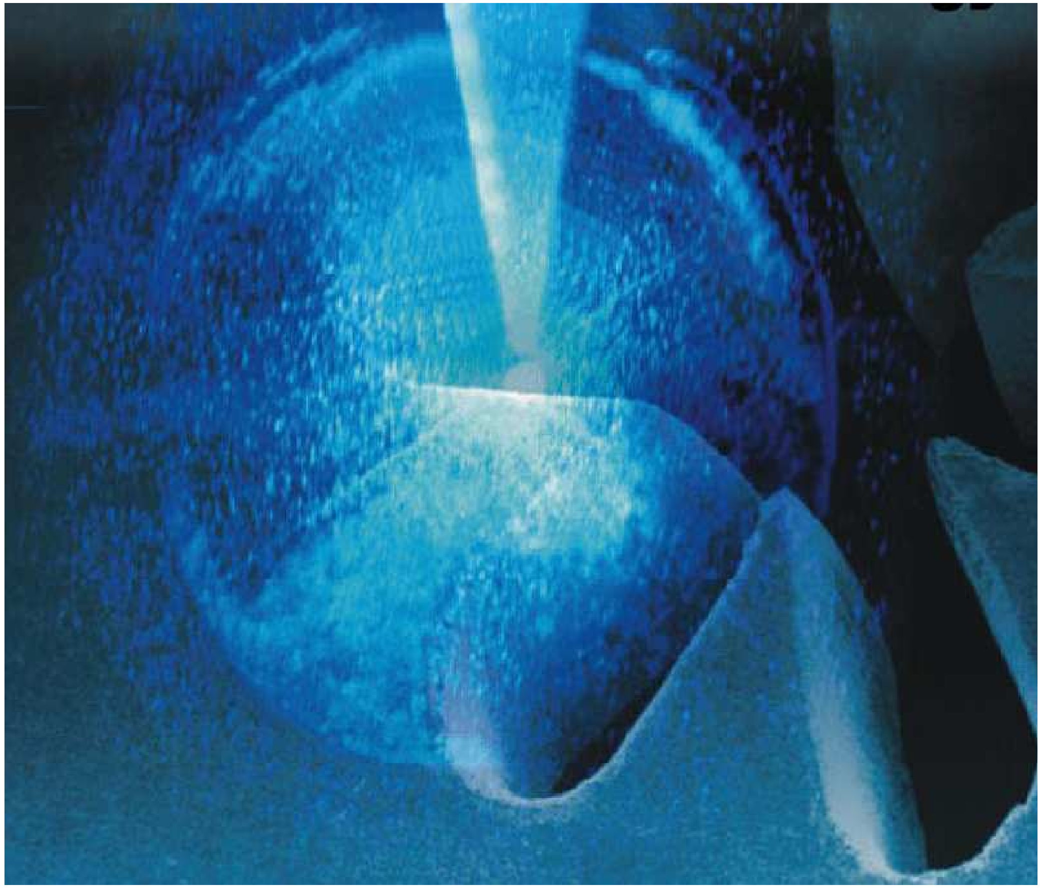
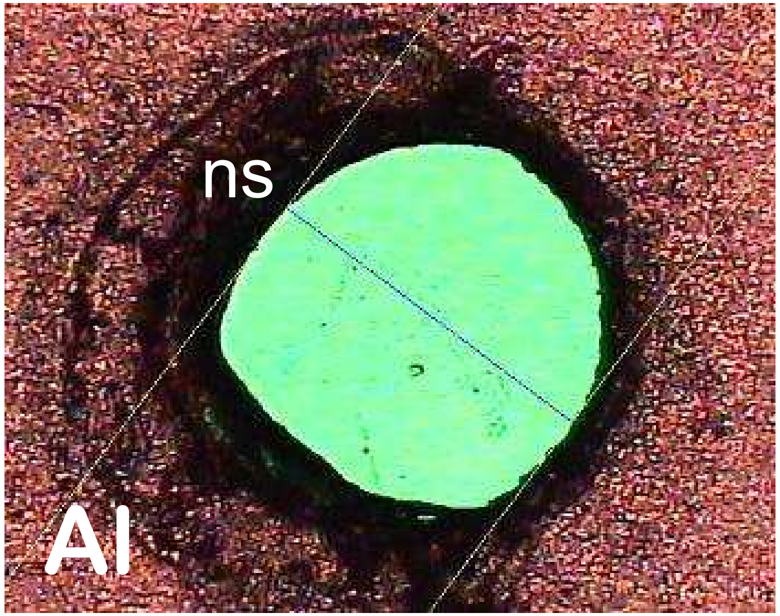
Picosecond Laser for Micromachining: Quality, Speed, Cost

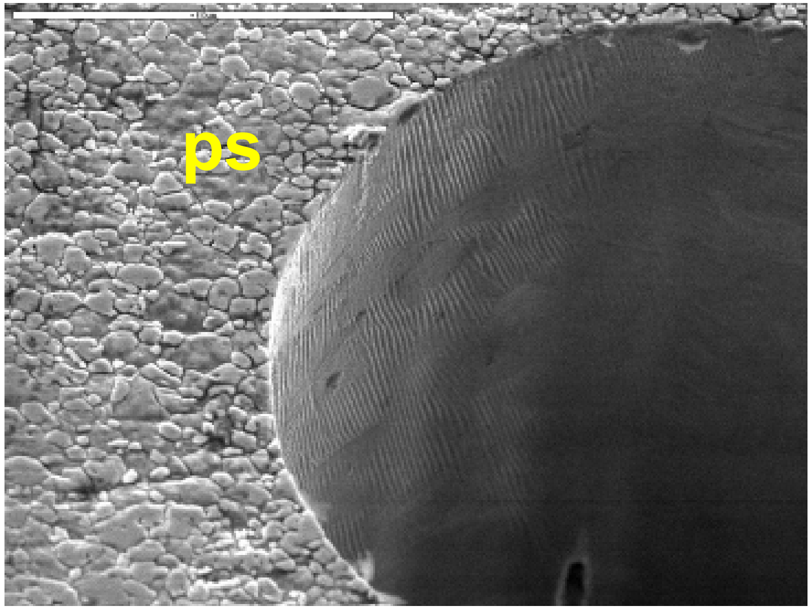
Bernhard Klimt,
Hatim Haloui, Dirk Müller

www. LUMERA-LASER .com



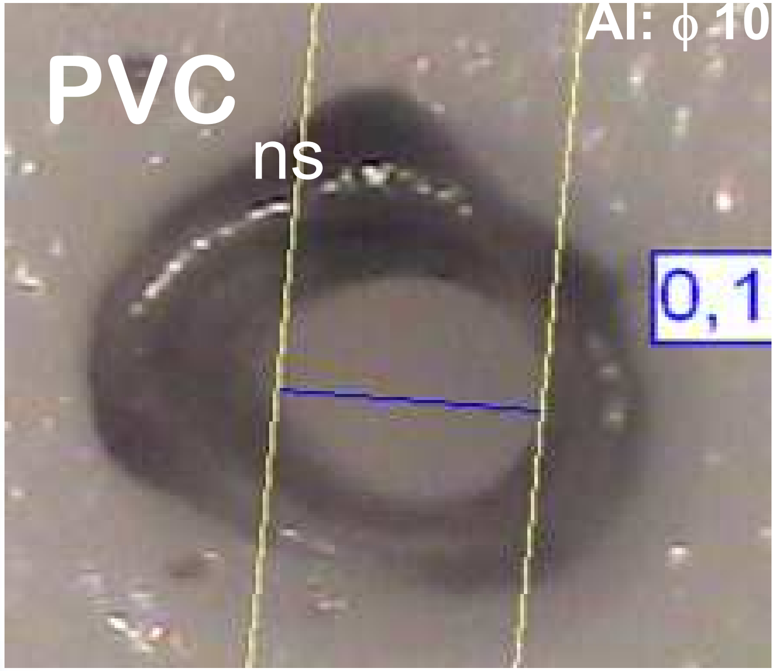
machining with ns vs ps- laser

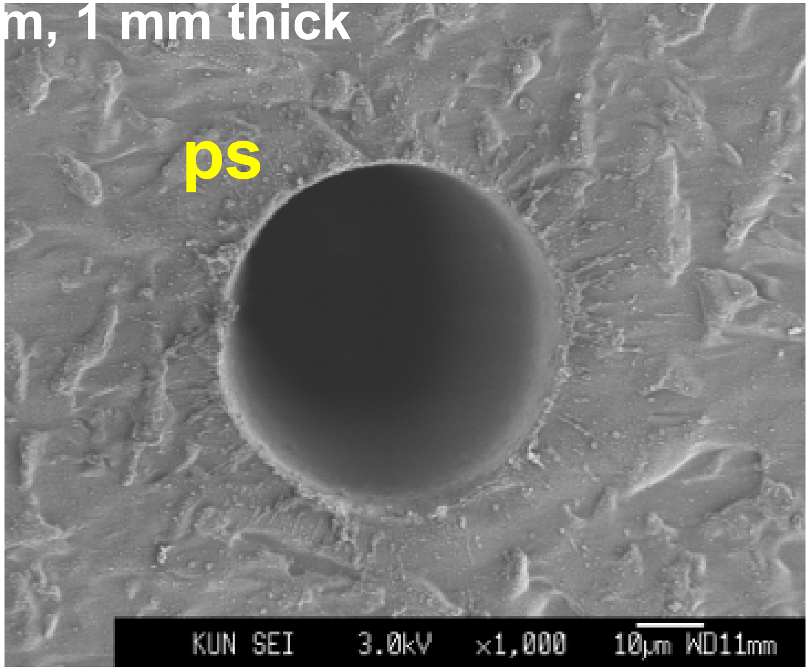




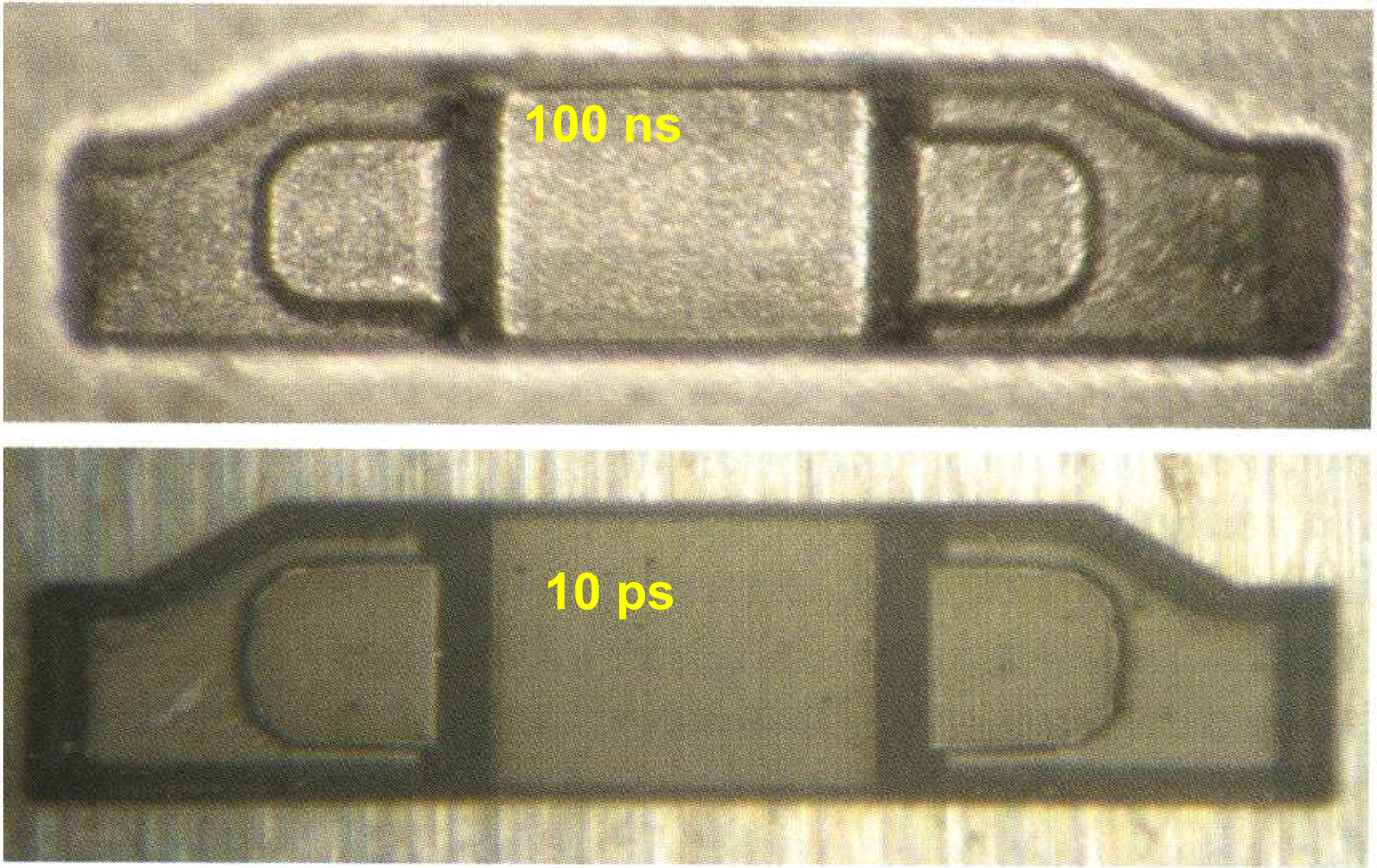
Al: ϕ 10

m, 1 mm thick





Micro mold in SST, ns vs ps laser

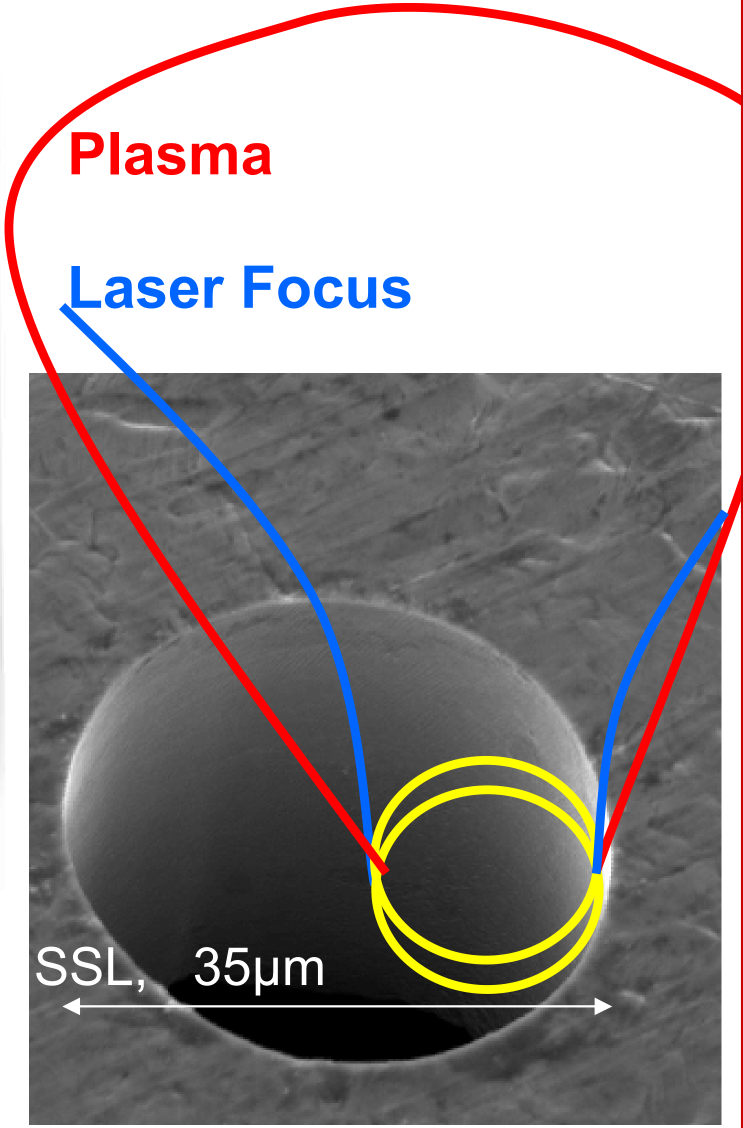


Excecutive summary

industrial

picosecond laser

RAPID series



removed material:

20-100nm thick/ pulse;

typ. dia 1-50µm

no thermal damage, high quality

any material!

up to 2mio p/s

6-60mm³/min (50W)

TCO: ~0.2€ /min

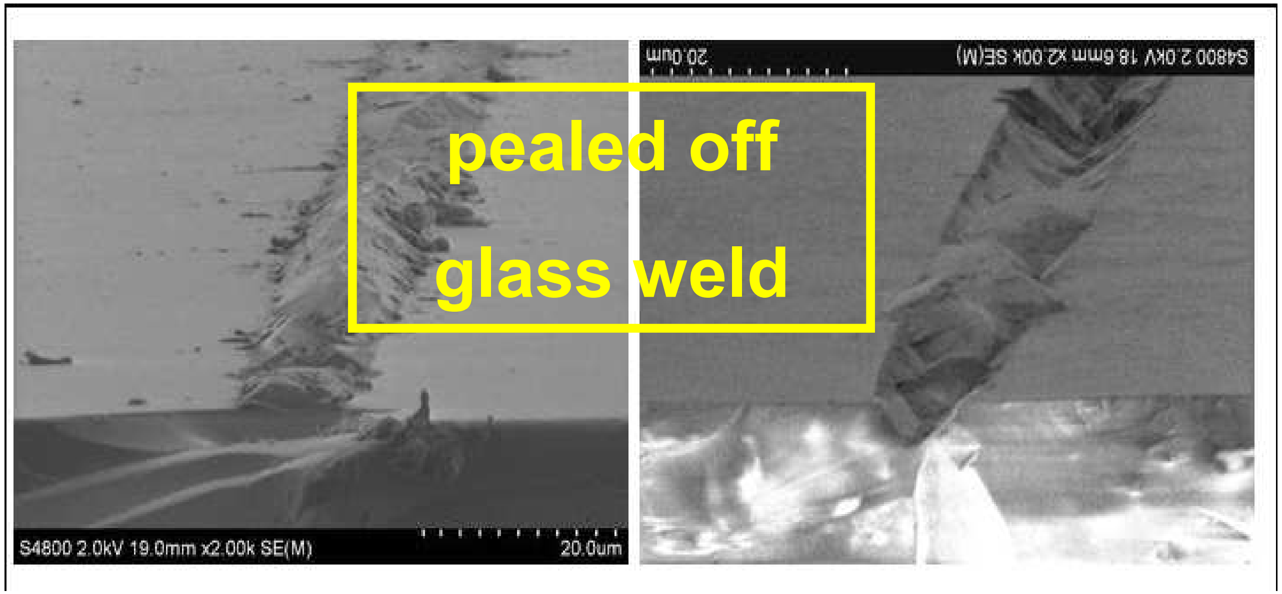
Processes with ps-laser pulses

- High quality, micro technology:
  micromaching + others

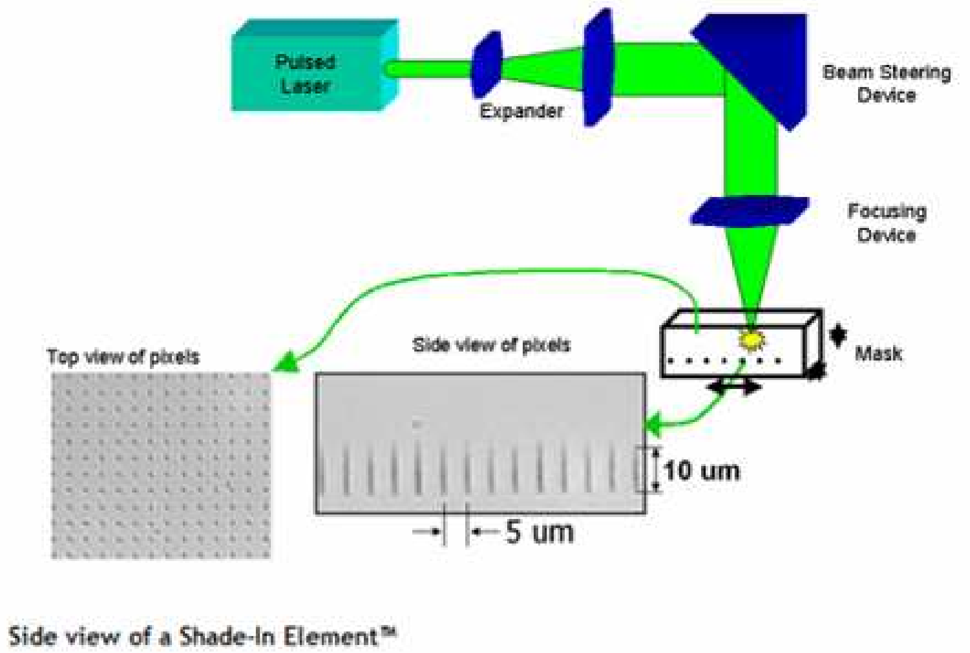
1. "cold" ablation (stoichiometric plasma; generate nano-particles; create coatings; remove mass; create micro-structure)
2. glass welding (thermal)
3. change refractive index in glass voxels
4. internal color change, marking
5. internal scribing/perforation (for separation)

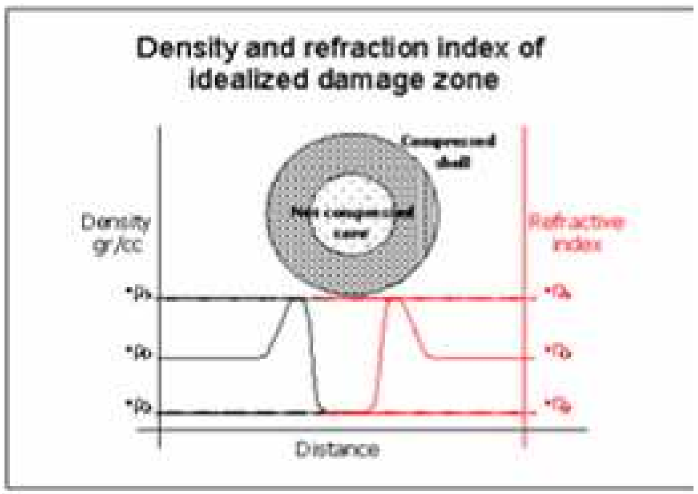
2. Glass welding

- **10ps, PRF 500kHz ; ~3µm focus, ~1.4µJ, 1064nm**
- **Fusion welding of different glass plates (fused silica, display glass / Schott D263) without cracks and thermal distortion: joining, sealing displays?**
- **v > 100mm/s; high joining efficiency**
- ***Characteristics of internal melting of glass for fusion.. Miyamoto, Herrmann; LMP 2007***



3. Change of refractive index





Change of refractive index

- **PIXER:**
  in voxels of mask material (glass) to correct CD of lithographic masks: yield increase!

