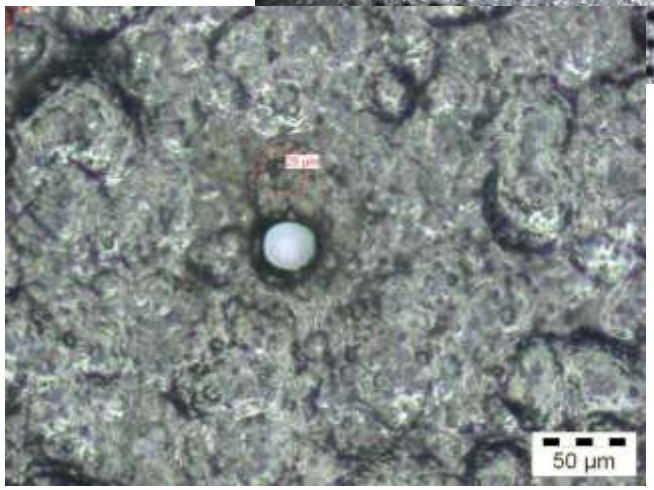
Material:	***Silicon nitride 1.5 mm***
Laser:	**LASAG LFS 150/ 50 µm**
Parameter:	***1.5 kW Peak power,***
	0.11 ms Pulse length
Comments:	***N2, 4 s/ 6 mm/min***
	Diameter: 0.098/0.096 mm





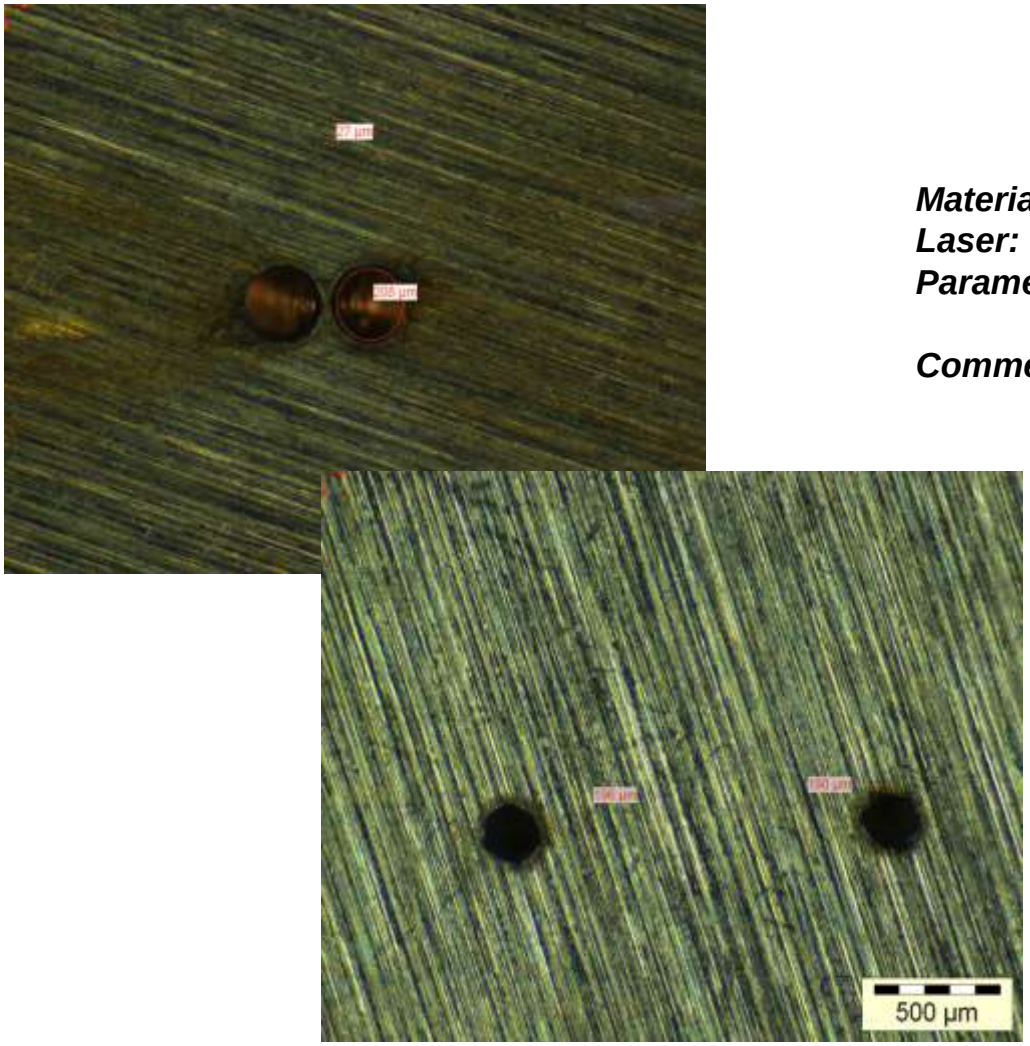
Applications – percussion drilling





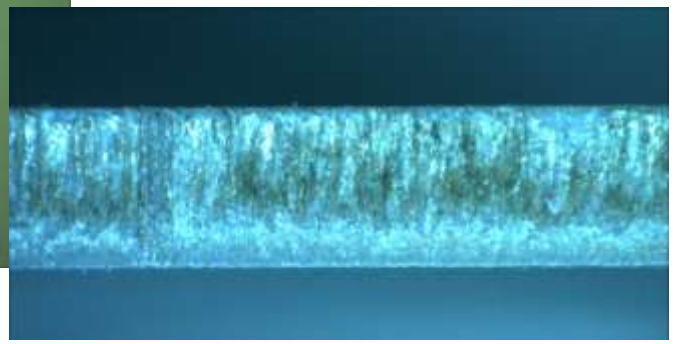
Material:	***Al 0.4 mm***
Laser:	***LASAG LFS 150 SM***
Parameter:	***0.7 kW Peak power,***
	0.05 ms Pulse length
Comments:	***N2, 0.1 s***