- **wave guide writing**

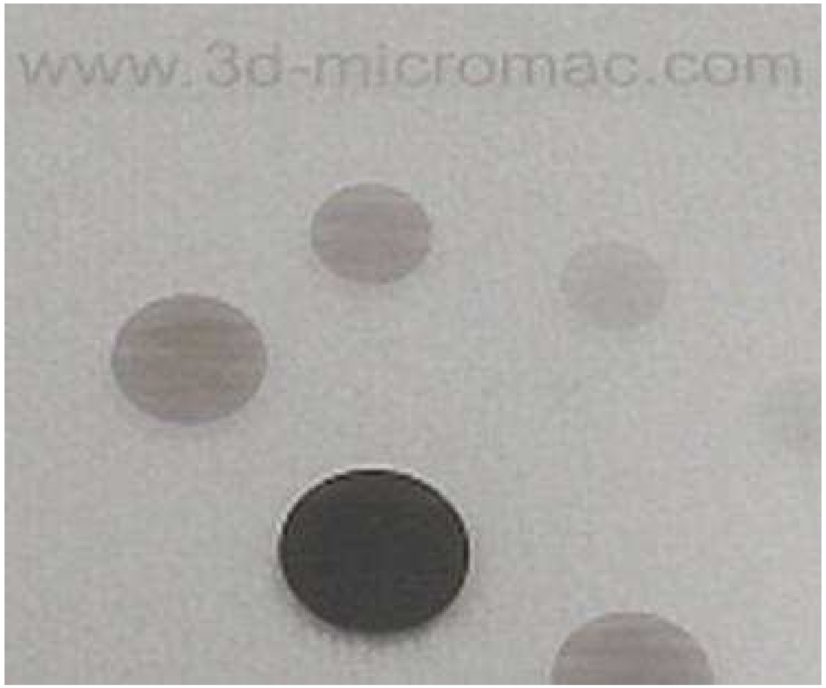
4. Internal color change

..in transparent materials

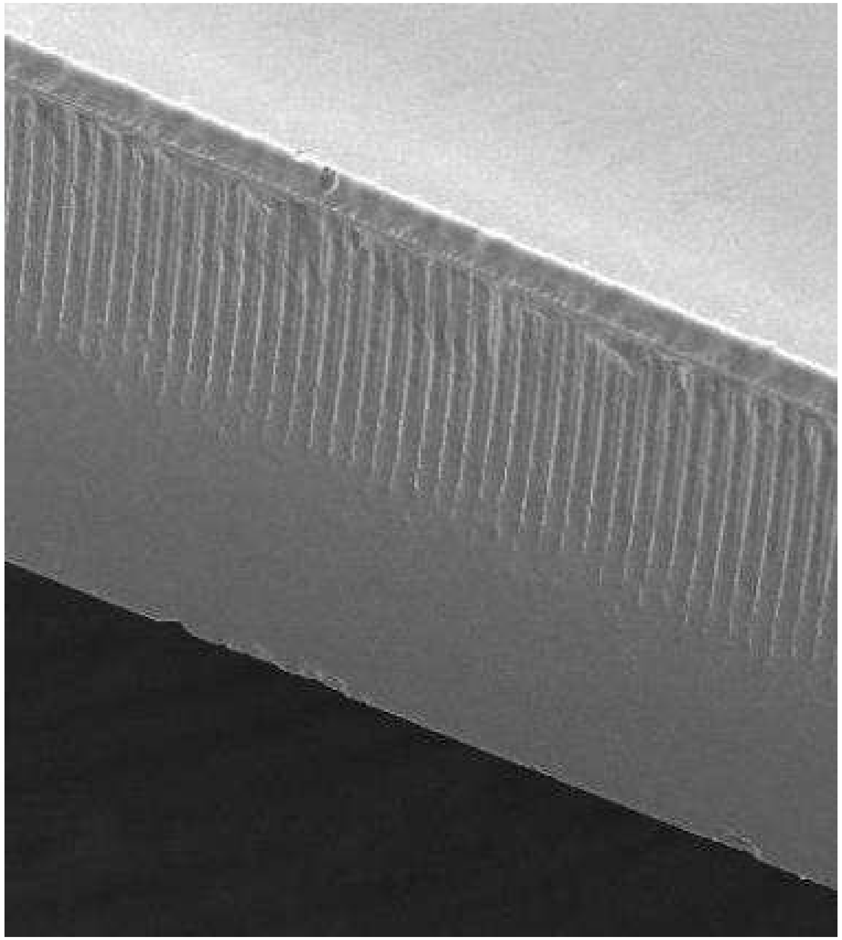
- **marking:**

  internal product identification (glasses, medical devices..)

  copy protection



5. Internal scribing



..in transparent materials:

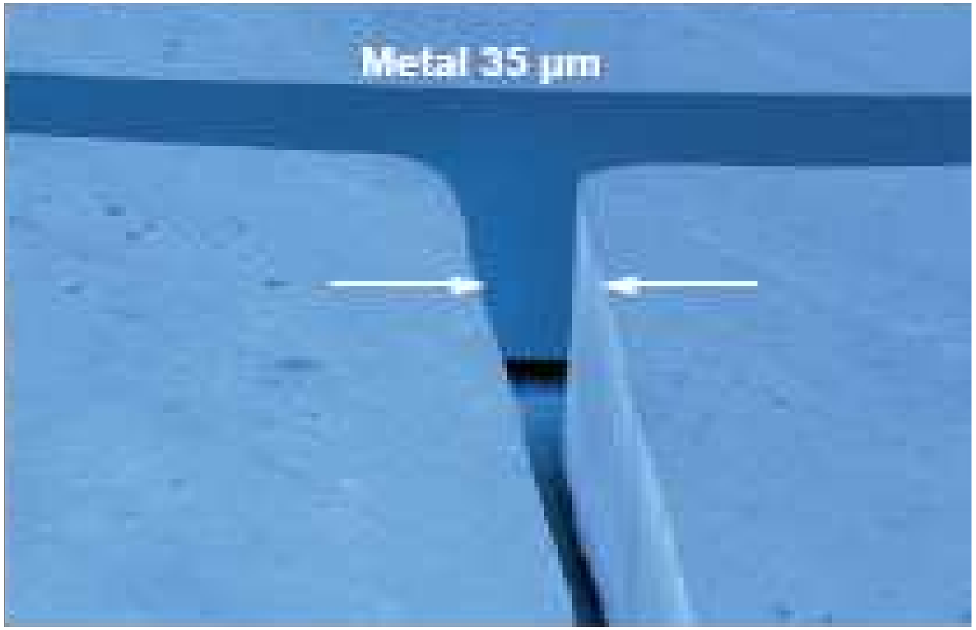
- separation
  of glass up to 1mm thickness,
- up to 1m/s ! , CAD-curved
- no debris, no electrically charged particles on surface
- patented process with fast auto-focus

1. Ablation

..of any material with the same laser!

- **generation of stoichiometric plasma for analytics, spectroscopy etc.**
- **nano-particles, generate coating**
- **tune mass by micro-ablation (μm^3, ~femtoliter, ~picogram)**

- **micro-structuring with high resolution and high quality**



Micromachining technologies

1. Mechanical: >50µm…; CAM
2. Ultra sound: >50µm, selected materials
3. EDM: conductors only , >50µm
4. Chemical / Lithography: high resolution, high through put for large batches; high cost, long lead time, waste disposal
5. Lasers (cw-ns): no wear and tear, no touch, no force, no contamination, CAM, lots of 1, all software controlled; but thermal side effects >10µm, micro cracks, recast, burr
6. ps-lasers: hardly any thermal side effects; quality improved by more then 1 order of magnitude!

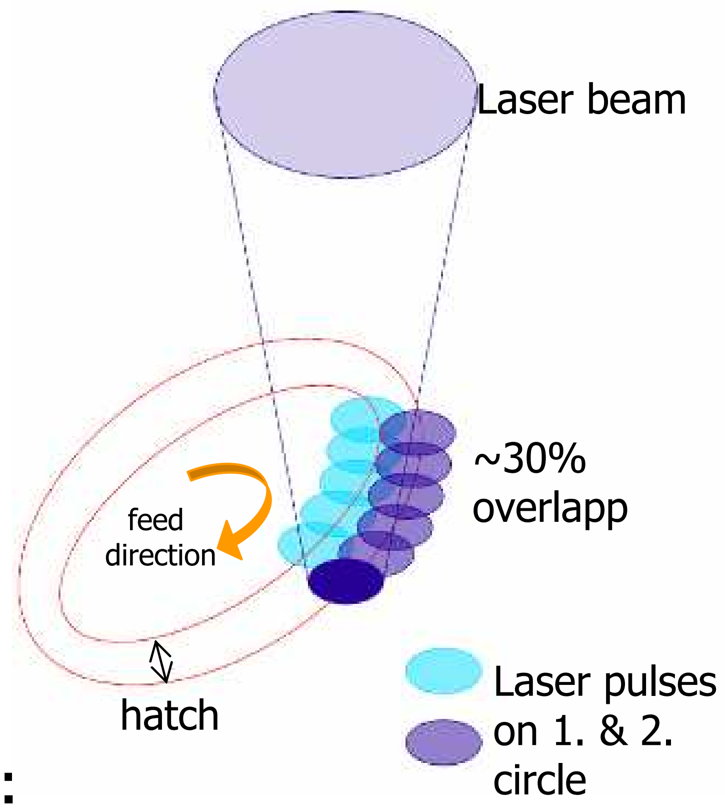
   ~20-100nm thin slice in focus area removed by 1 pulse

   universal tool for all materials

   Especially useful for 50-1µm and tough materials!

Application parameters

- Ablation threshold 0.2 – 2J/cm²
- Micromachining dimension,
  focus ~dia 10µm:
- pulse energy E ~1µJ
  System losses; SHG, THG?
  Larger spots? bursts : …50µJ
- Through put: high PRF up to 2MHz
  Ablation rate with HYPER RAPID 50W:…~60mm³/min, …~10⁹ µm³/s:
  Process speed: e.g. trench with 20mm³/min: ~33µm wide, ~1µm deep:
  up to 10m/s
- Result:
  in 1 min 600m trench for ~0.2€ TCO!



Micromachining Systems

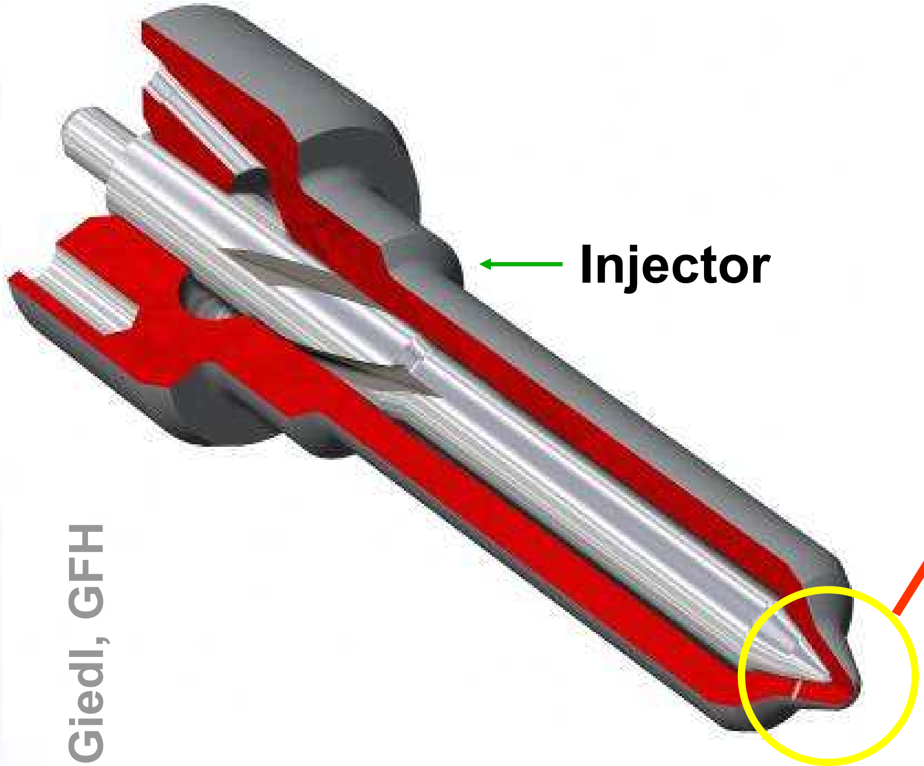
…with picosecond laser

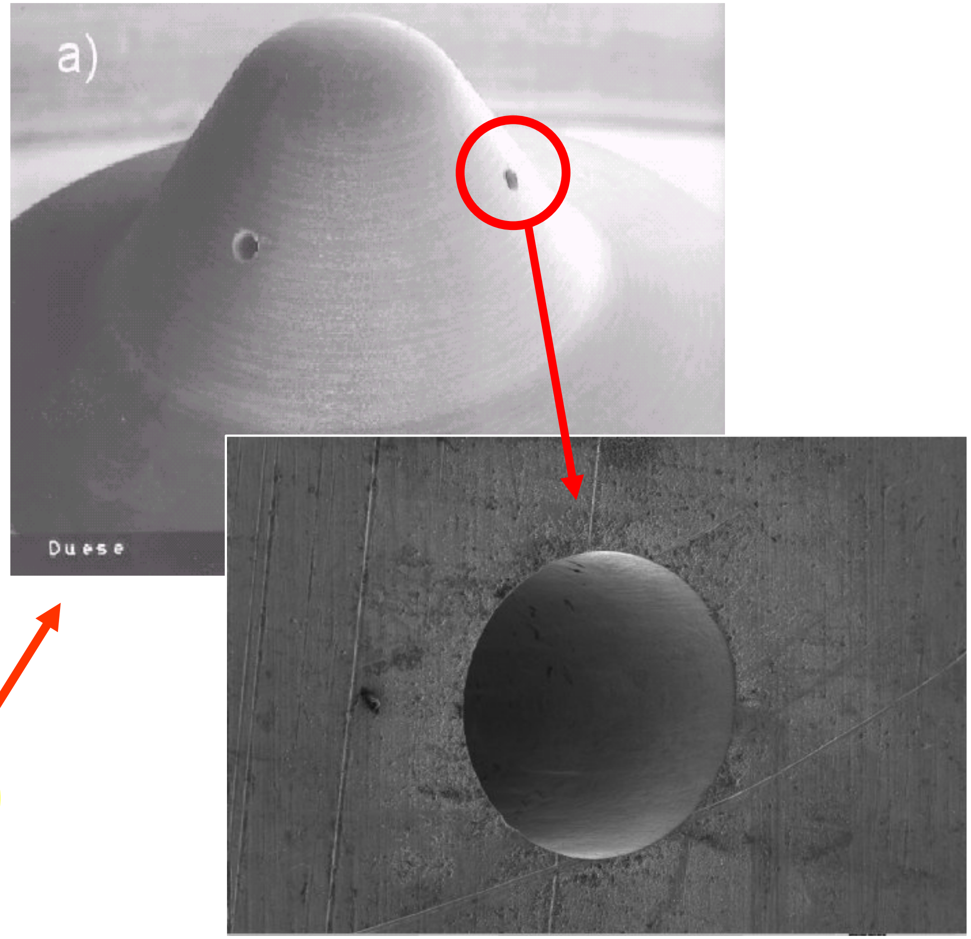
LASERTEC 40 *PrecisionTool*
www.gildemeister.com

Applications examples

a variety of different materials..