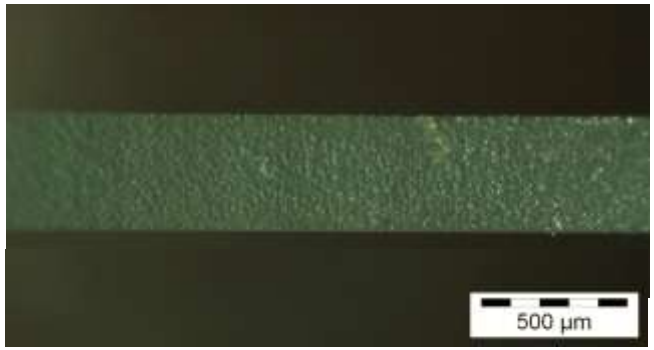
Applications – injection nozzles (trucks)



Material:	***Stainless steel 2 mm***
Laser:	**LASAG LFS 150/ 50 µm**
Parameter:	***1.5 kW Peak power,***
	0.11 ms Pulse length
Comments:	***O2, 3 s/ 20 mm/min***
	Diameter: 0.2 mm
	angle 17°

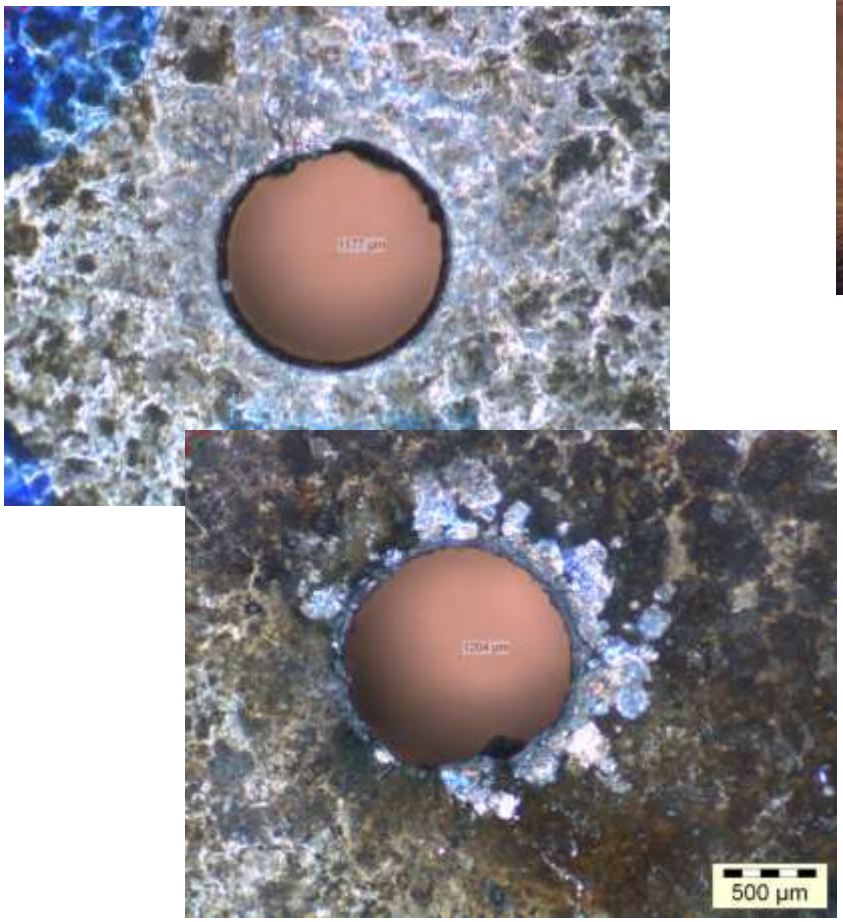
Applications – Sapphire cutting

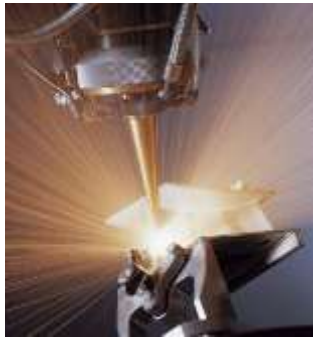




Material:	***Sapphire 1 mm***
Laser:	***LASAG LFS 150 SM***
Parameter:	***1.2 kW Peak power, 0.08 ms Pulse length***
Comments:	***N2, 200 mm/min 1 s***