Drilling of injection nozzles

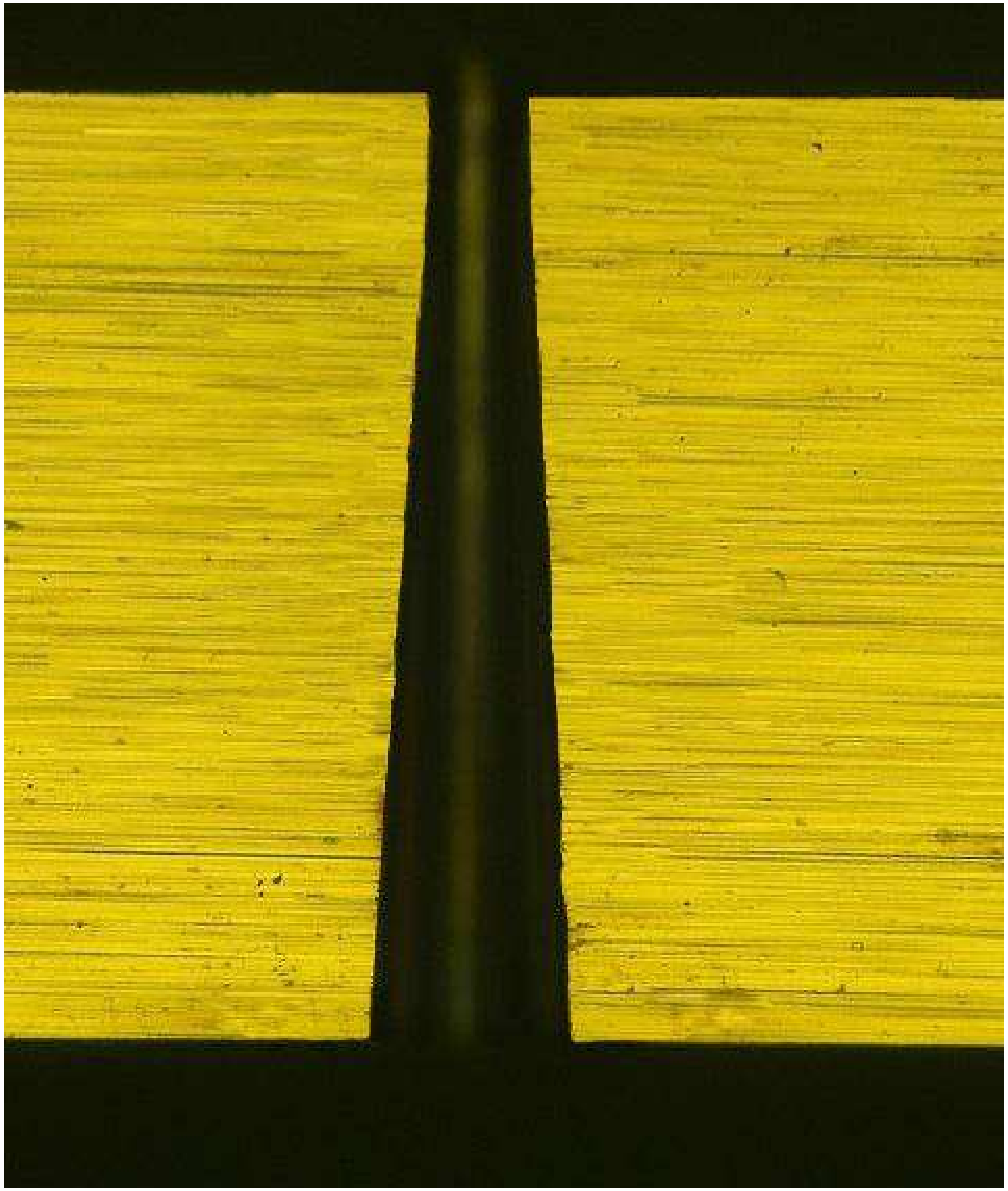




Source: R. Giedl, GFH

Spray holes: Ø ~100 µm, P >1000 bar

Nozzel drilling



1mm thick SST

60 / 120µm

532nm, 25W

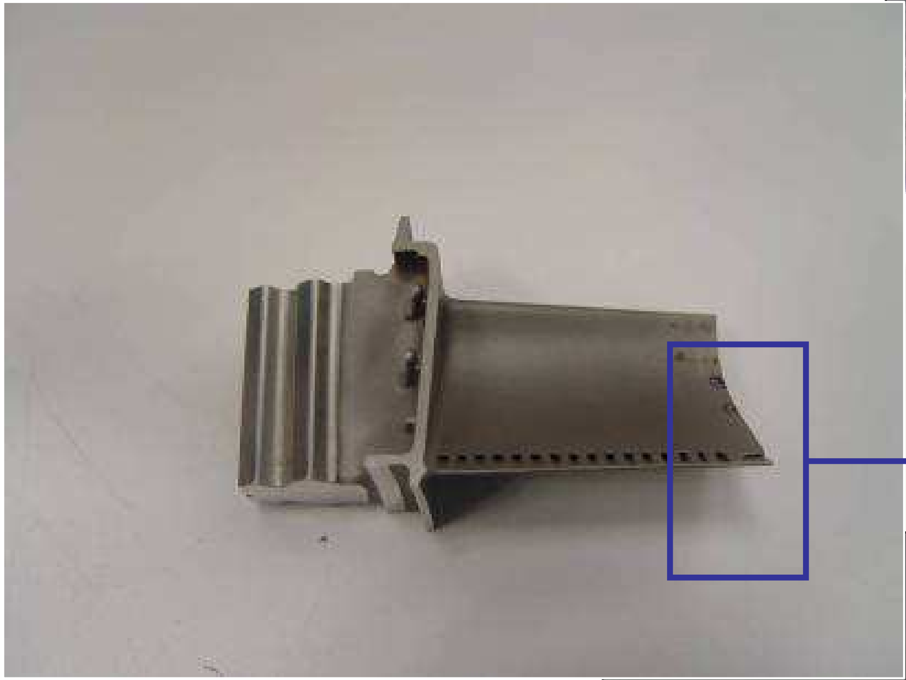
500kHz

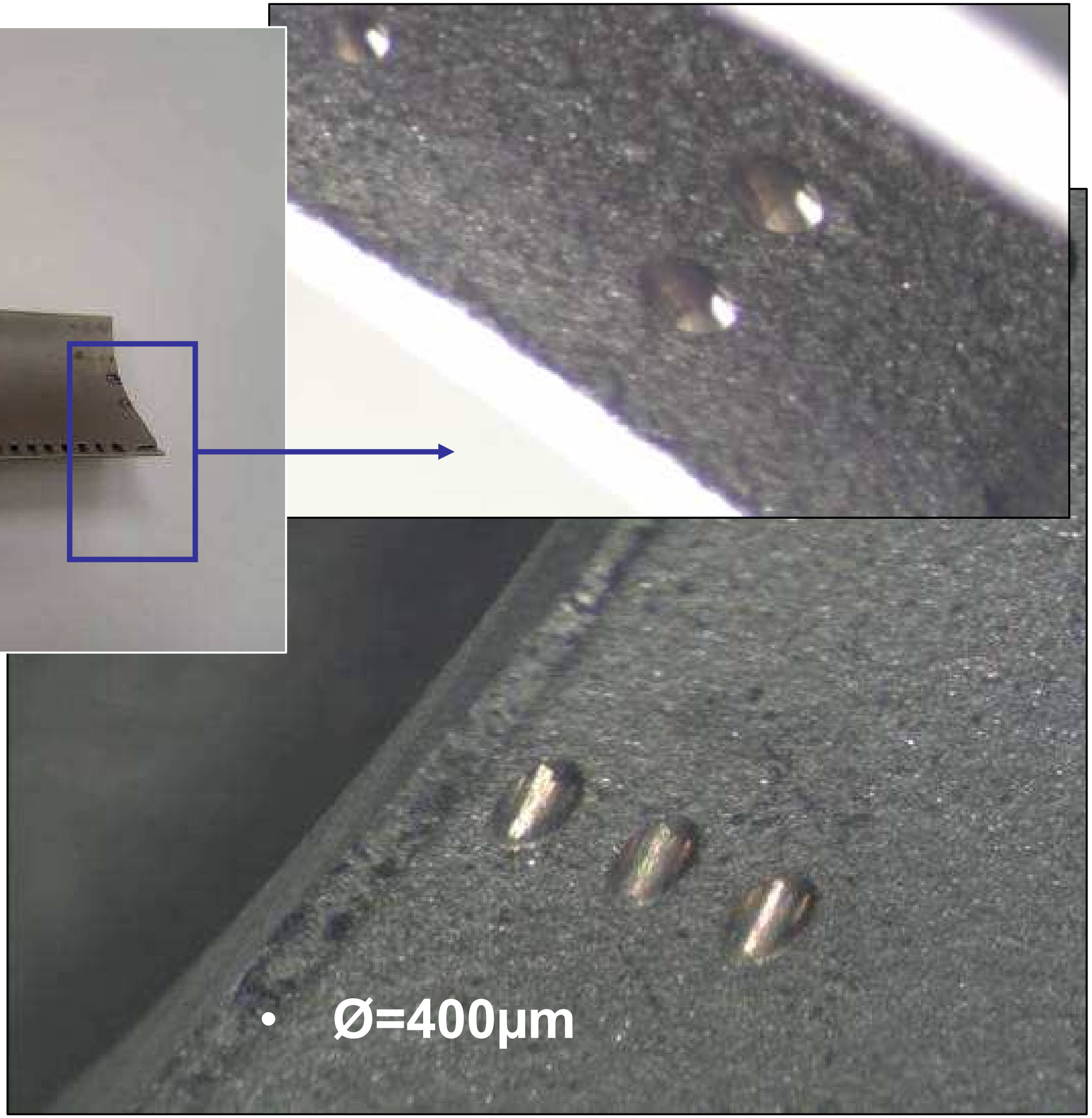
Through in 5s

Ready in 15s

Courtesy of ExOne

High aspect ratio holes, tilted



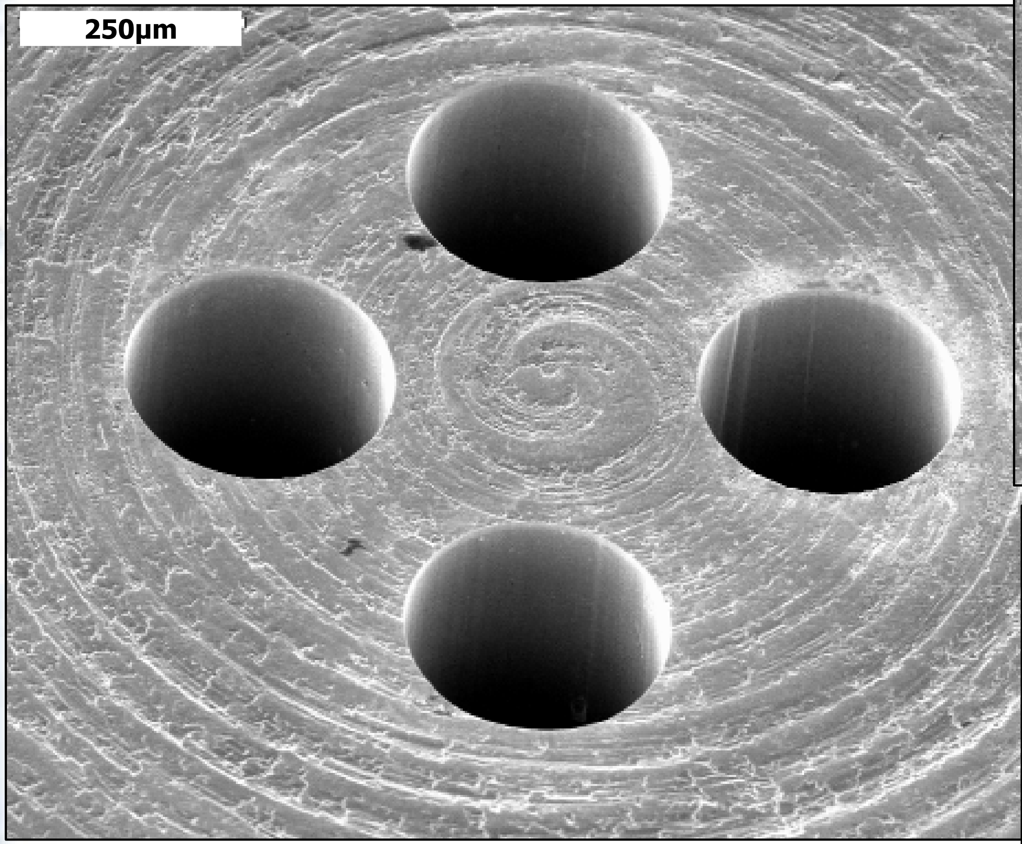


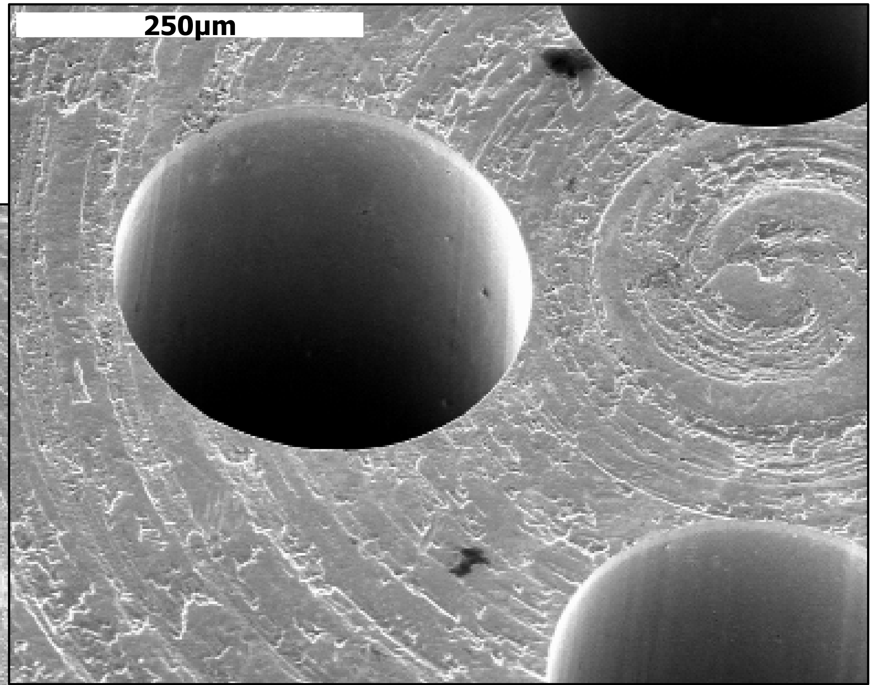
1mm Ni-alloy
400µm dia
60° tilt

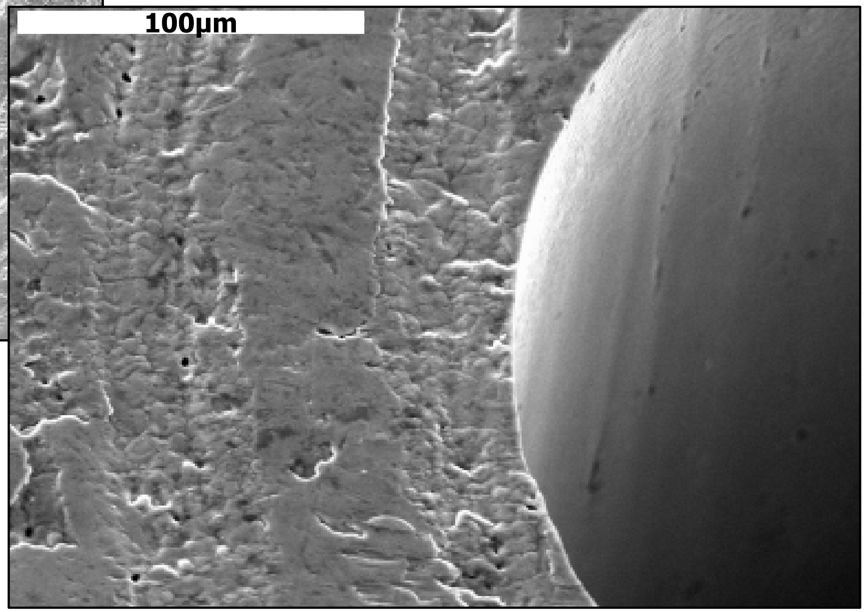
Very good surface quality

Stainless steel drilling

Ø=250µm, thickness: 300µm





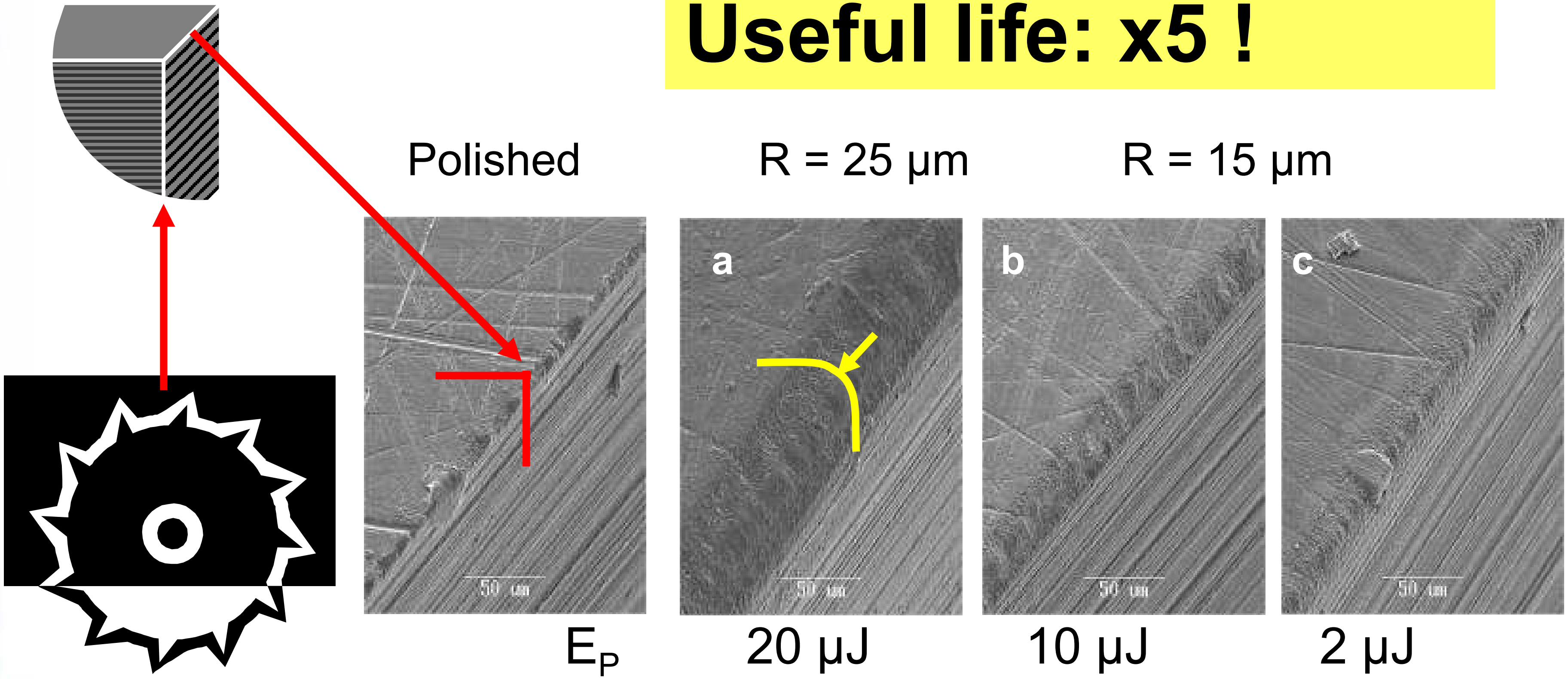


processing time : 5s / hole

Edge rounding on Tools

Edge rounding of carbide metals for High-Precision Tools (www.geospan.de)

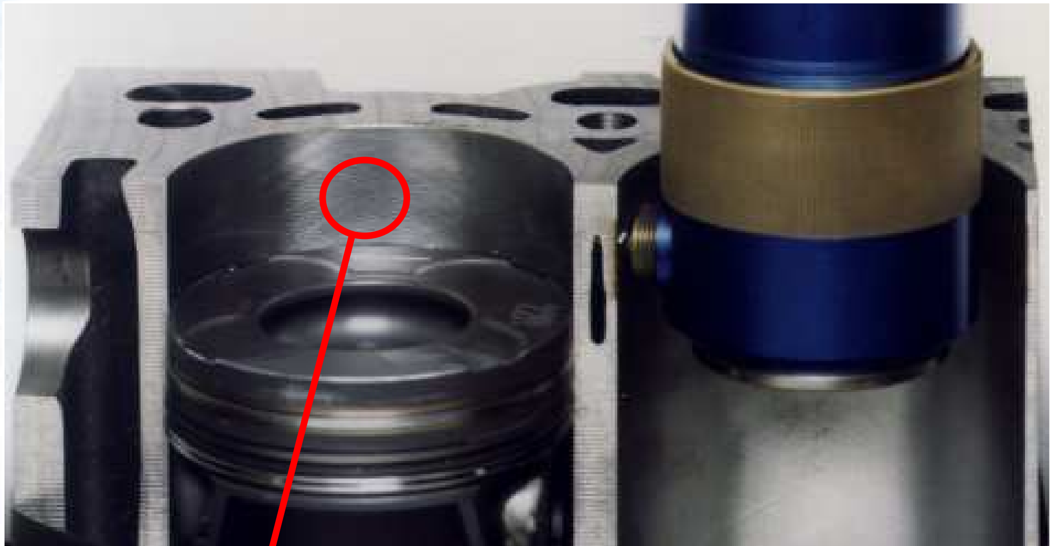
Useful life: x5 !

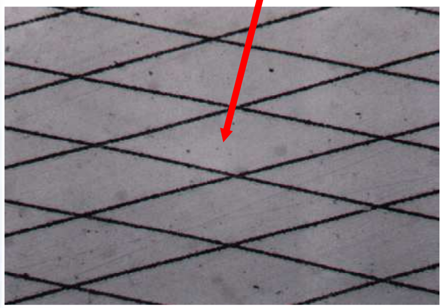


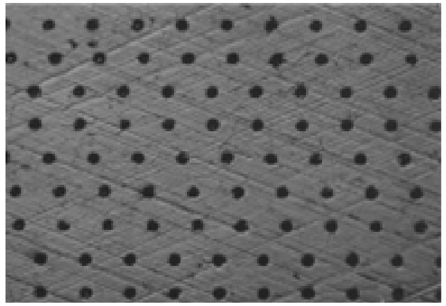
532 nm, 30 kHz, 1 mm/s; *use 1000 kHz ⇨ 30 mm/s*

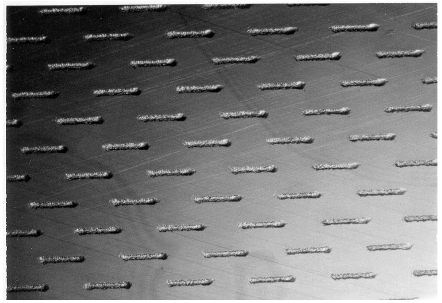
Courtesy of Frank Siegel, LZH

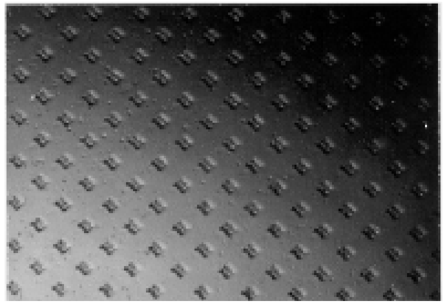
Reduced Friction











Source: Gehring

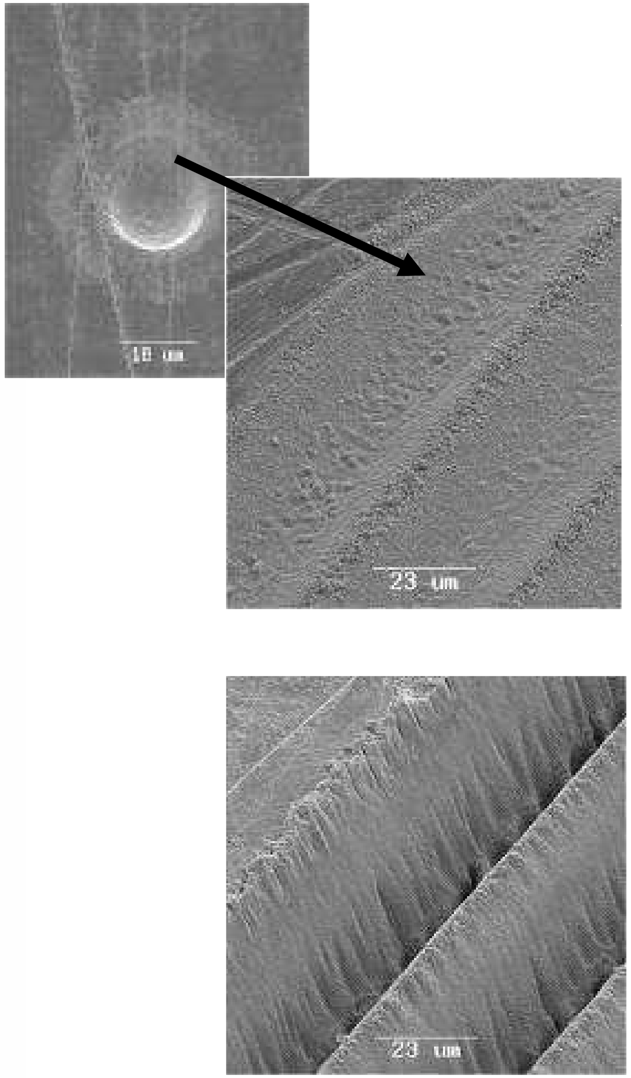
Advantage:
Reduction of oil consumption (3 to 7 fold)

Reduction of particle emission

ps: precise, no post-processing

Reduction of Friction

microstructures on metallic surfaces with reduced friction



Courtesy of Frank Siegel, LZH

Molybdenum 180µm holes

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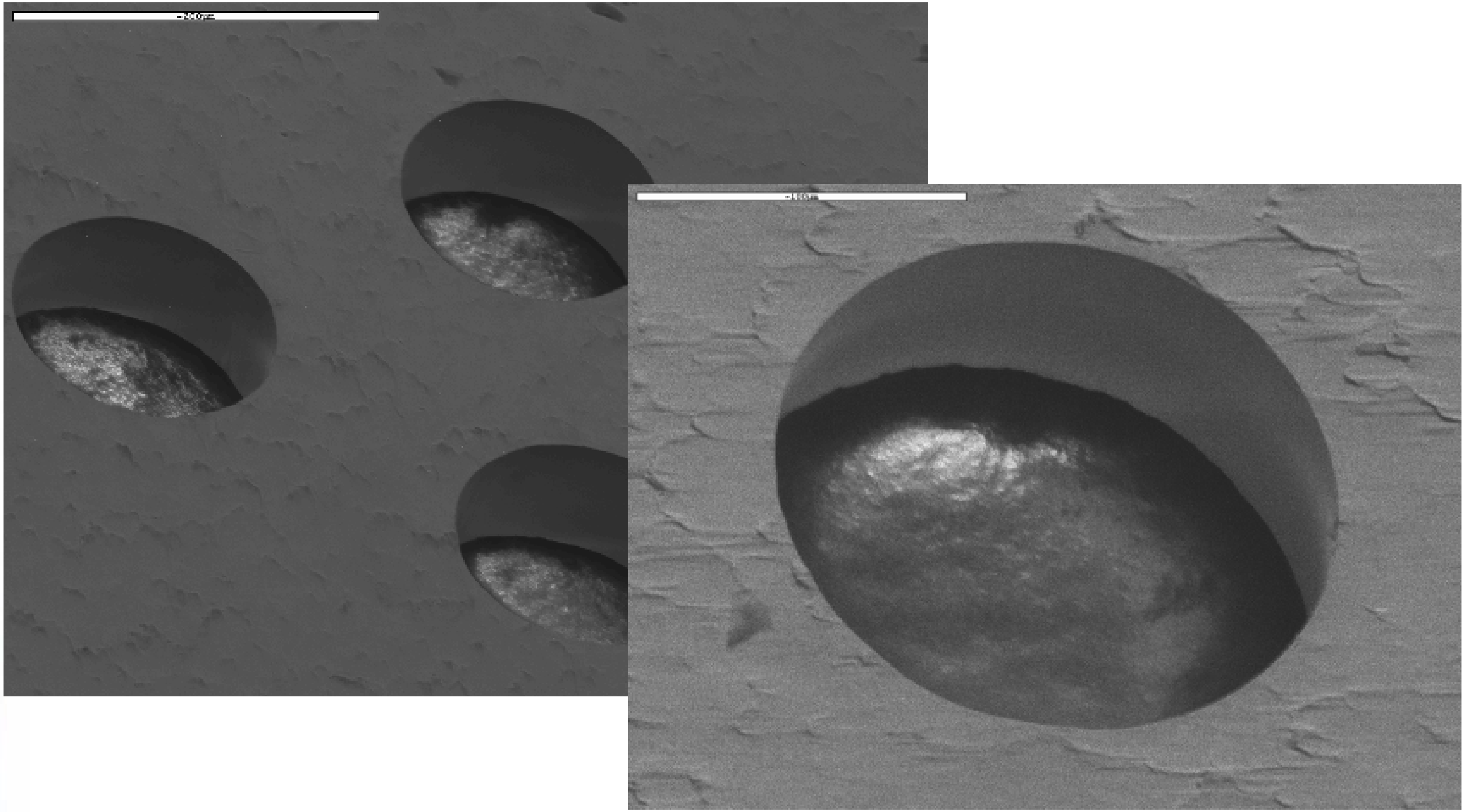