Applications – Ni-based alloys drilling

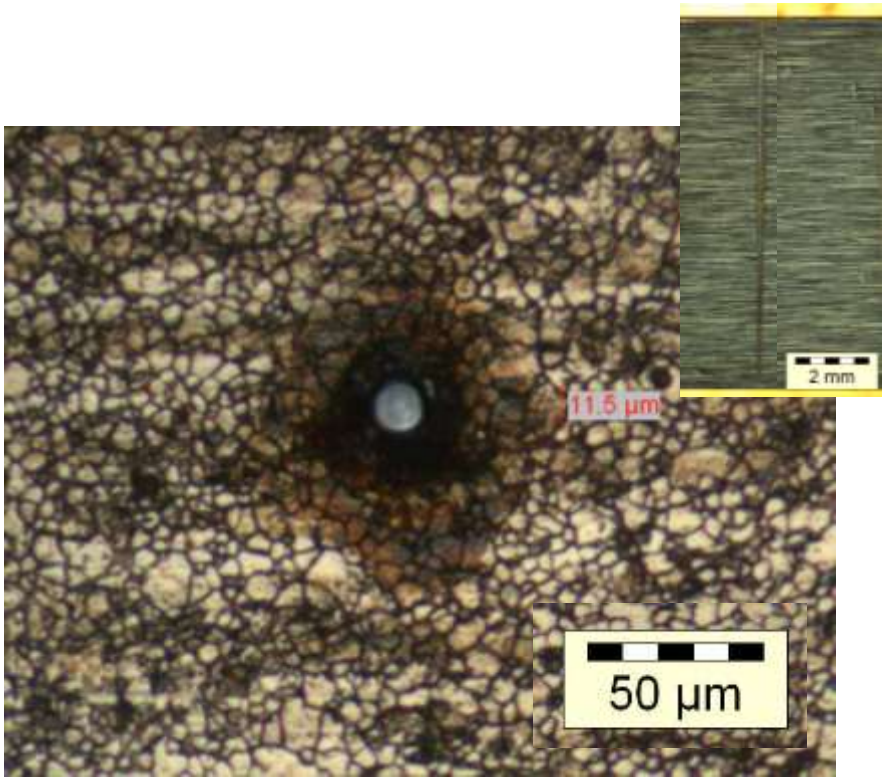




Material:	***alloy 625 6 mm***
Laser:	***IPG YLS-600/6000-QCW***
Parameter:	***6 kW Peak power,***
	1 ms Pulse length
	120 W Average Power
Comments:	***O2, 2 s***

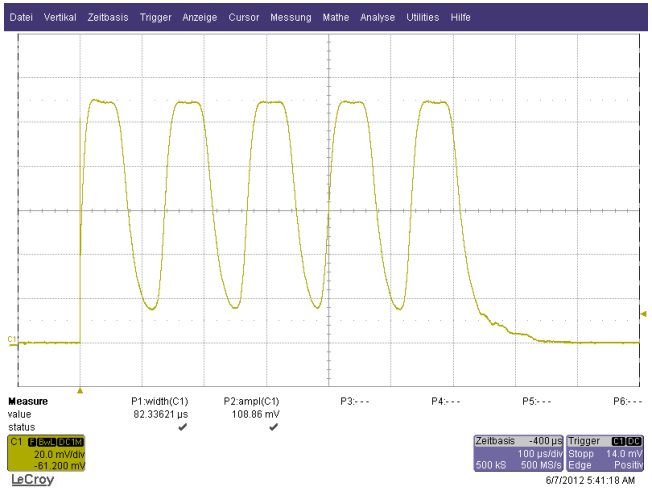
Limitation for trepanning 12 mm !

Applications – percussion drilling



Material: ***1.4301 1 mm***
Laser: ***LASAG LFS 150 SM***
Parameter: ***1.5 kW Peak power,***
0.2 ms Pulse length
Comments: ***O2, 20 s***
Pulse shape with Modulation

Aspect ratio: > 1:100 !

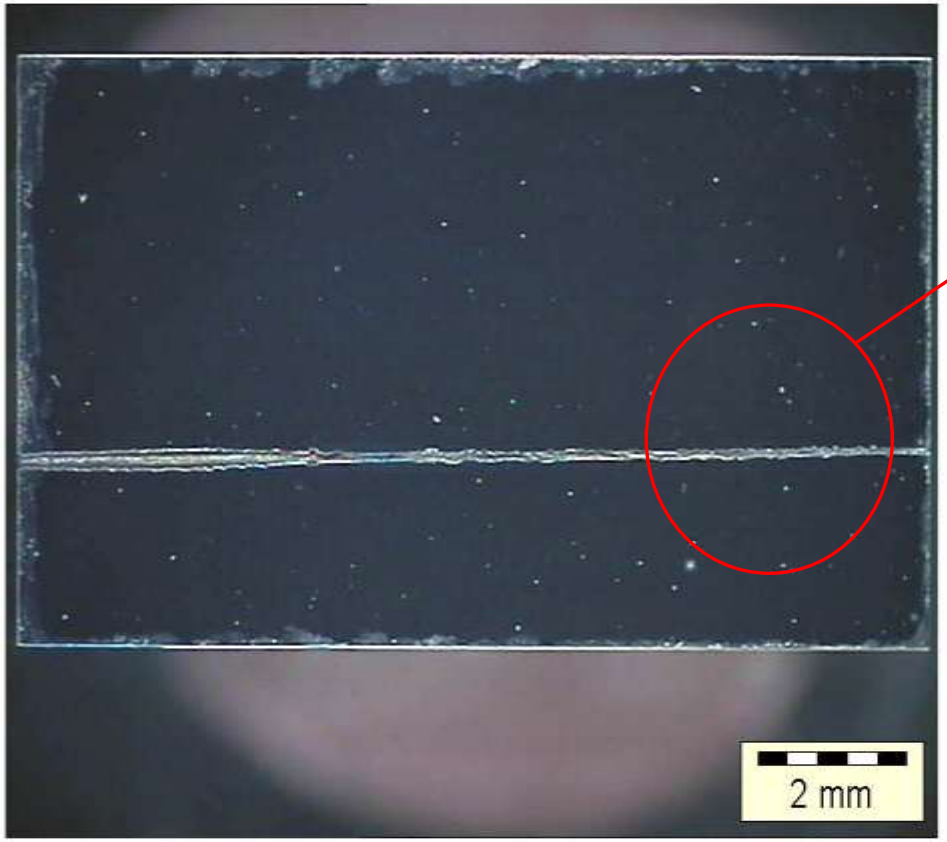


Process efficiency improvement by pulse modulation

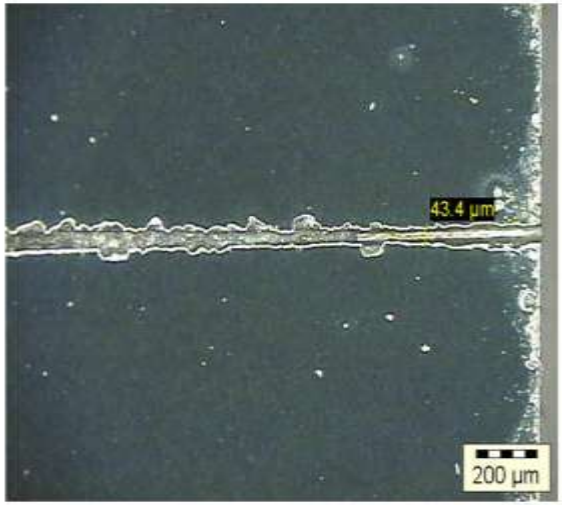
Applications – percussion drilling

4

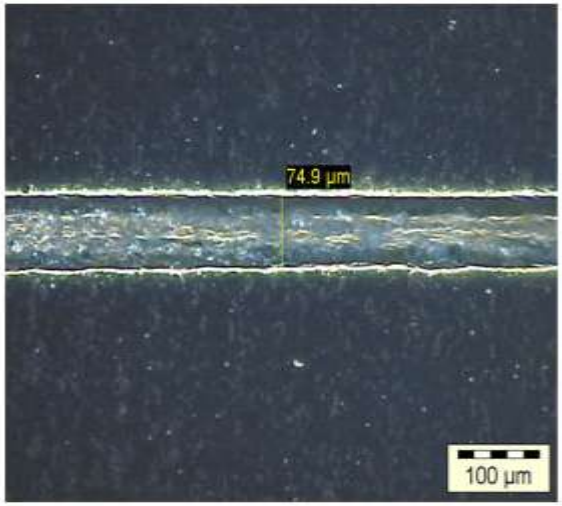
a)



b)



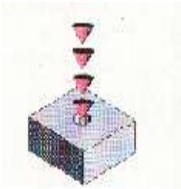
c)

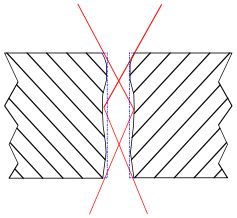


a), b): 45 µm-hole in 12 mm tungsten carbide

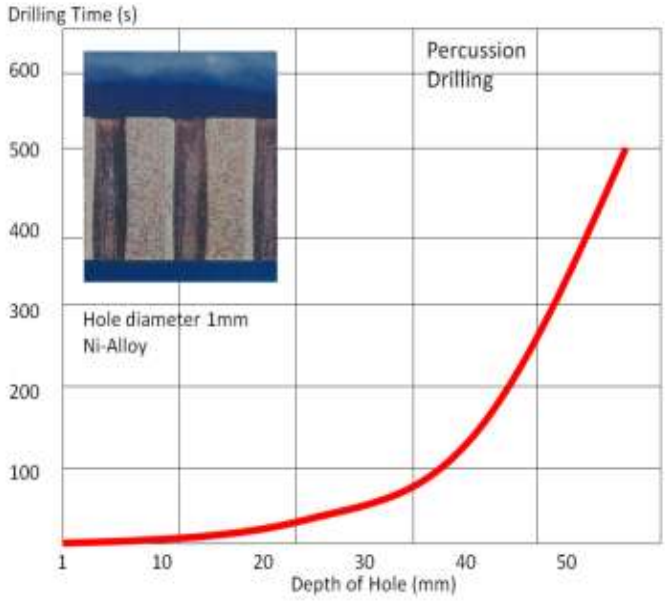
c): 75 µm-hole in 16 mm steel

Applications – percussion drilling





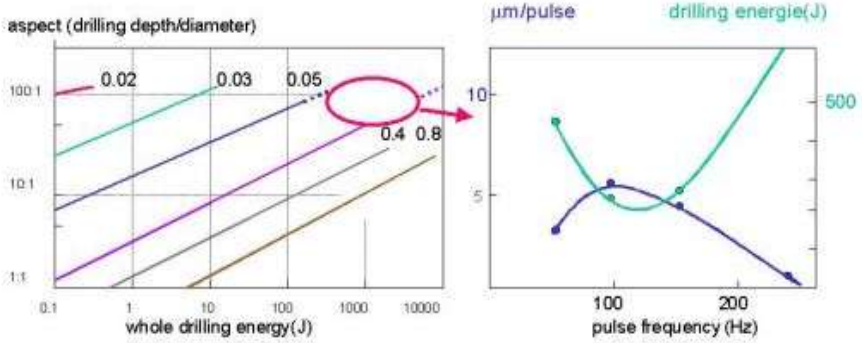
Single Pulse Percussion	High Frequency Percussion	Highest Frequency Percussion
<10Hz	50-300Hz	10-100kHz
0.1-1ms	0.01-0.1ms	10-100ns
10-100J	0.1-1J	0.0001-0.01J