150µm hole in 0.5mm Al

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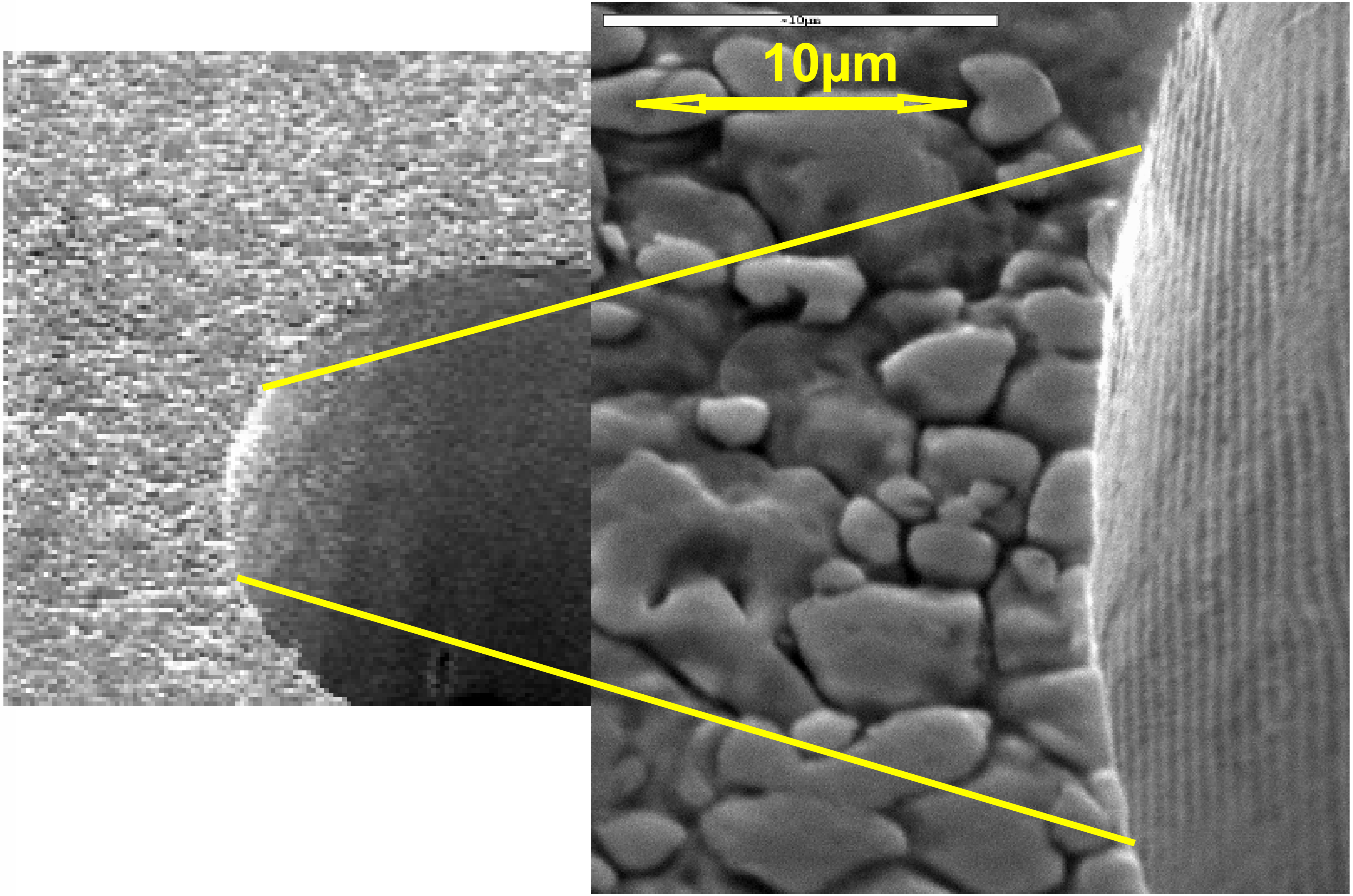
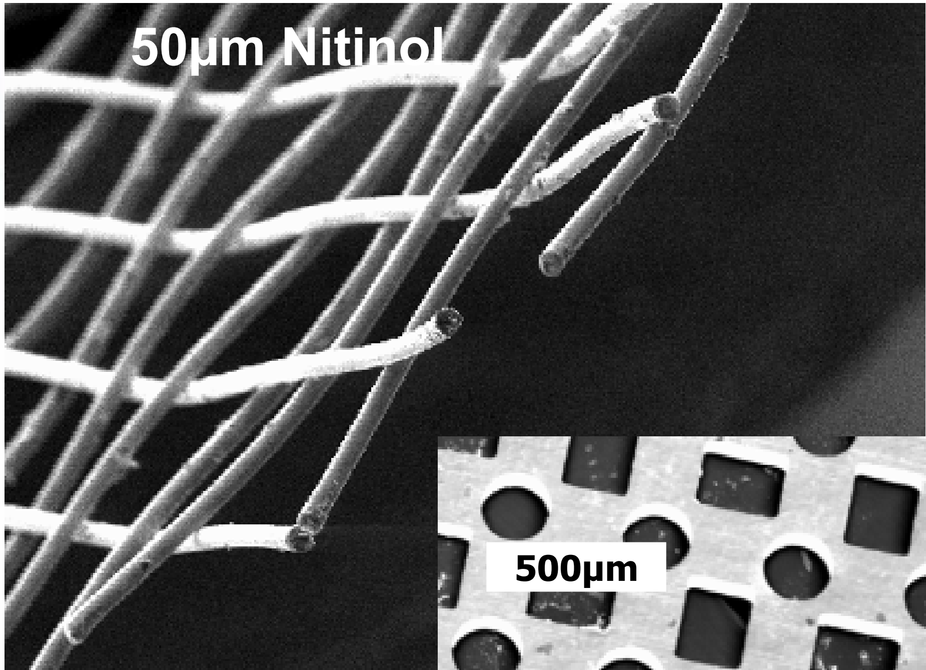
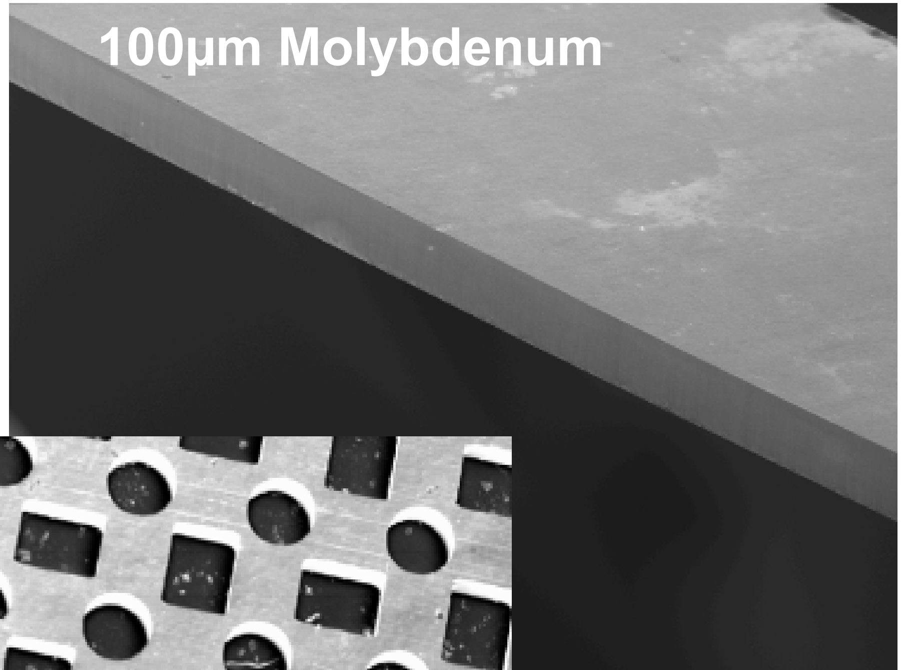
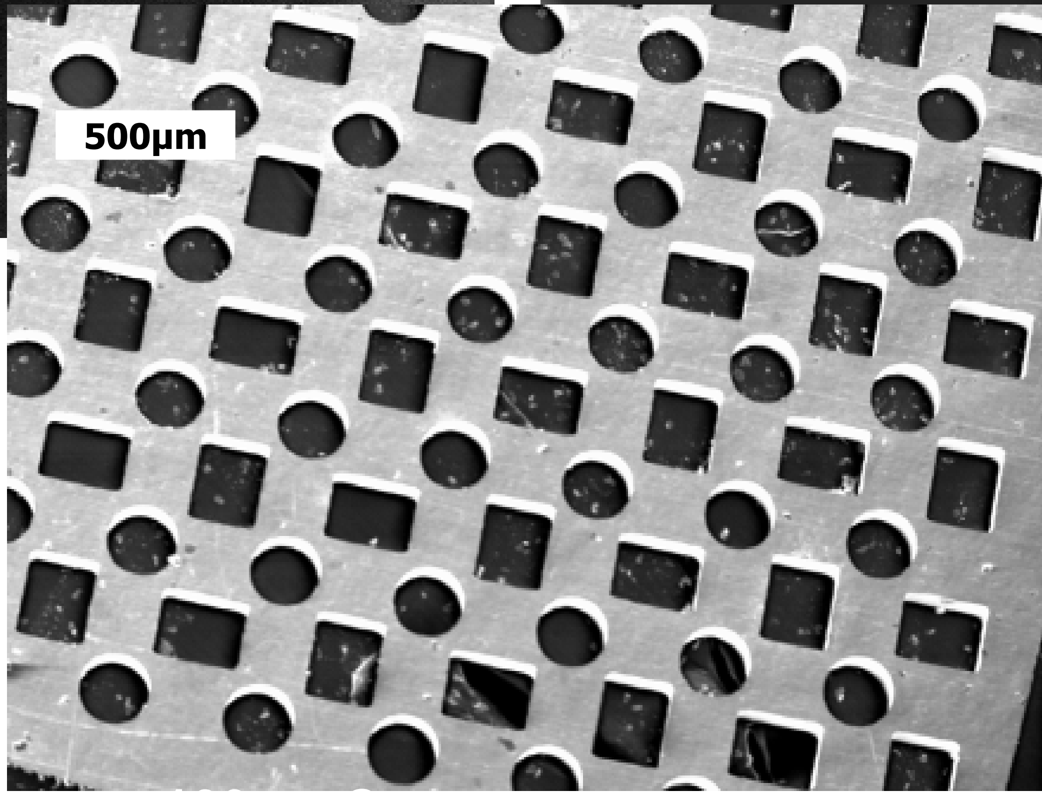