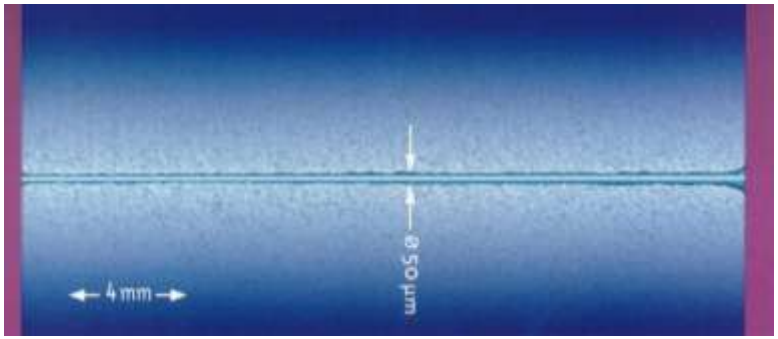


strategies:
pulse frequency< 20 Hz

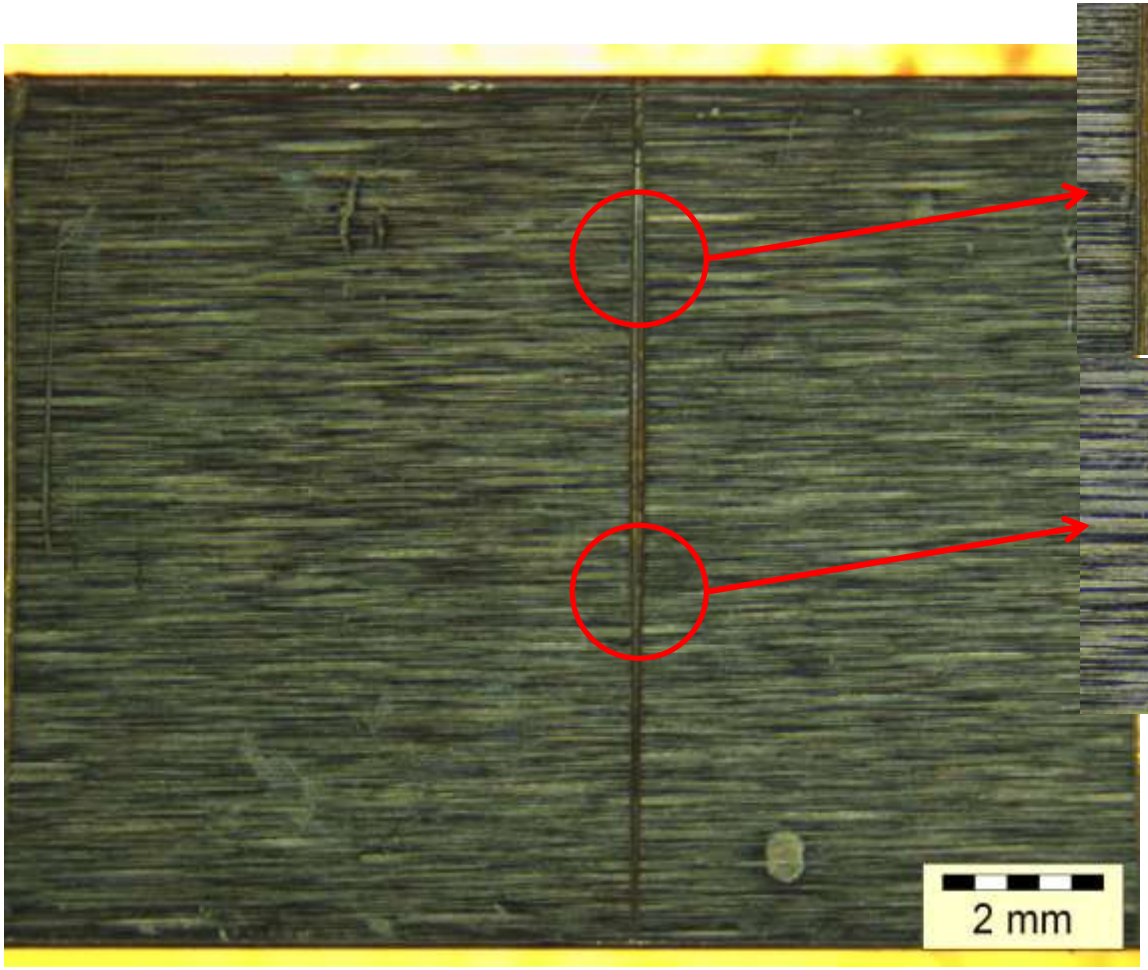
pulse frequency > 50Hz

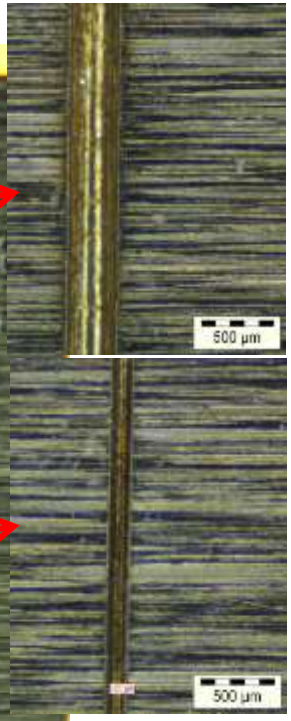
example:
stainless steel d= 8mm , aspect ratio = 90:1





Applications – percussion drilling

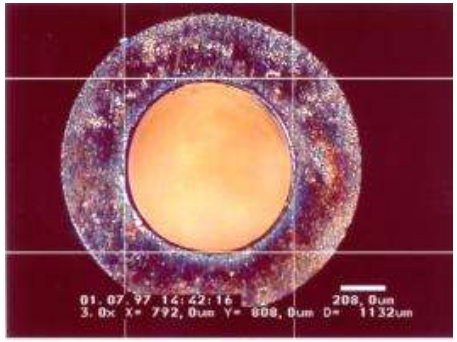


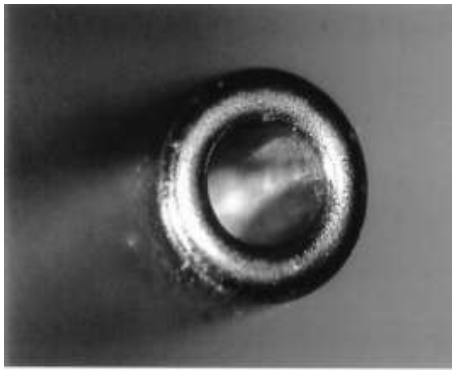


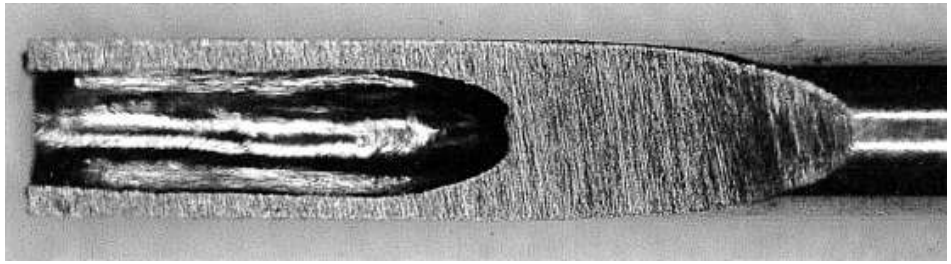
Material:	***Carbon steel 10 mm***
Laser:	***LASAG LFS 150/ 50 µm***
Parameter:	***1.5 kW Peak power,***
	0.1 ms Pulse length
Comments:	***O2, 80 s***

Applications – needle drilling

Material: ***stainless steel***
Laser: **LASAG NA**
Parameter: ***0.2 ms Pulse length***
Comments: ***no gas, 1 pulse***
0.05 – 0.4 mm
Aspect ratio 1:4 – 1:8

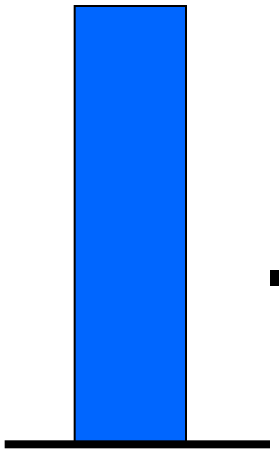




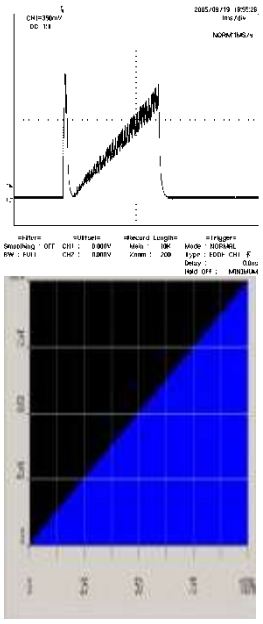


Applications – percussion drilling

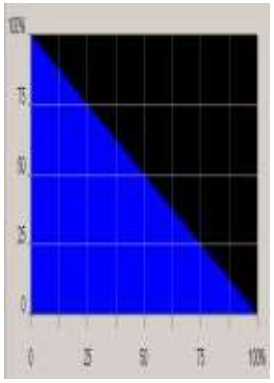
experiment: using of free scalable pulse shaping for controlling the energy application into the material



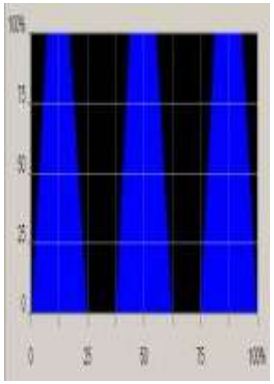
< 1ms



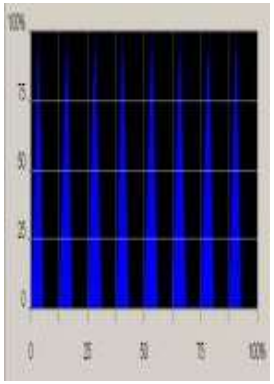
Leading edge



trailing edge



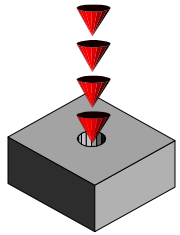
3 peaks

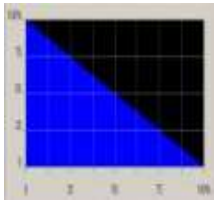


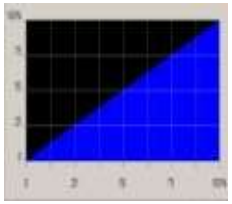
8 peaks

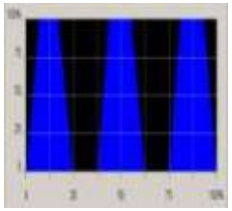
Pulse duration: 1ms<T<7ms packages of energy: 0.1ms<T<3ms