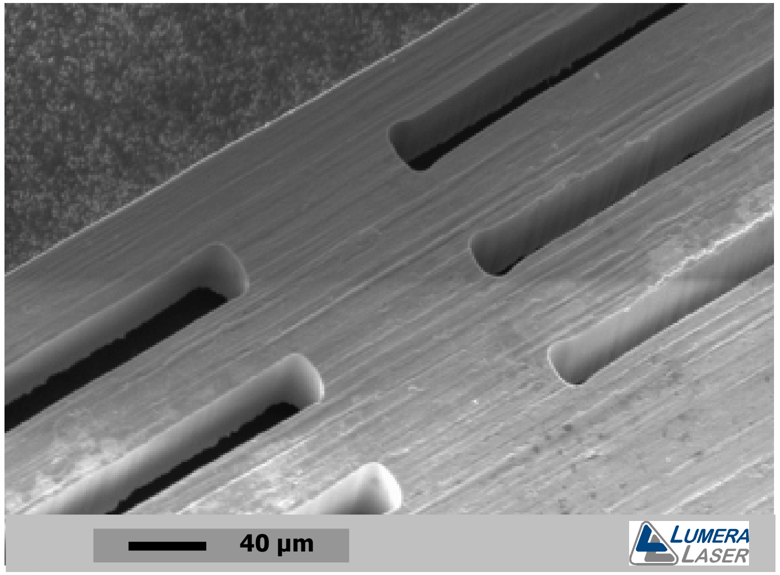
Cutting of metals

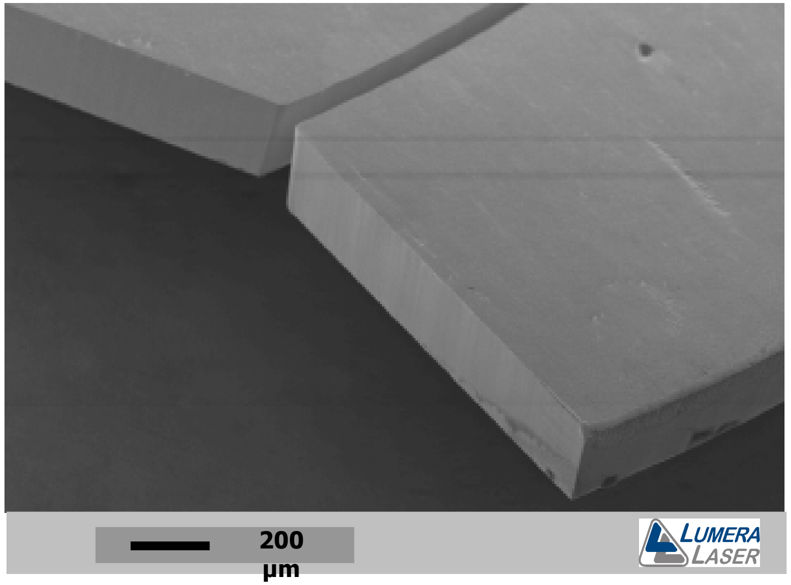


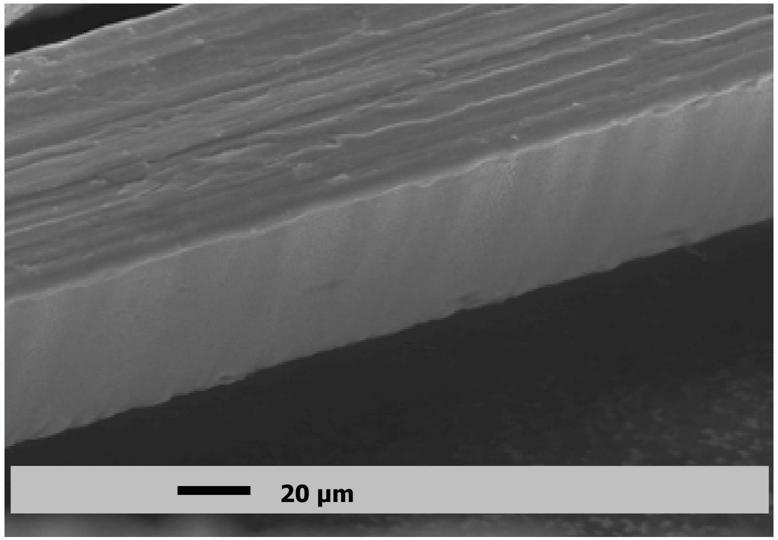


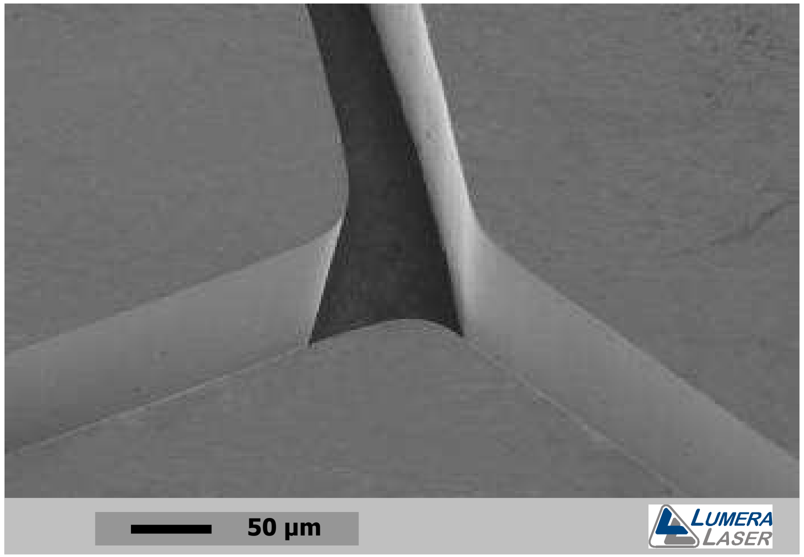


Slots in metal foils





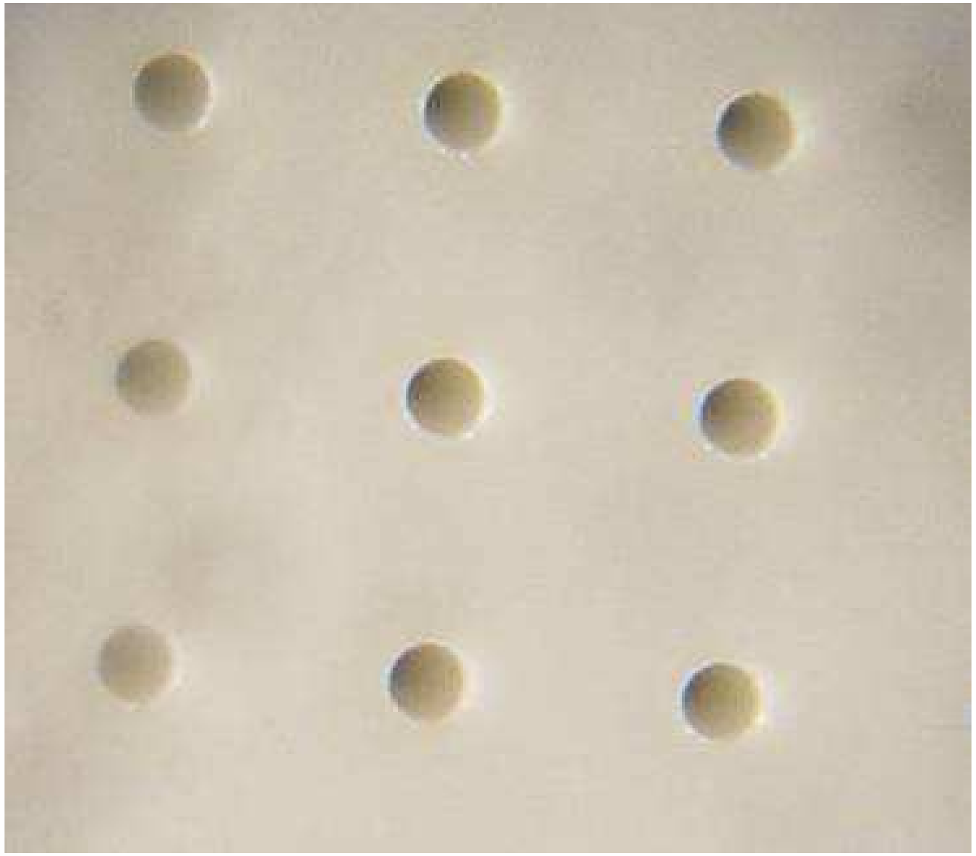




15µm slots in 20µm metal alloy

30µm slots in 100µm tungsten

Holes on ceramic



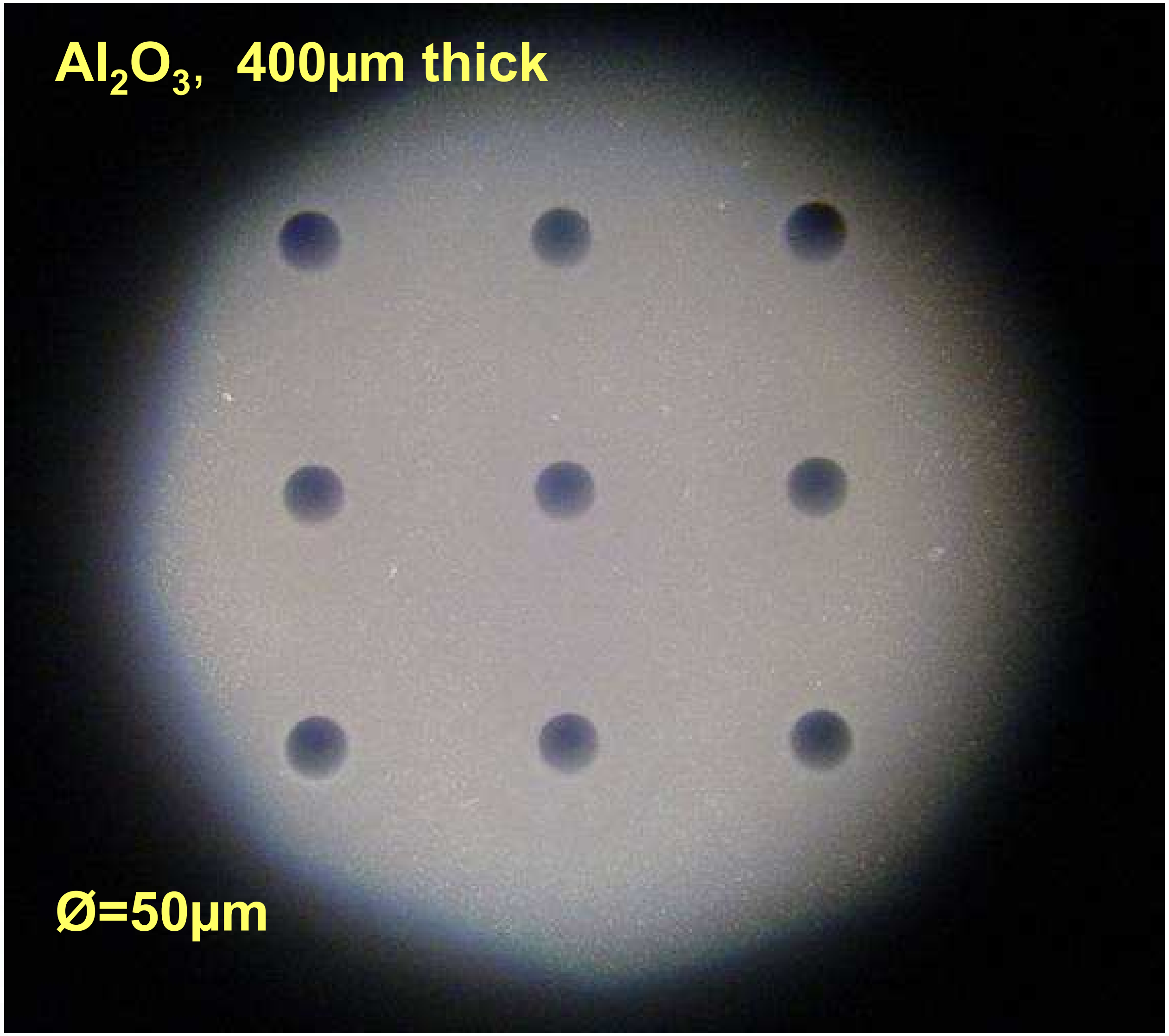
Diameter : 100 µm

Thickness: 1 mm

1 sec / hole

HYPER-RAPID
1064nm, 50W

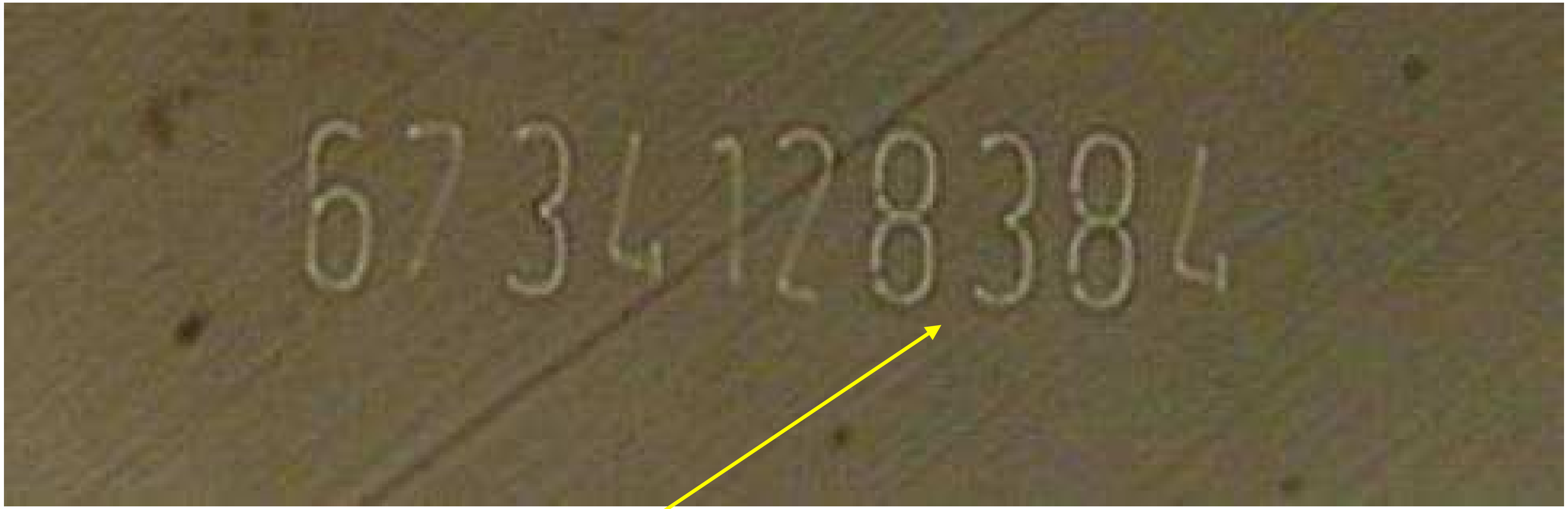
Drilling ceramics, test plates

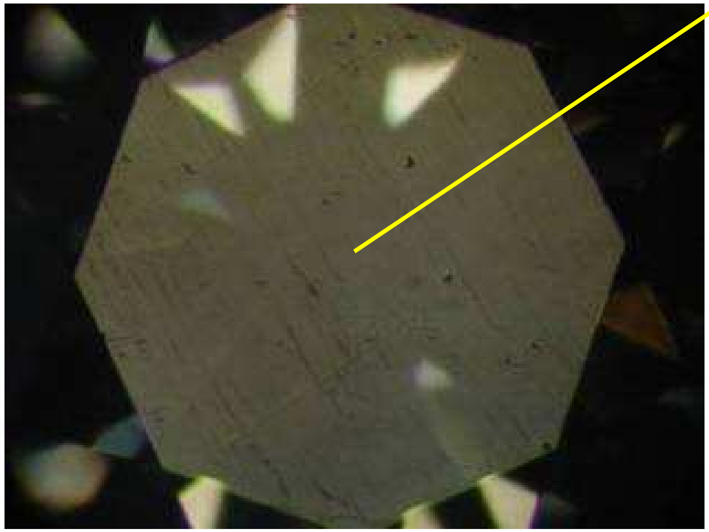


~10% of cost !

vs mechanical drilling

Diamant marking with ps-laser





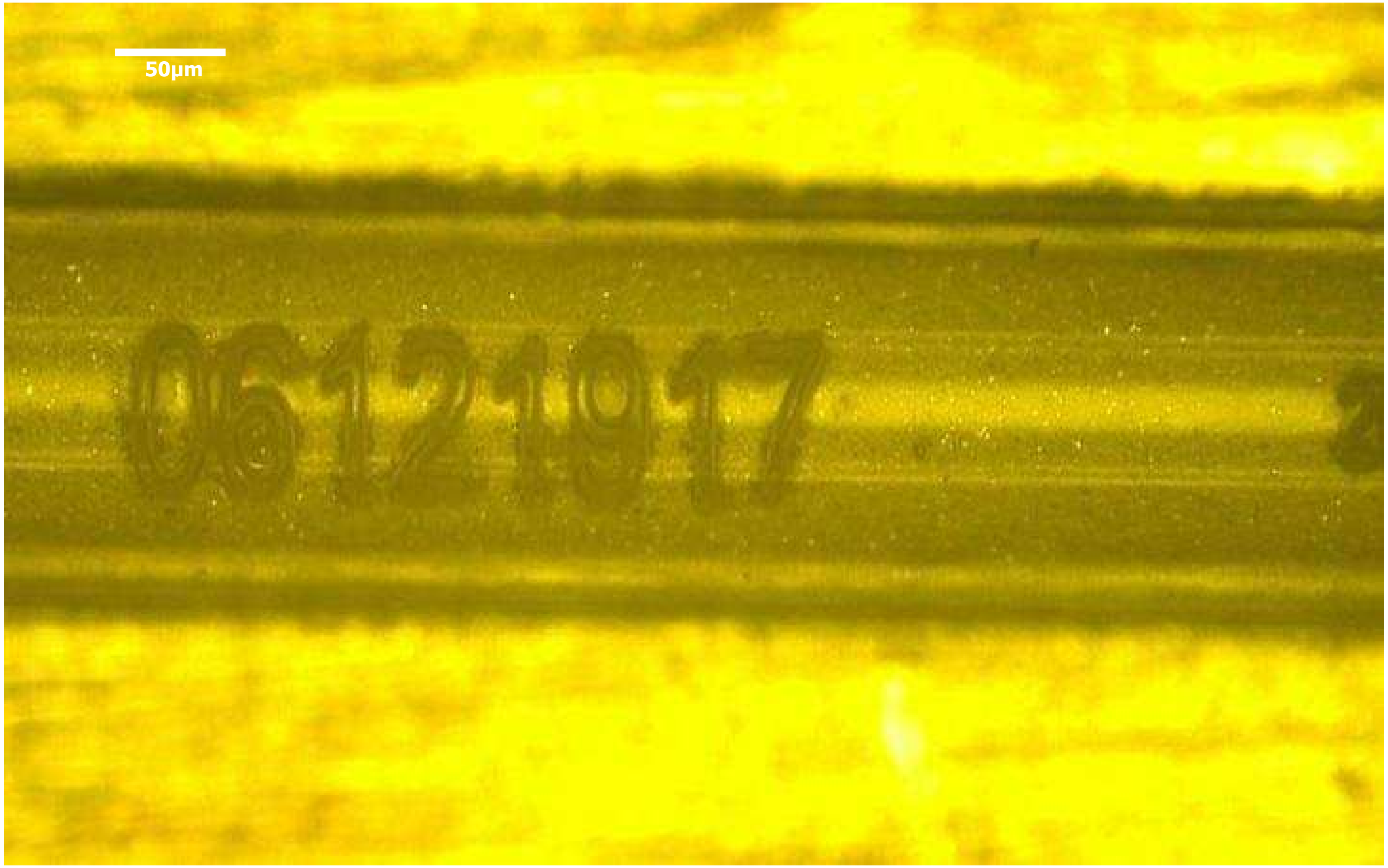
Line width ~ 5µm

Dimension < 500µm

λ=355 nm

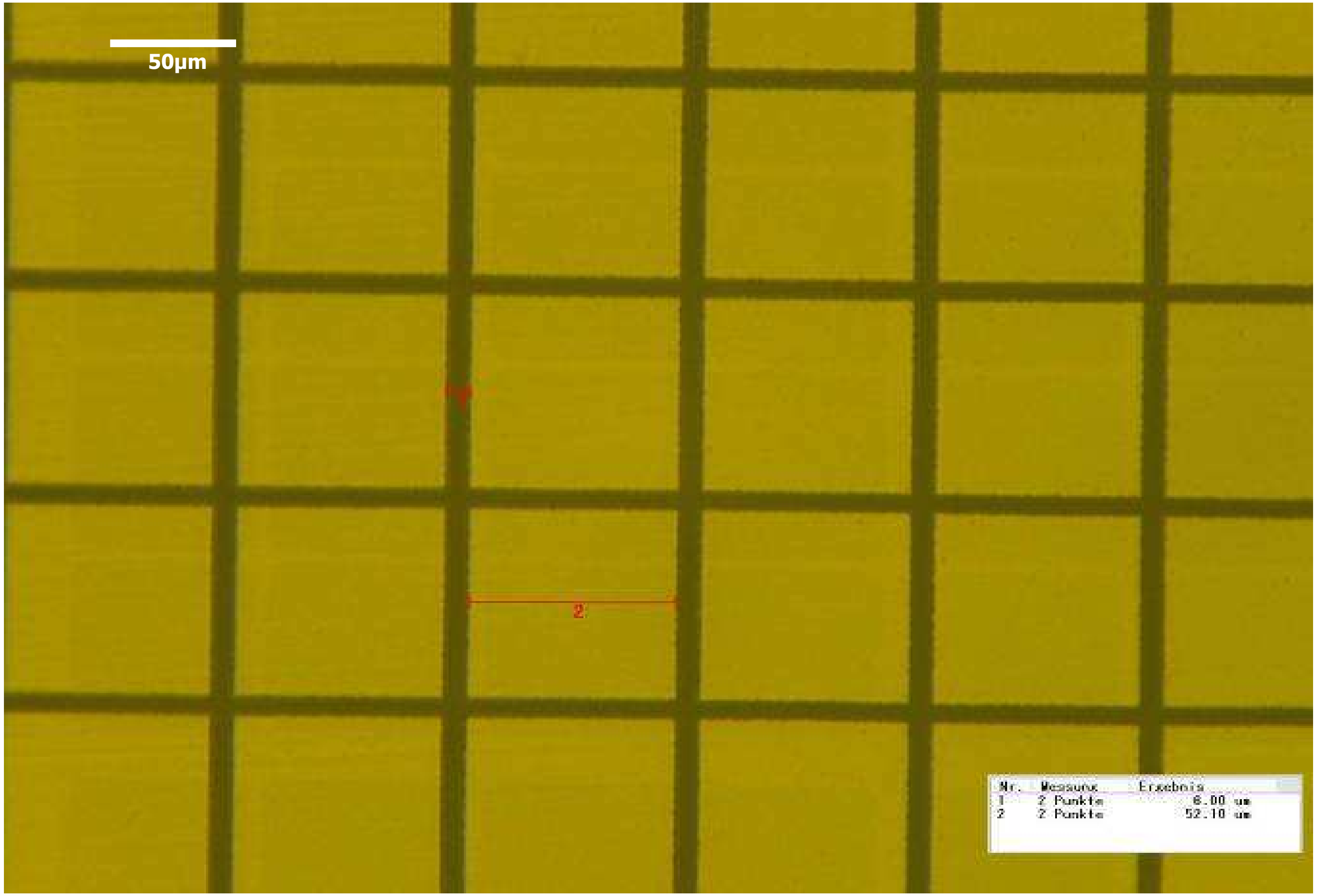
Marking of glass tubes

line 5µm wide, 400 characters/s; HYPER RAPID 50, 1064nm



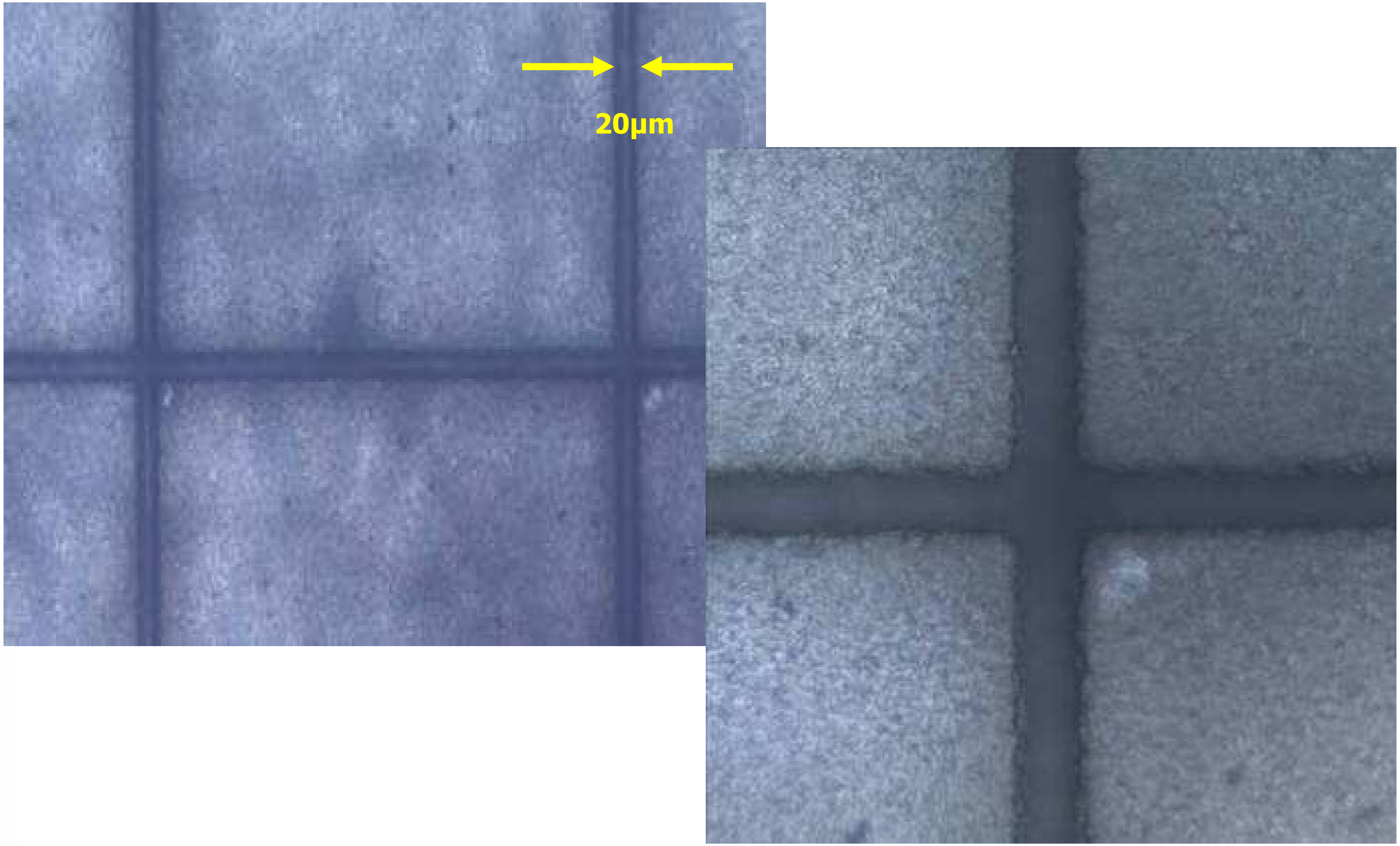
Borosilicate glass scribing

grooves 5µm wide, 1µm deep, 1m/s; HYPER RAPID 50, 1064nm



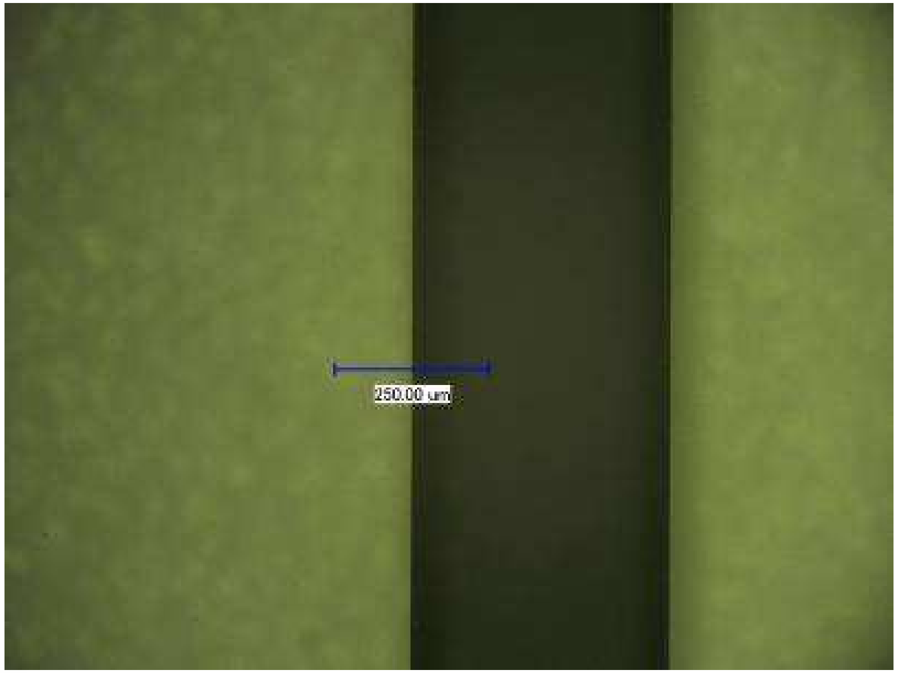
Scribing of glass

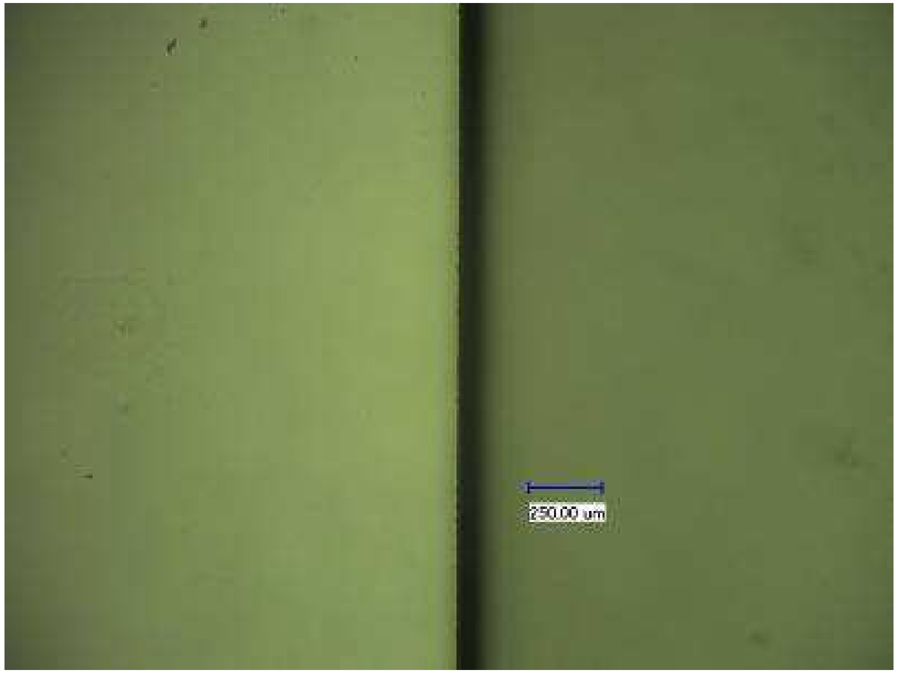
grooves 20µm wide, 40µm deep, 8cm/s; SUPER RAPID, 1064nm



Borosilicate glass cutting

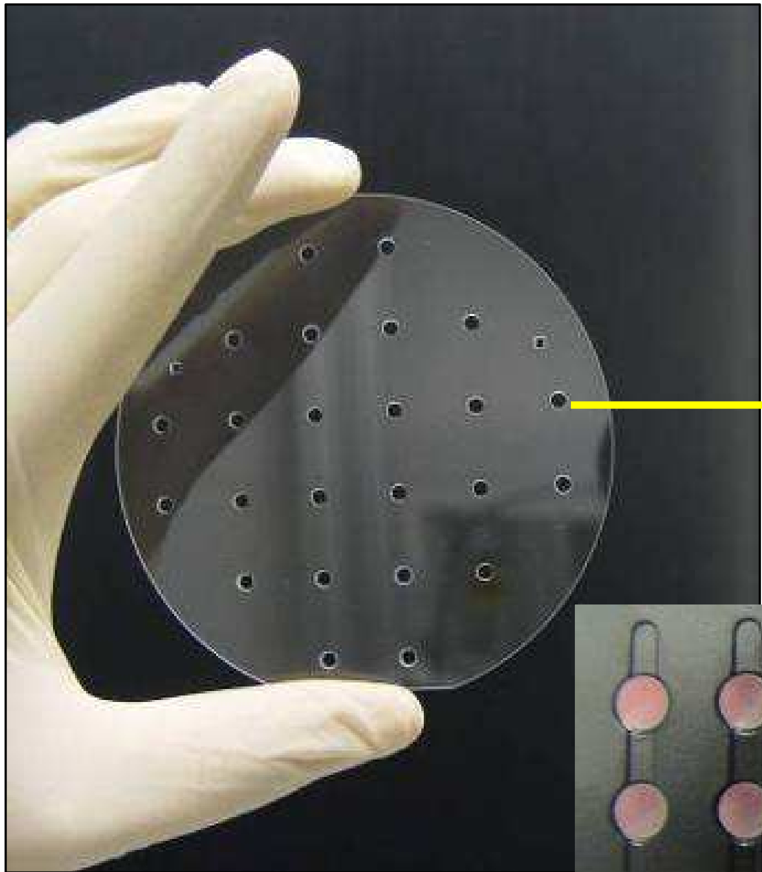
thickness 0.4 mm, 10mm/s, 40mm³/s ; HYPER RAPID 50, 1064nm

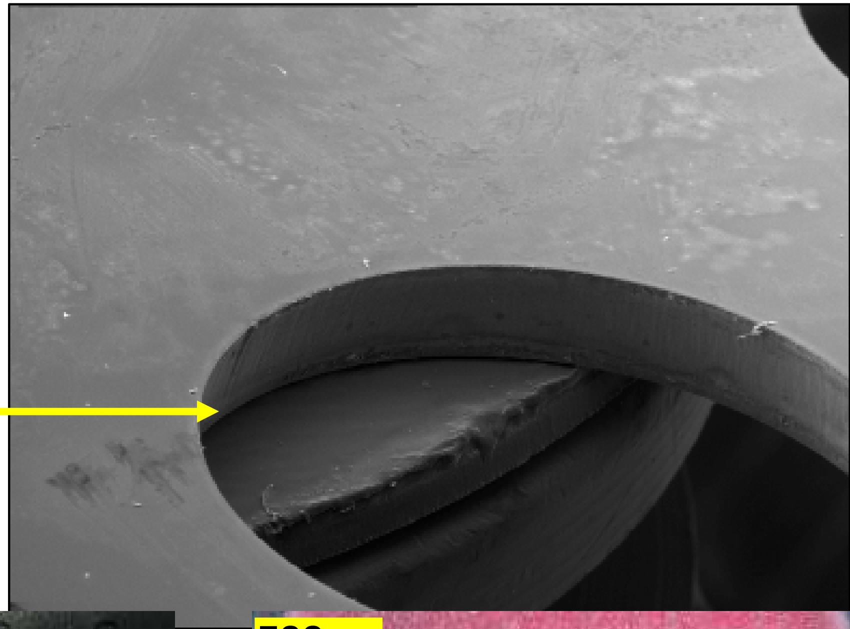


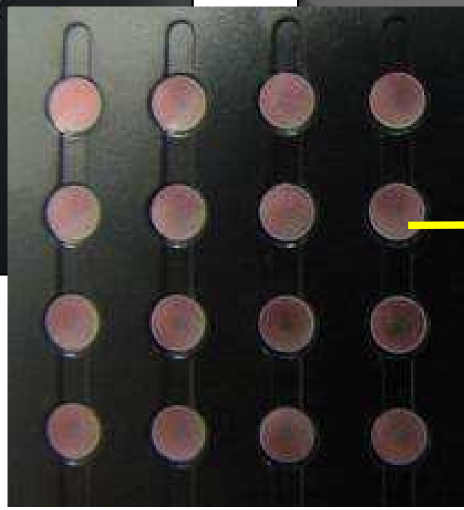


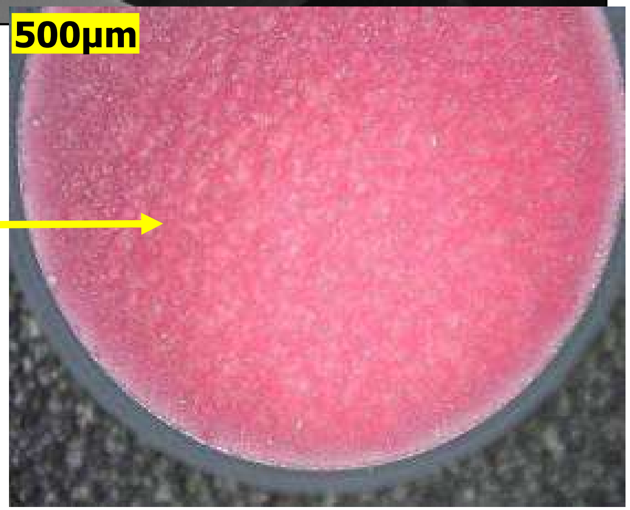
Borosilicate glass cutting

Glass wafer, 25 holes, Ø = 3 mm, d = 0.5 mm









With dielectric coating

Diameter 3.5 mm

Thickness 150µm

Cutting glass fibre composite

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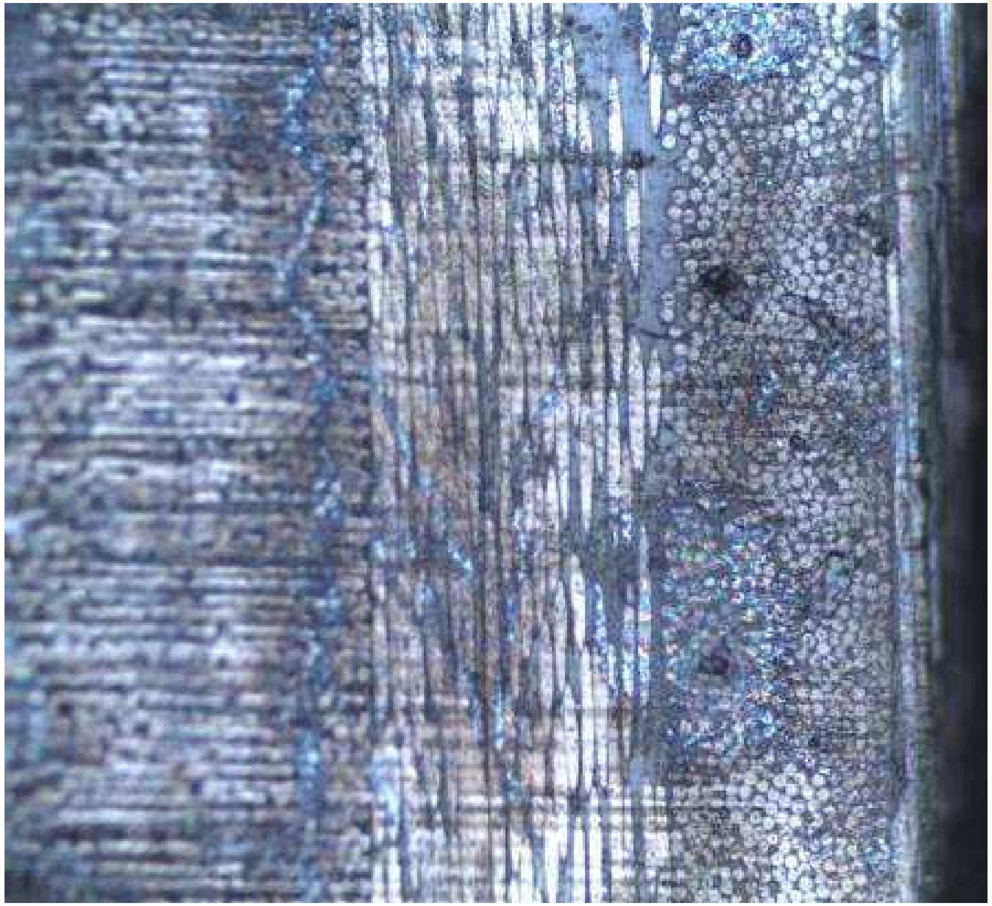
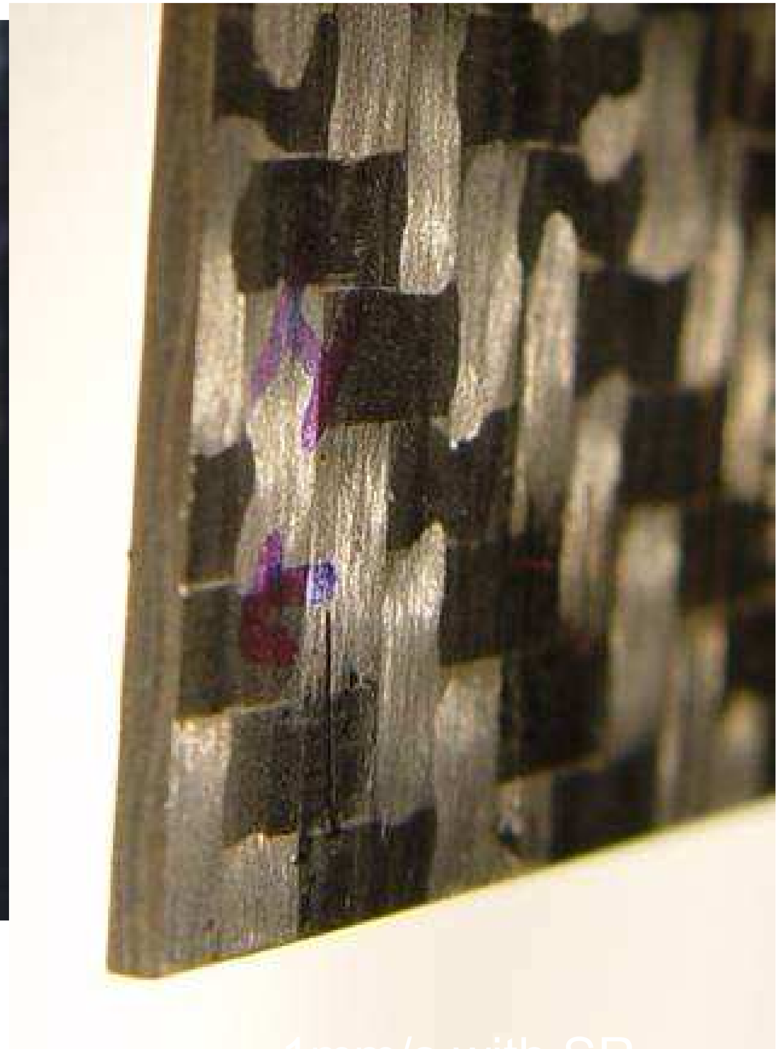
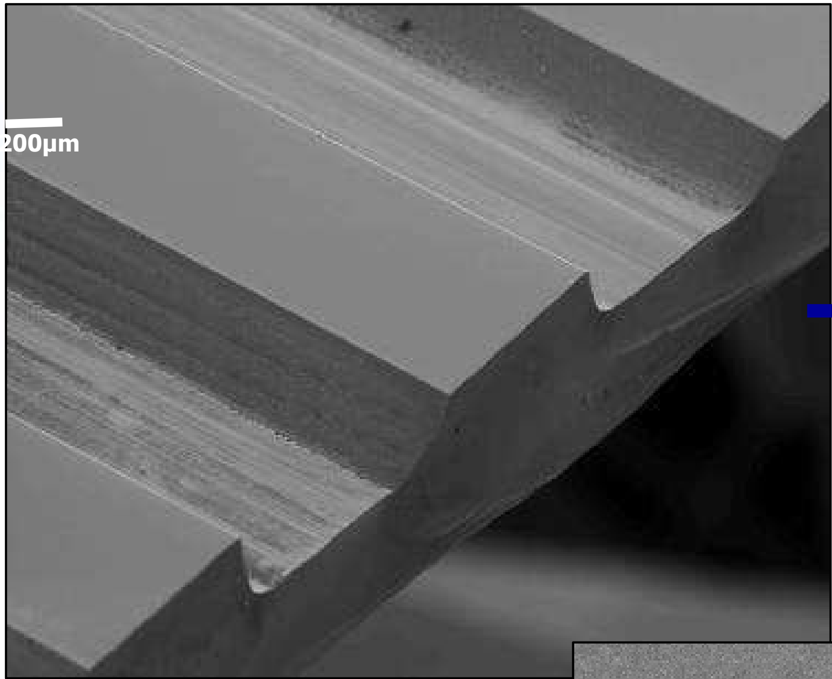
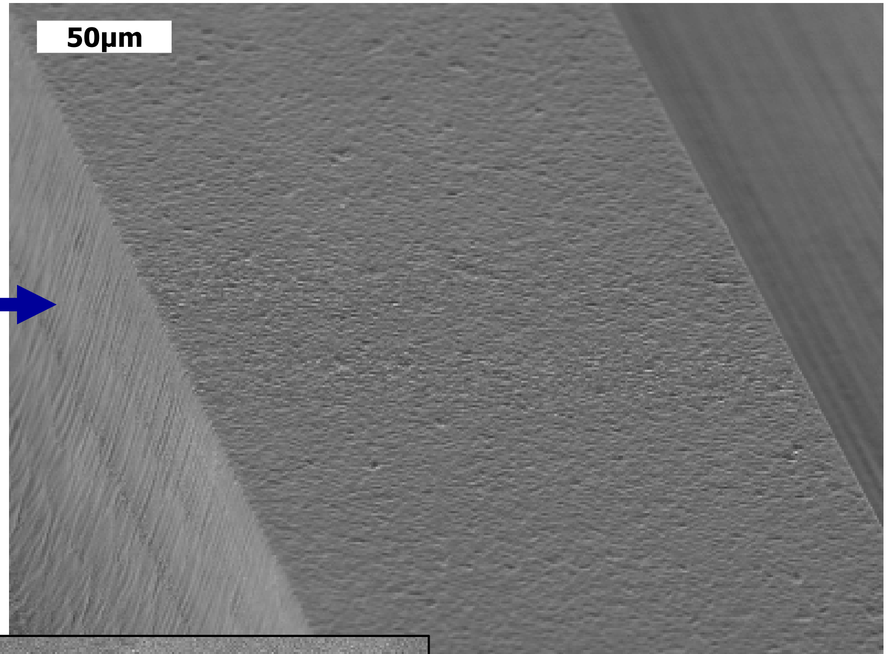
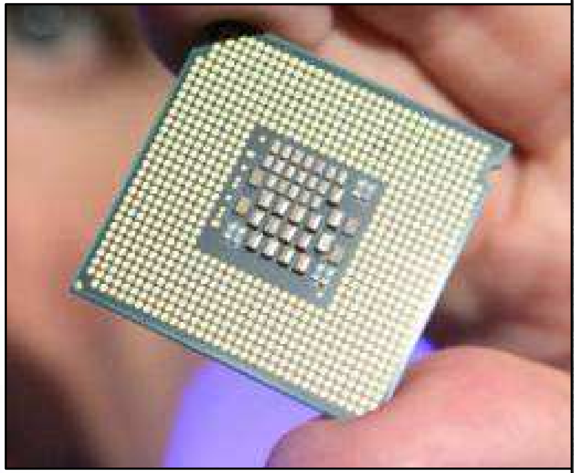


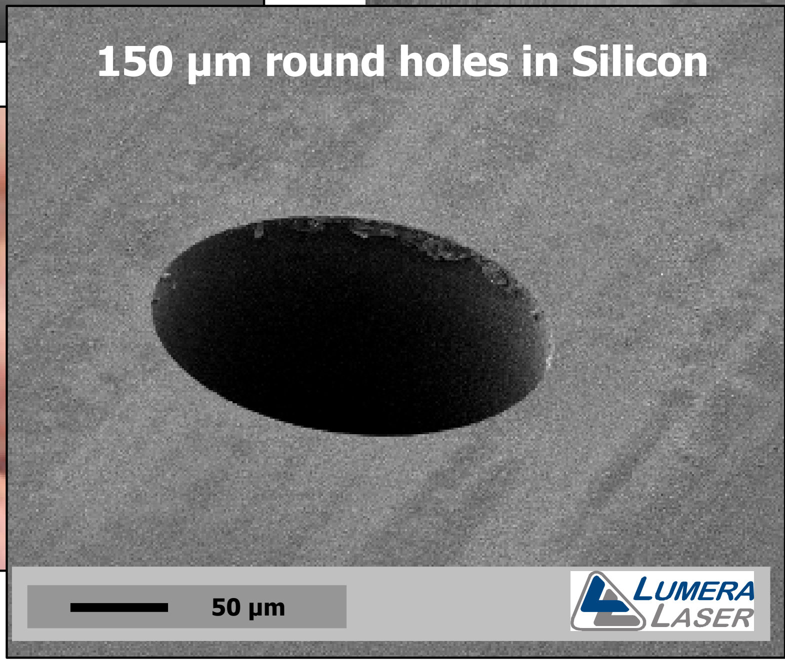


Grooves and holes in silicon









thickness 200µm
dia 150mm

5 holes/s

Surface structuring of sapphire

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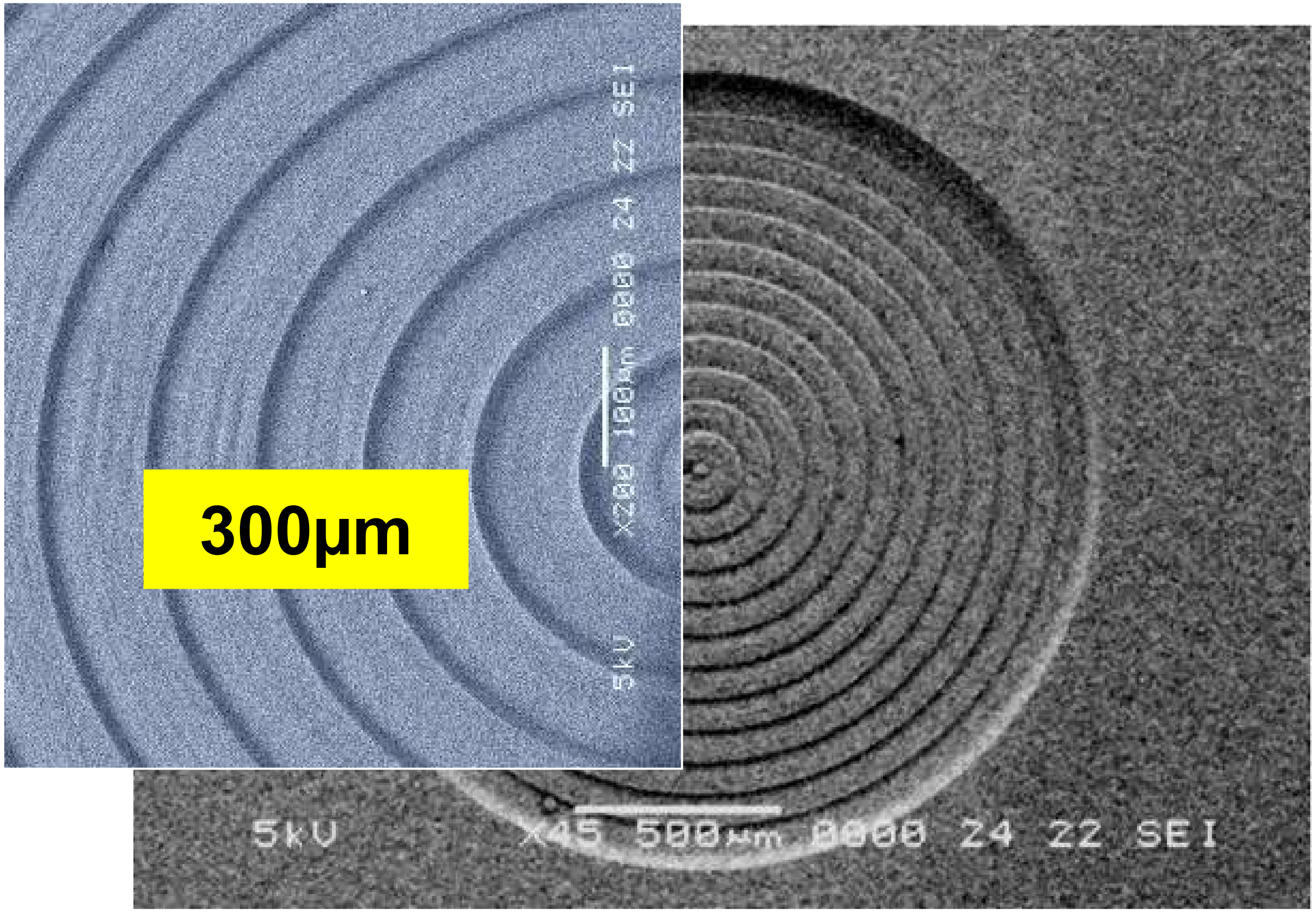
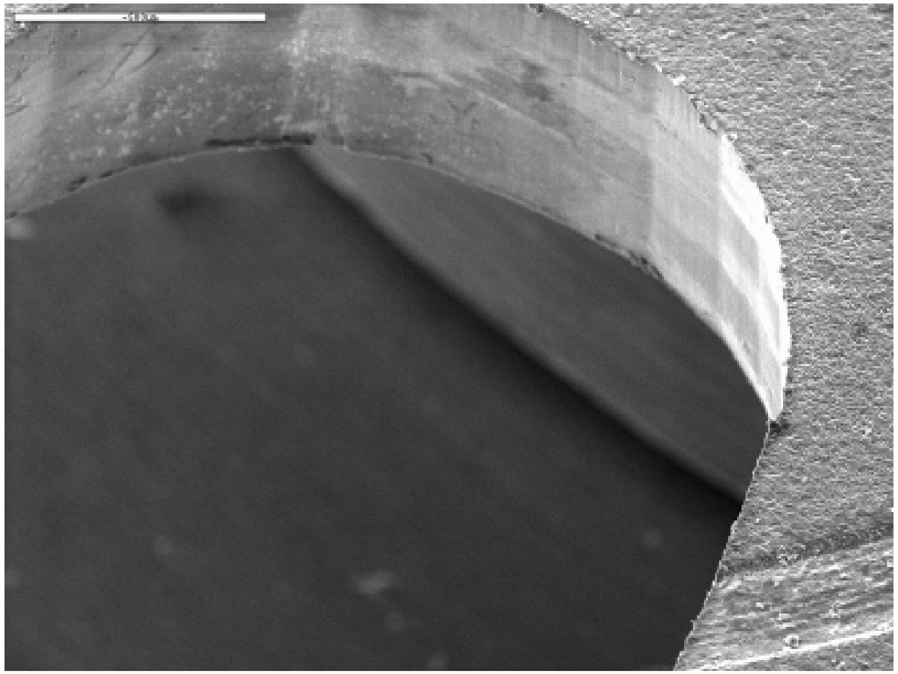
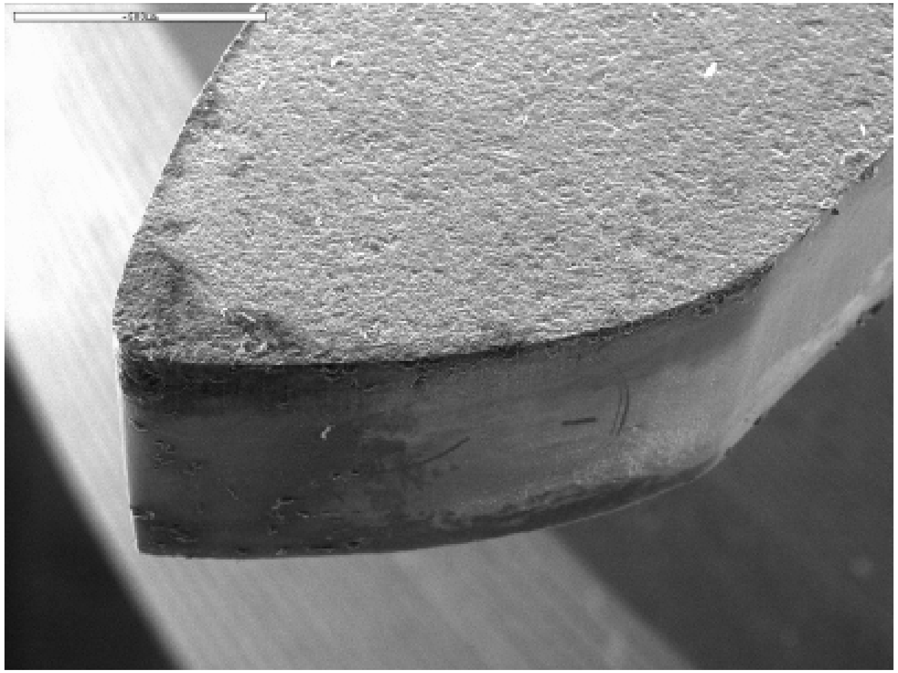
SAPPHIRE
steps
W100 µm x
D10 µm