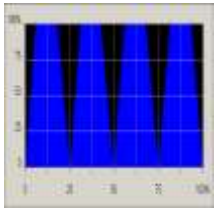
Applications – percussion drilling



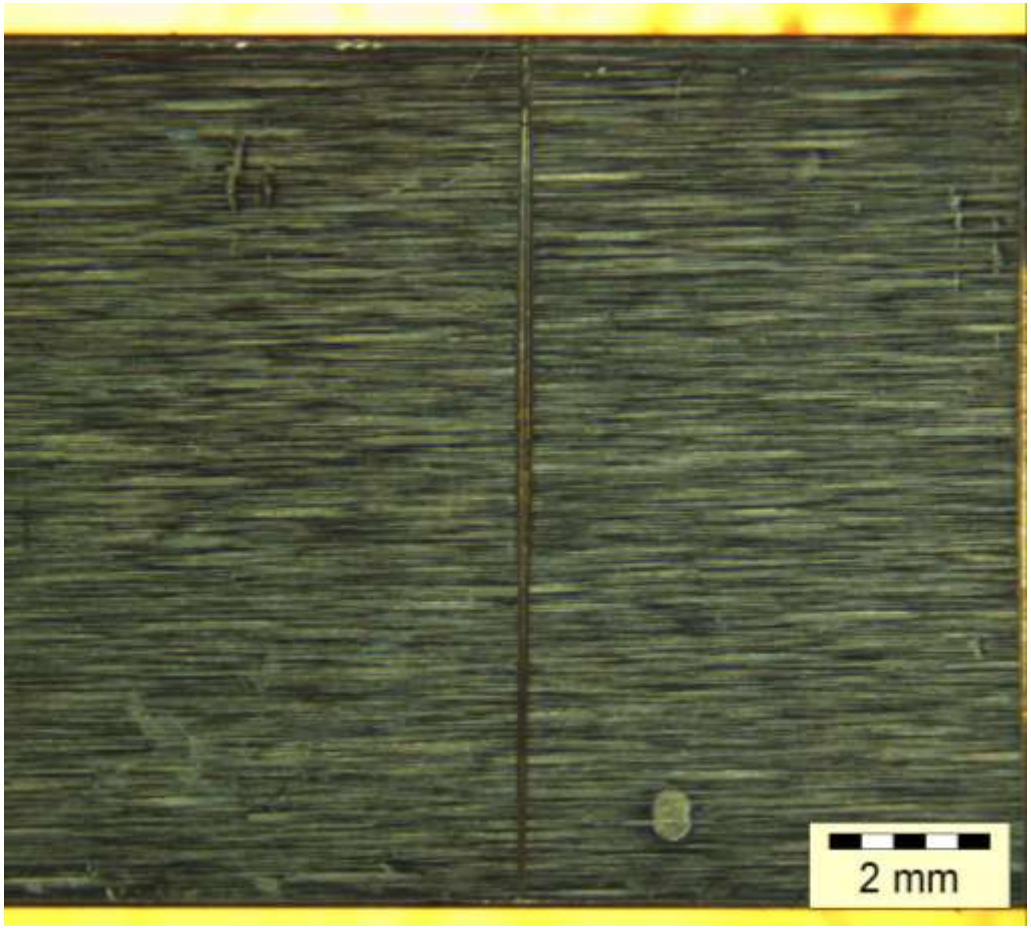


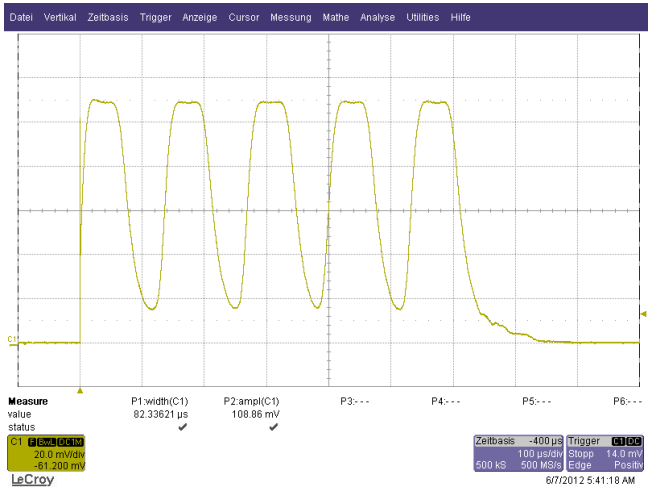






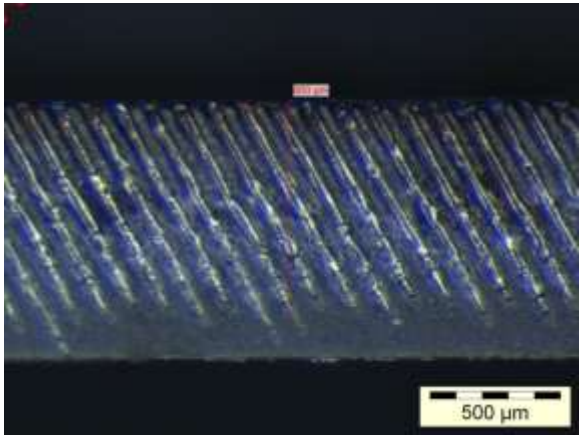
Applications – percussion drilling



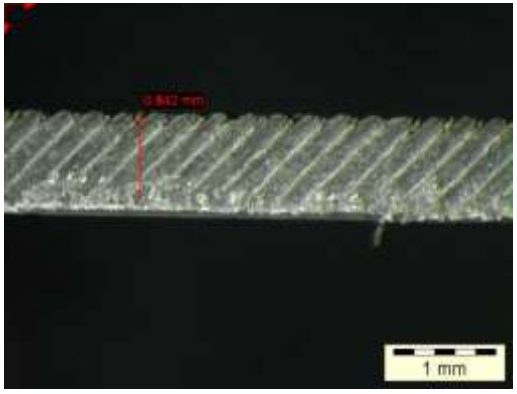


Material:	***Carbon steel 10 mm***
Laser:	***LASAG LFS 150/ 50 µm***
Parameter:	***1.5 kW Peak power, 0.2 ms Pulse length***
Comments:	***O2, 50 s***

Applications – scribing



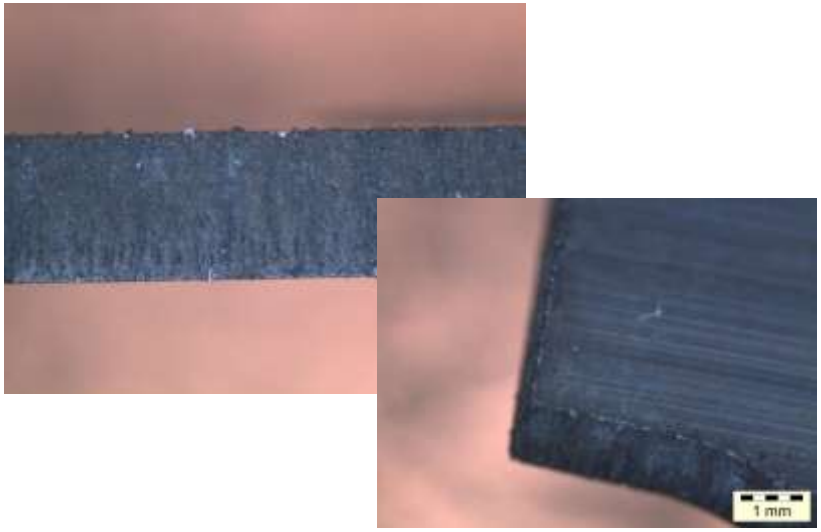
Material: ***C70***
Laser: **LASAG LFS 150/ 50 µm**
Parameter: ***1.5 kW Peak power,***
0.1 ms Pulse length
60 W Average Power
Comments: ***Air, 3 m/min***



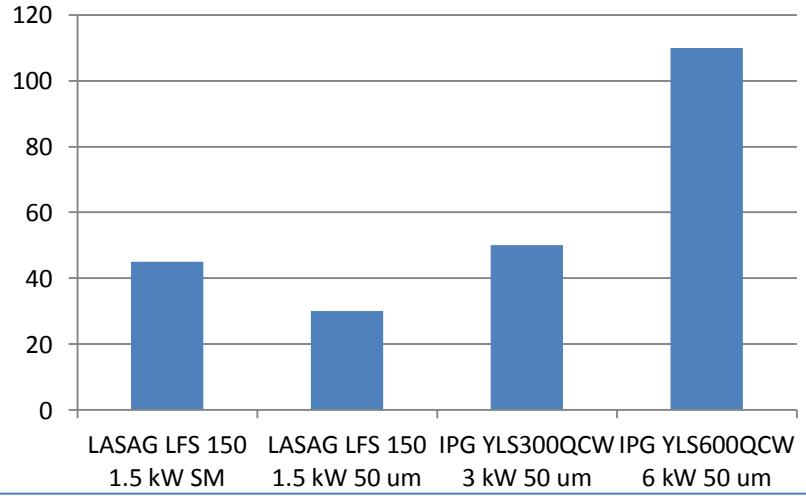
Material: ***C70***
Laser: **LASAG KLS 246**
Parameter: ***0.75 kW Peak power,***
0.2 ms Pulse length
15 W Average Power
Comments: ***Air, 1.8 m/min***

(Comparence to 200 W cw fiber laser: 0.5 mm - 1 m/min)

Applications – tungsten carbide cutting



Material: ***Tungsten carbide 1 mm***
Laser: **LASAG LFS 150/ 50 µm**
Parameter: ***1.5 kW Peak power,***
0.5 ms Pulse length
150 W Average Power
Comments: ***Air, 3 m/min***



Tungsten carbide 2 mm

speed mm/min

Comparison: LASAG FLS 352 N – 80 mm/min

Comments and Conclusions

- Pulsed fibre laser technology is ready to use
- Pulsed fiber laser technology can cover many typical LPSSL applications
- High beam quality in combination with high peak power is expanding existing application limits
- Diodes offer new process features for cutting and drilling
- QCW fiber lasers close the gap between fibre lasers and LPSSL’s

Questions or comments?

Thank you for your attention!

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