Sapphire cutting

thickness 0.5mm, 1mm/s cutting; HYPER RAPID 50, 355nm

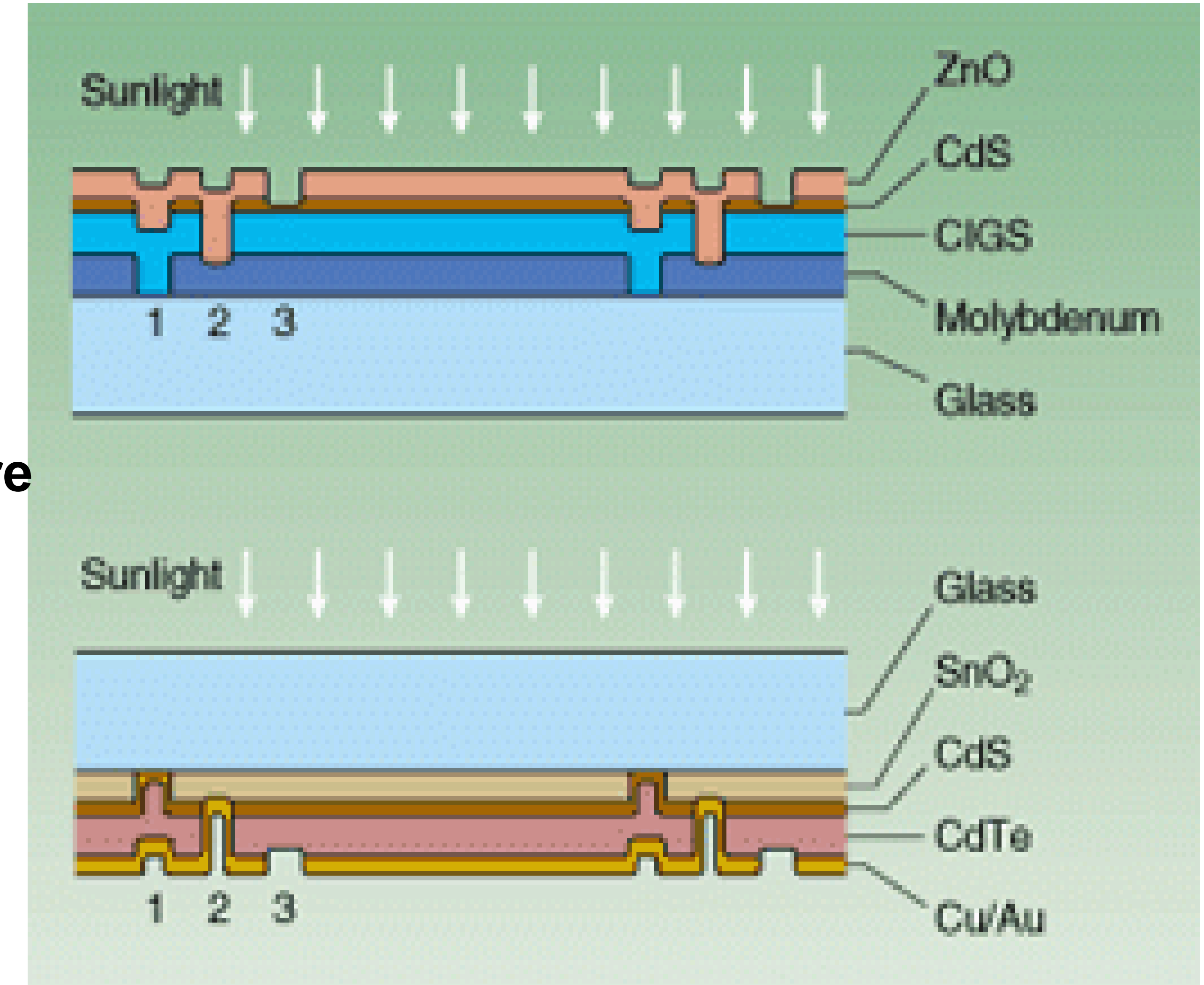




Thin Film Laser Scribing

mechanical scribes for P2 and P3 due to melting of molybdenum layer when using ns IR or green lasers.

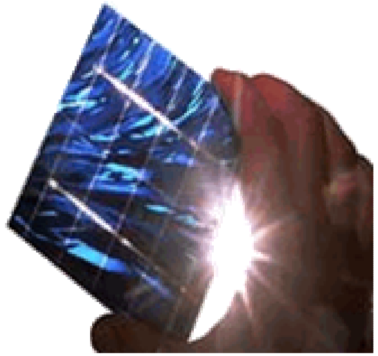
Picosecond lasers are under evaluation for application in P2 and P3 scribes.



A. Compaan,
Laser Focus World

Photovoltaics

Ablation of SiO_2-or SiN-layer on Si; dia 50µm



τ~30ns **τ~10ps**

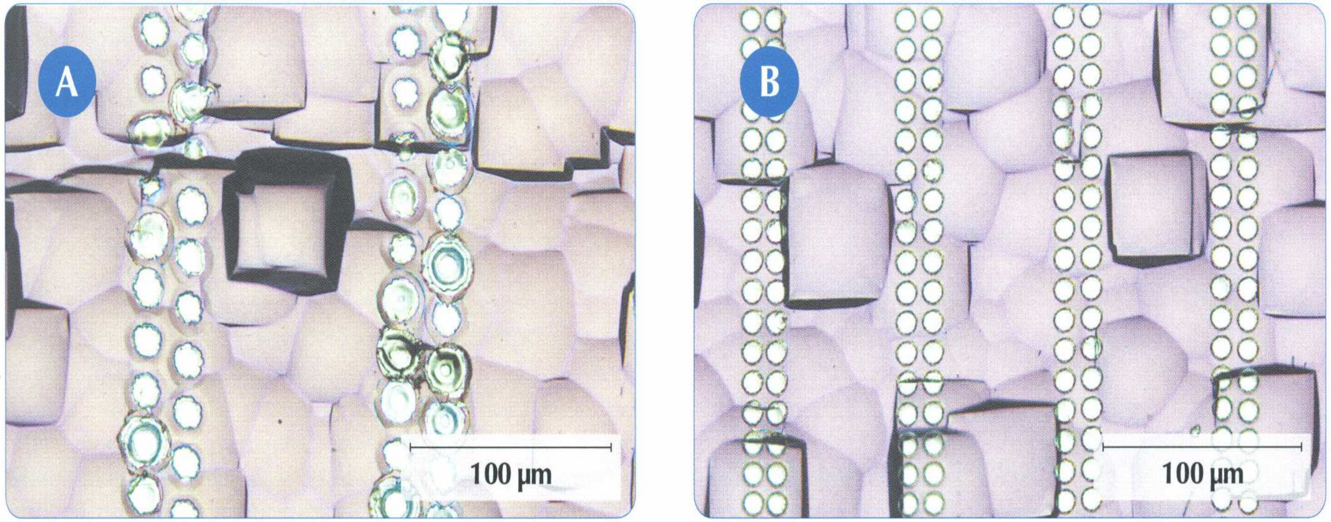
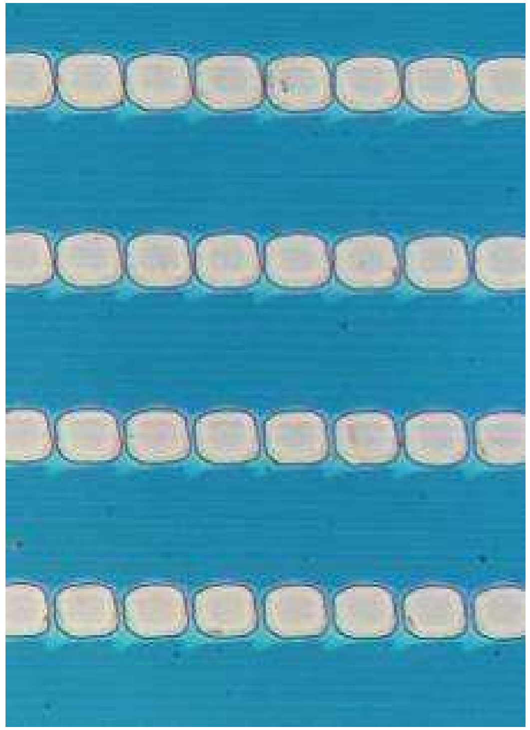


Abb. 27: Lichtmikroskopische Aufnahme einer mit SiO_2 bedeckten Siliciumoberfläche nach lokaler Laserablation mit Hilfe A) eines $Nd:YVO_4$ Lasers (λ=355 nm) mit einer Pulsdauer von ca. 30 ns und B) eines $Nd:YVO_4$ Ultrakurzpulslasers (λ=532 nm) mit einer Pulsdauer von ca. 10 ps.

Fig. 27: Light optical microscope picture of a SiO_2-covered silicon surface after local laser ablation using A) a $Nd:YVO_4$ laser (λ=355 nm) with a pulse duration of about 30 ns and B) a $Nd:YVO_4$ ultra-short pulse laser (λ=532 nm) with a pulse duration of about 10 ps.

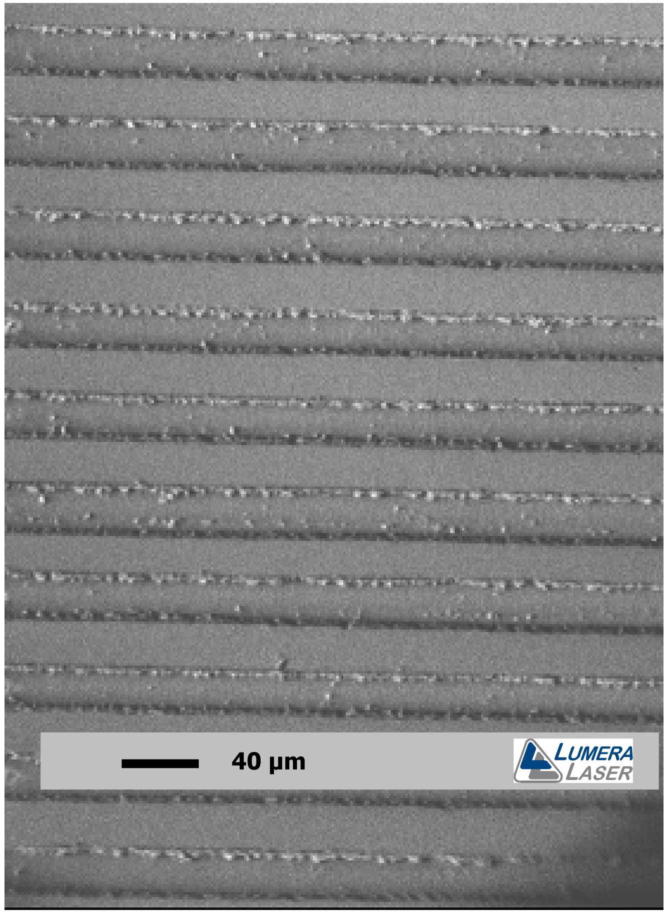


Source: ISFH

HYPER-RAPID: 1mio holes / s

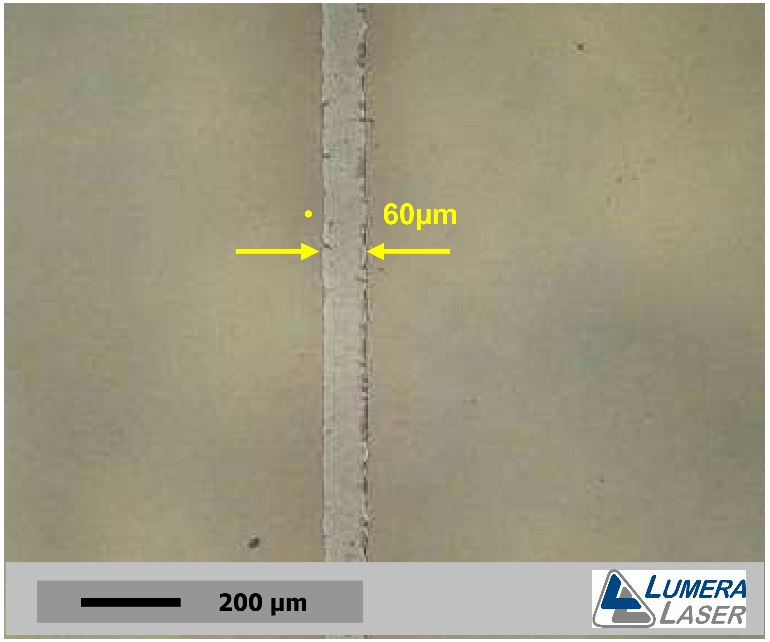
Transparent Conductive Oxide

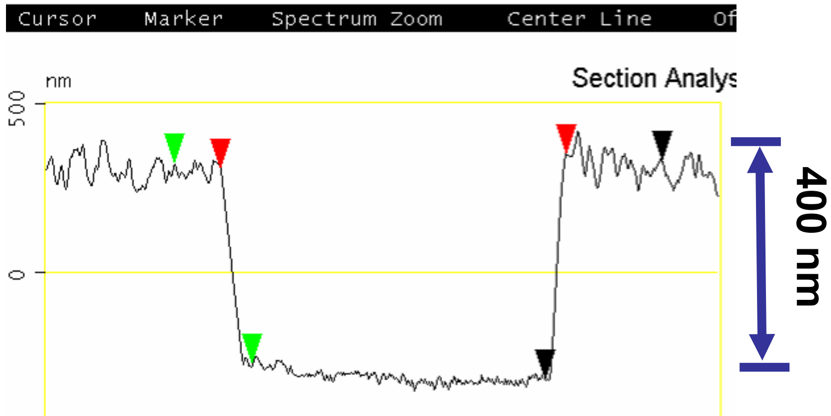
TCO on plastic



width=20µm
thickness: 500nm

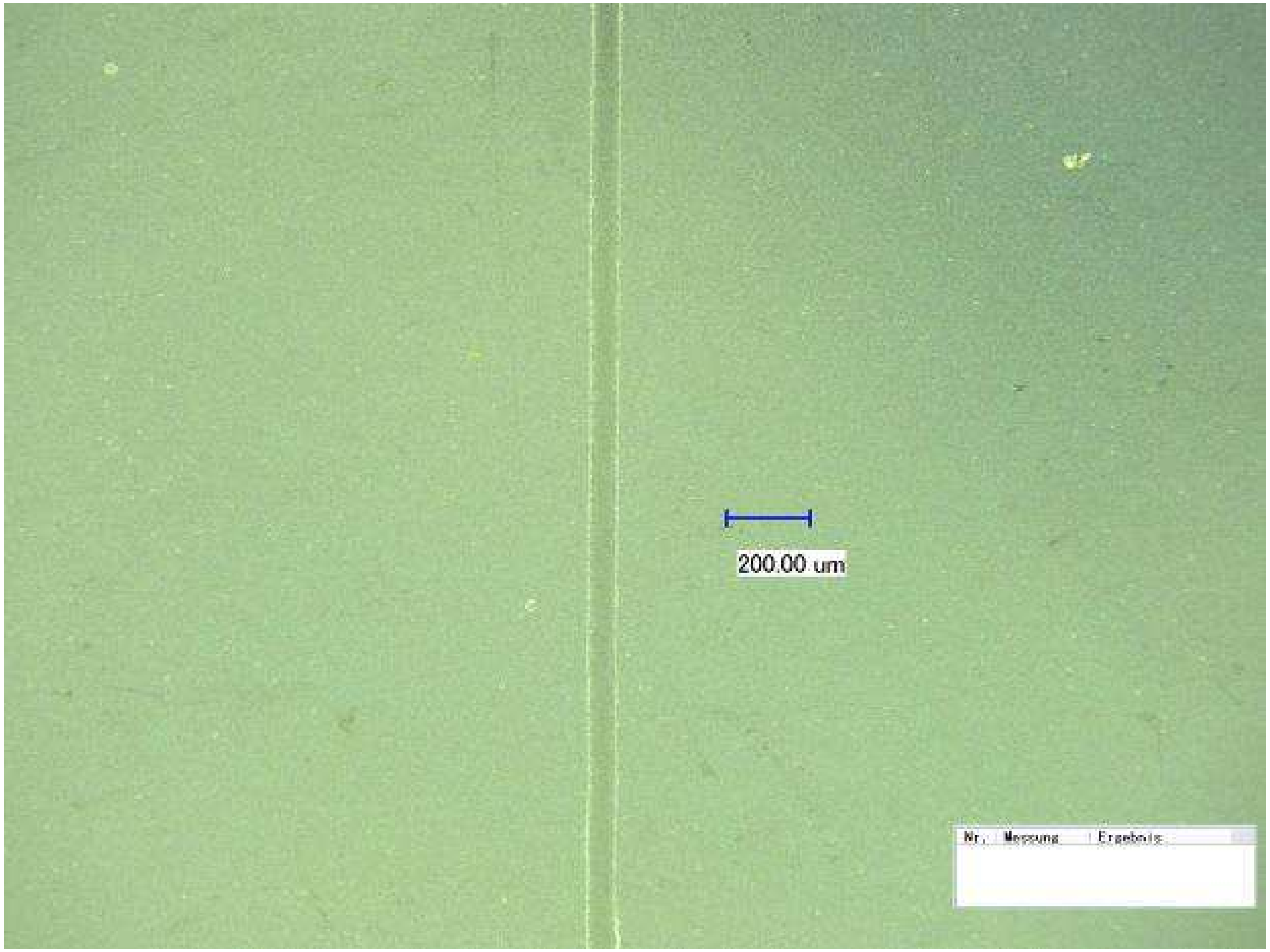
TCO on glass





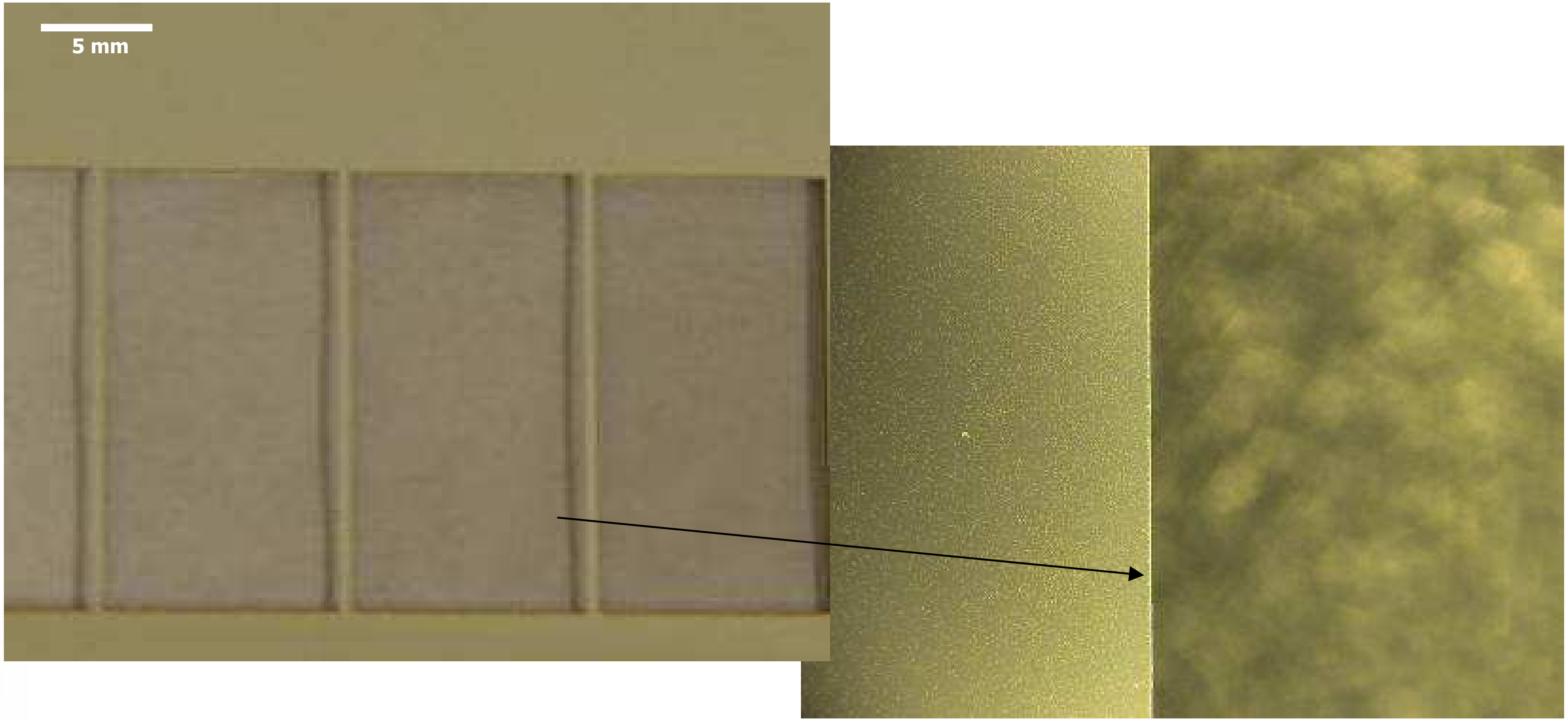
ITO removal on glass

lines 50µm wide, 200nm deep, >5m/s; HYPER RAPID 50, 1064nm



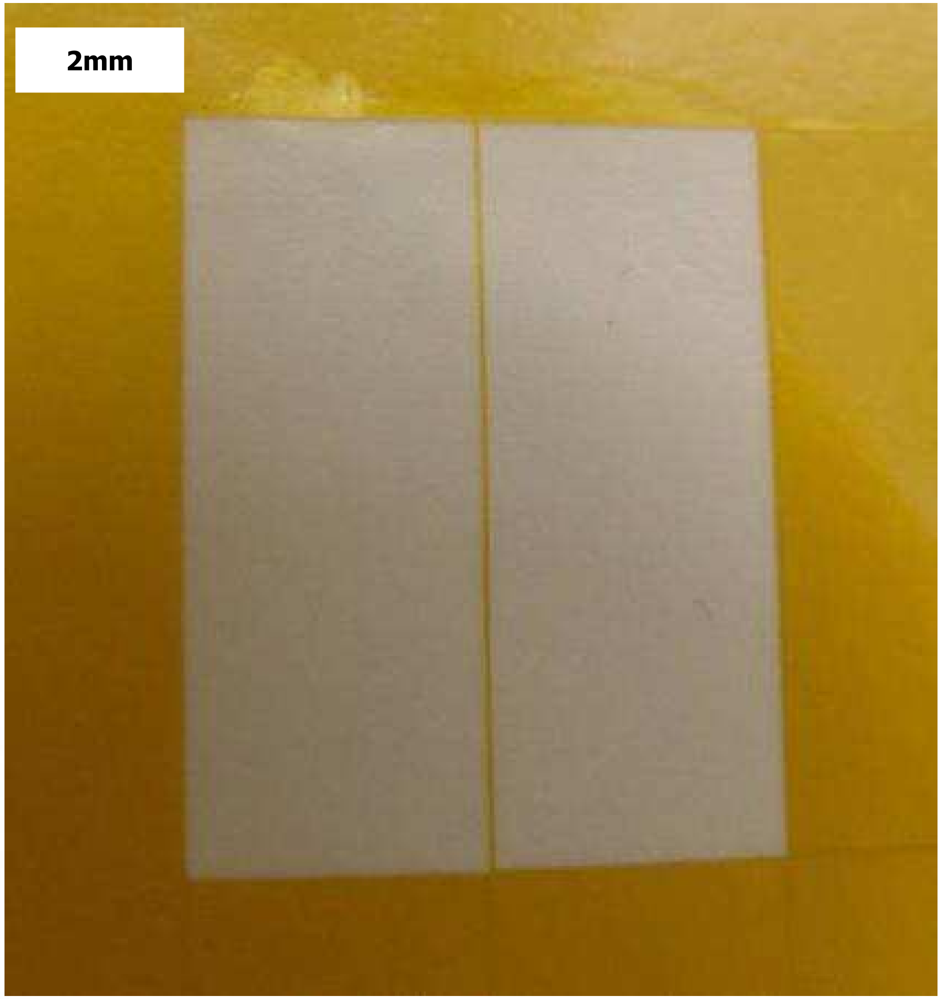
Removing metal layer on glass

200nm thick metal coating; 1cm²/s; RAPID, 1064nm

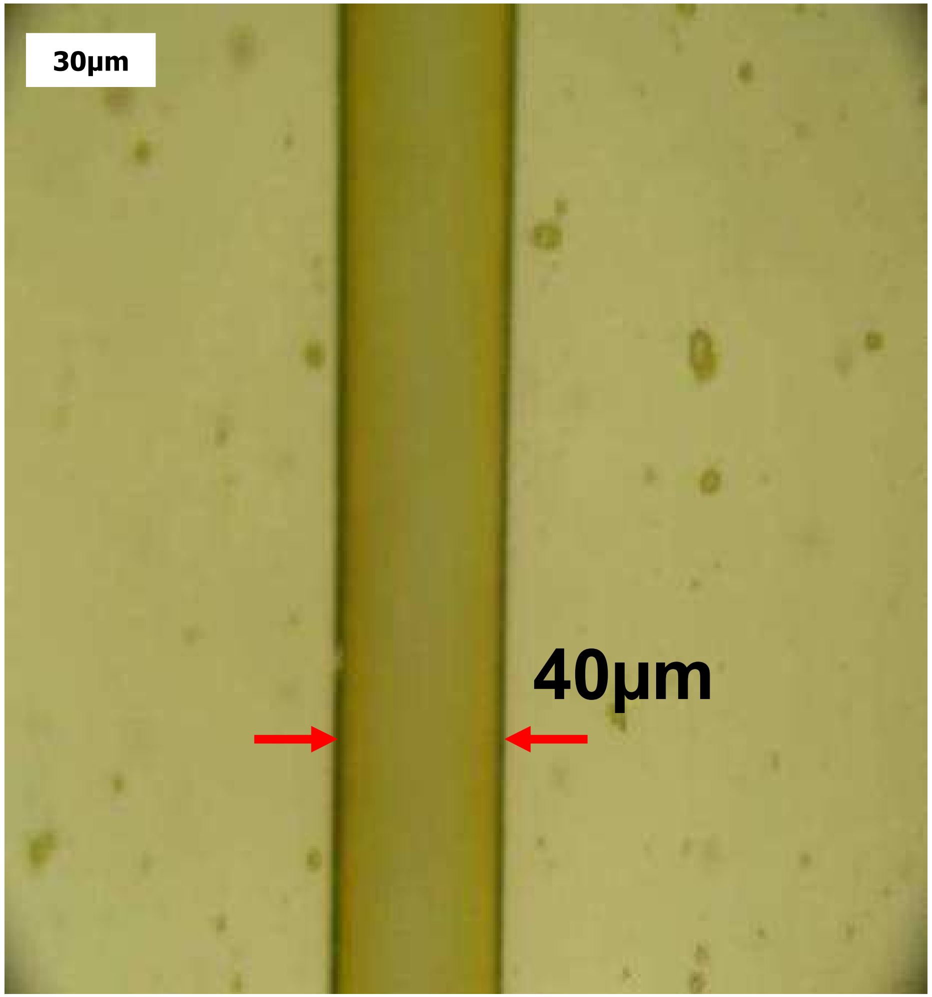


Capton

30µm capton on paper



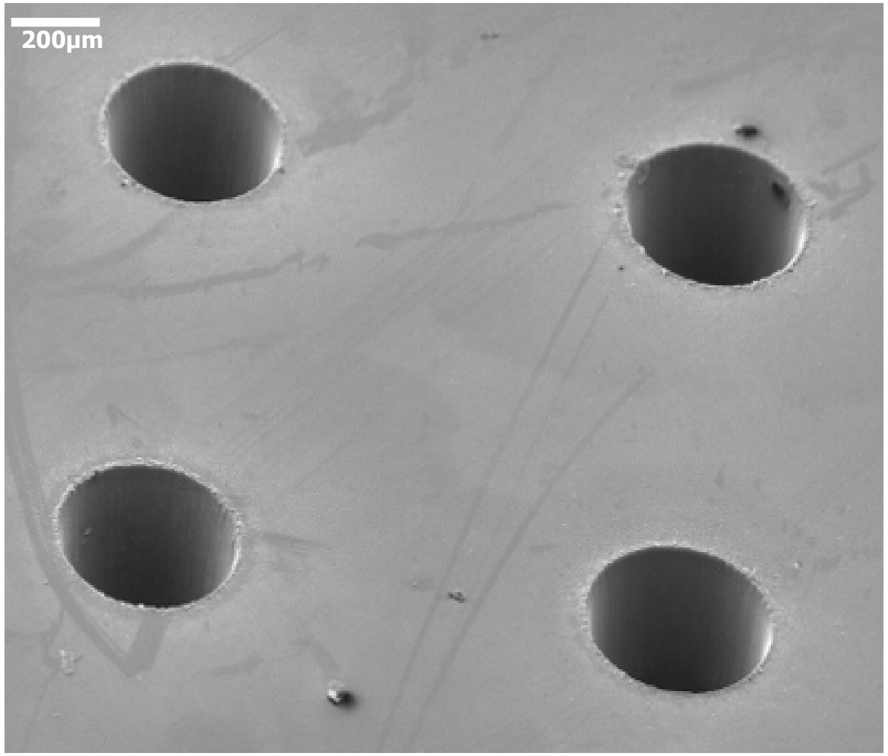
Grooves in capton



PET & Nylon

..thermally sensitive materials

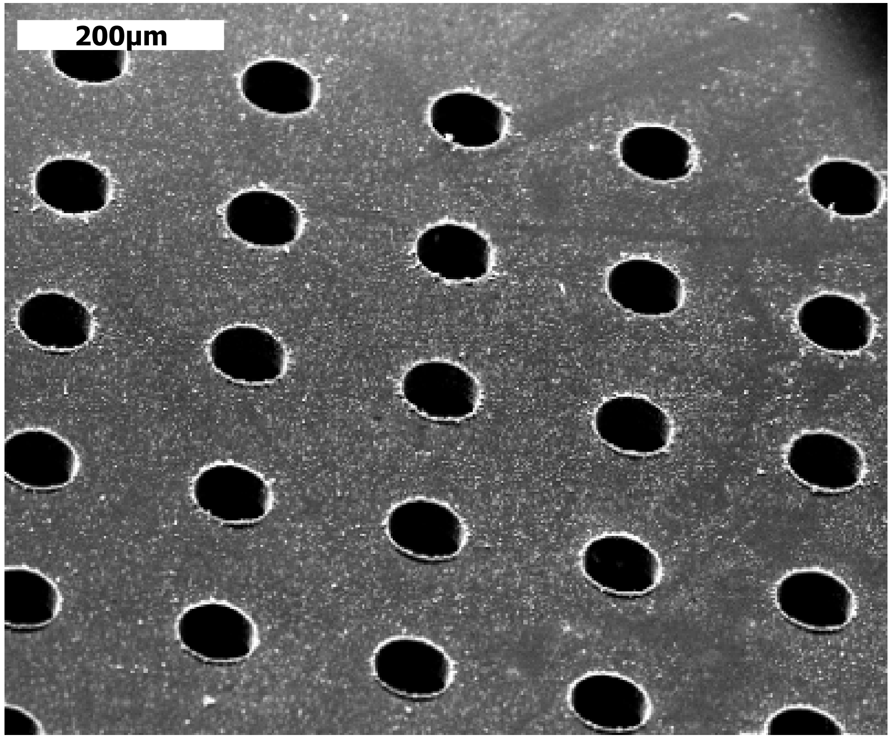
PET



Ø=250µm

thickness: 350µm

Nylon

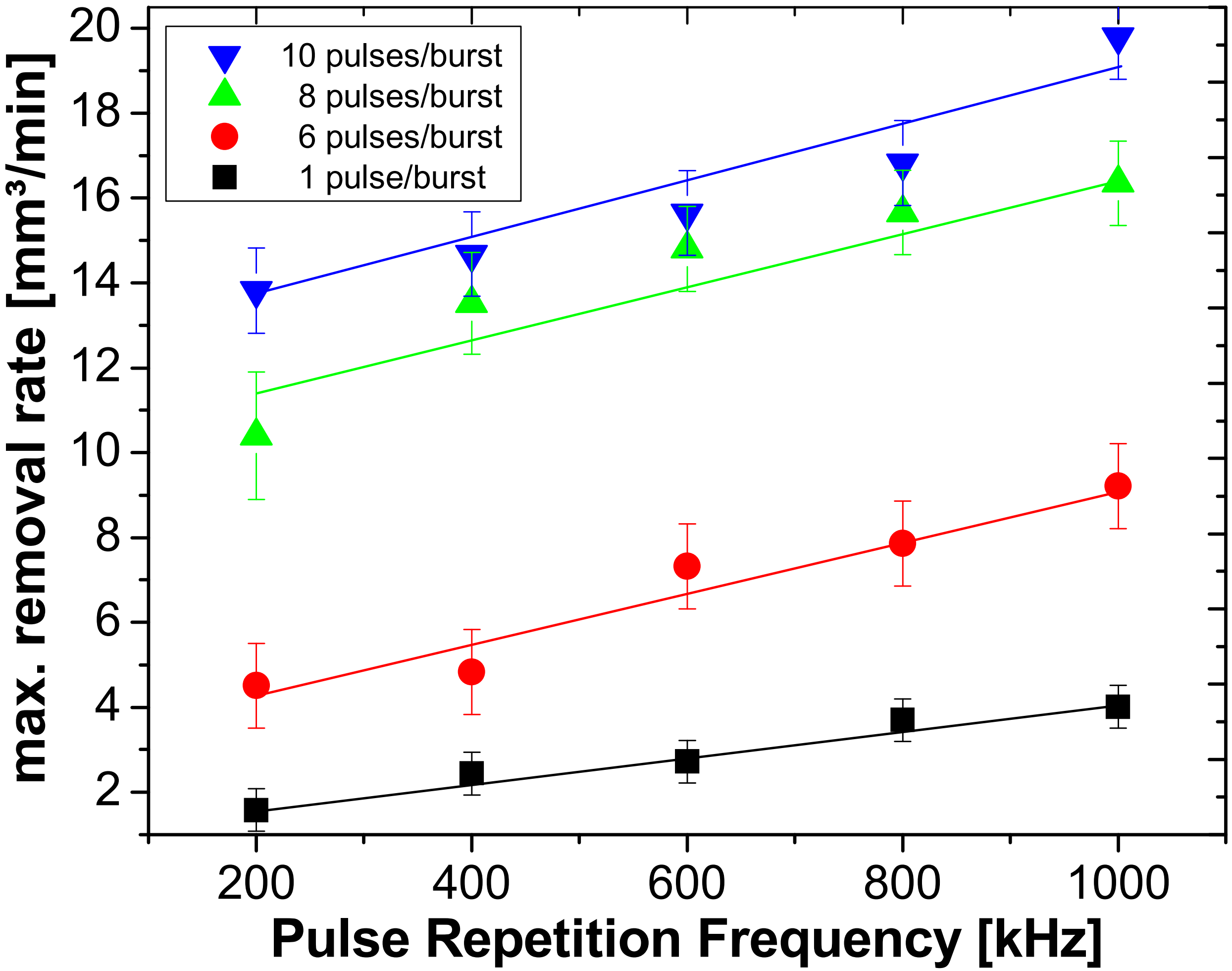


Ø=100µm

thickness: 50µm

Burst Machining of Tungsten Carbide

Hyper Rapid 50, 1064 nm, **constant average power of 50W @1MHz**

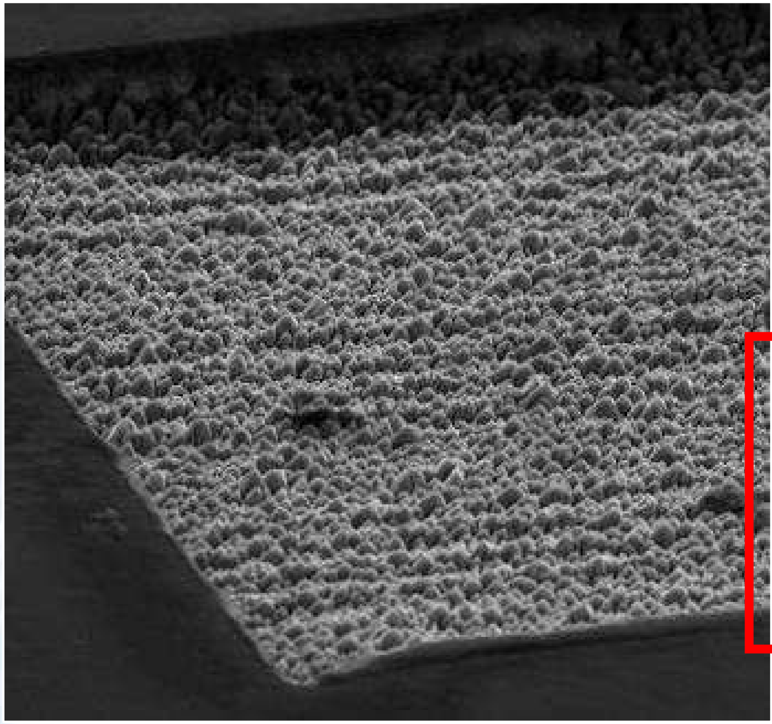


- **high rep. rate + burst: 14x removal rate**

Burst Mode: Quality

Burst moide increases removal rate & surface quality, e.g. on Si:

1 pulse

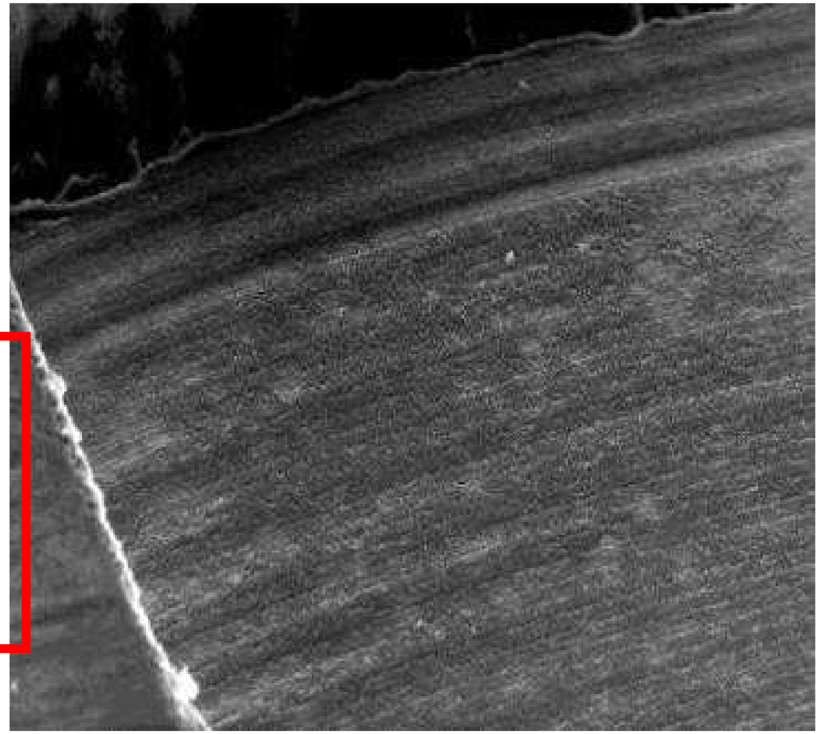


8x

→

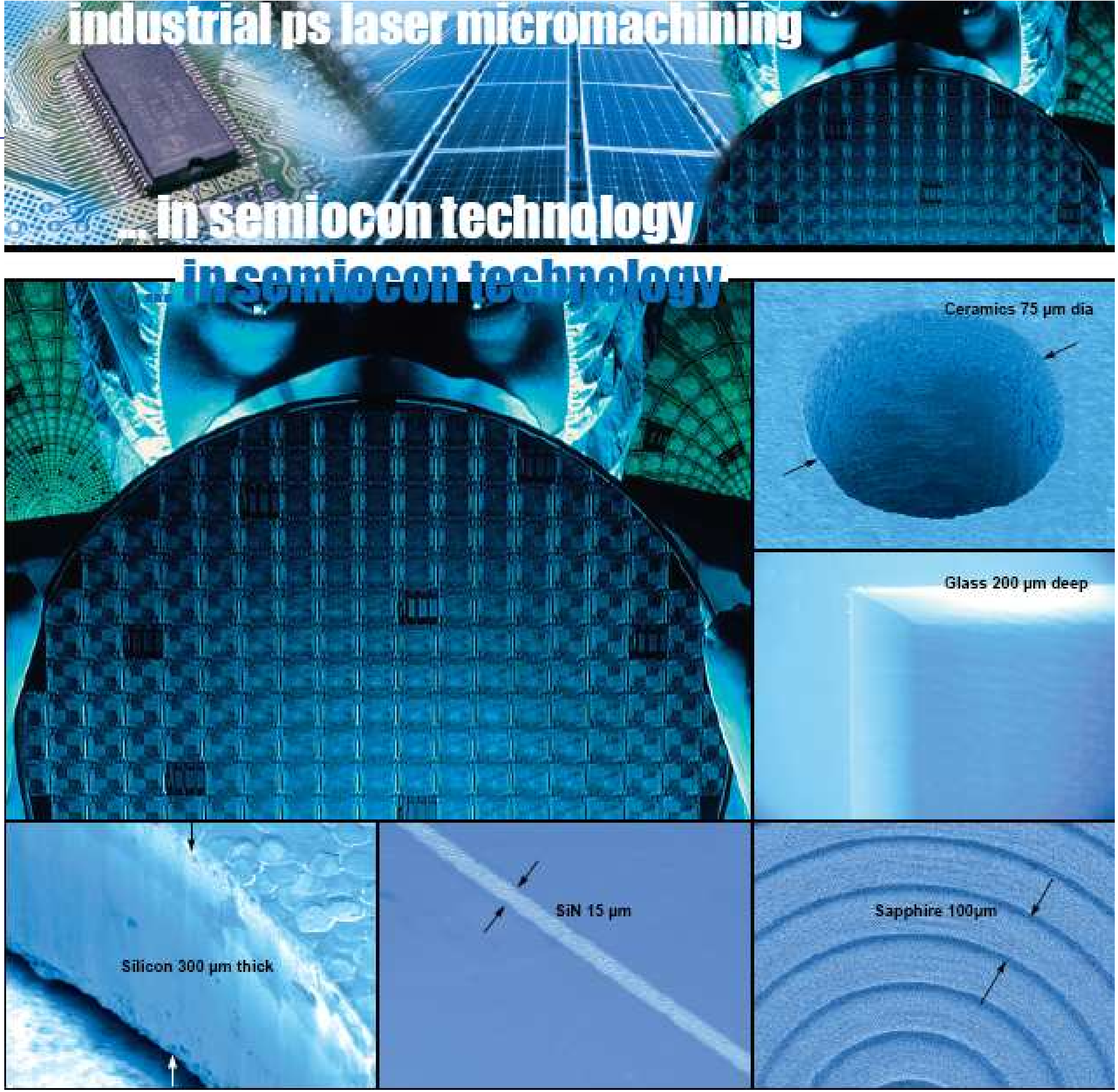
removal rate

5 pulses (20 ns separation)



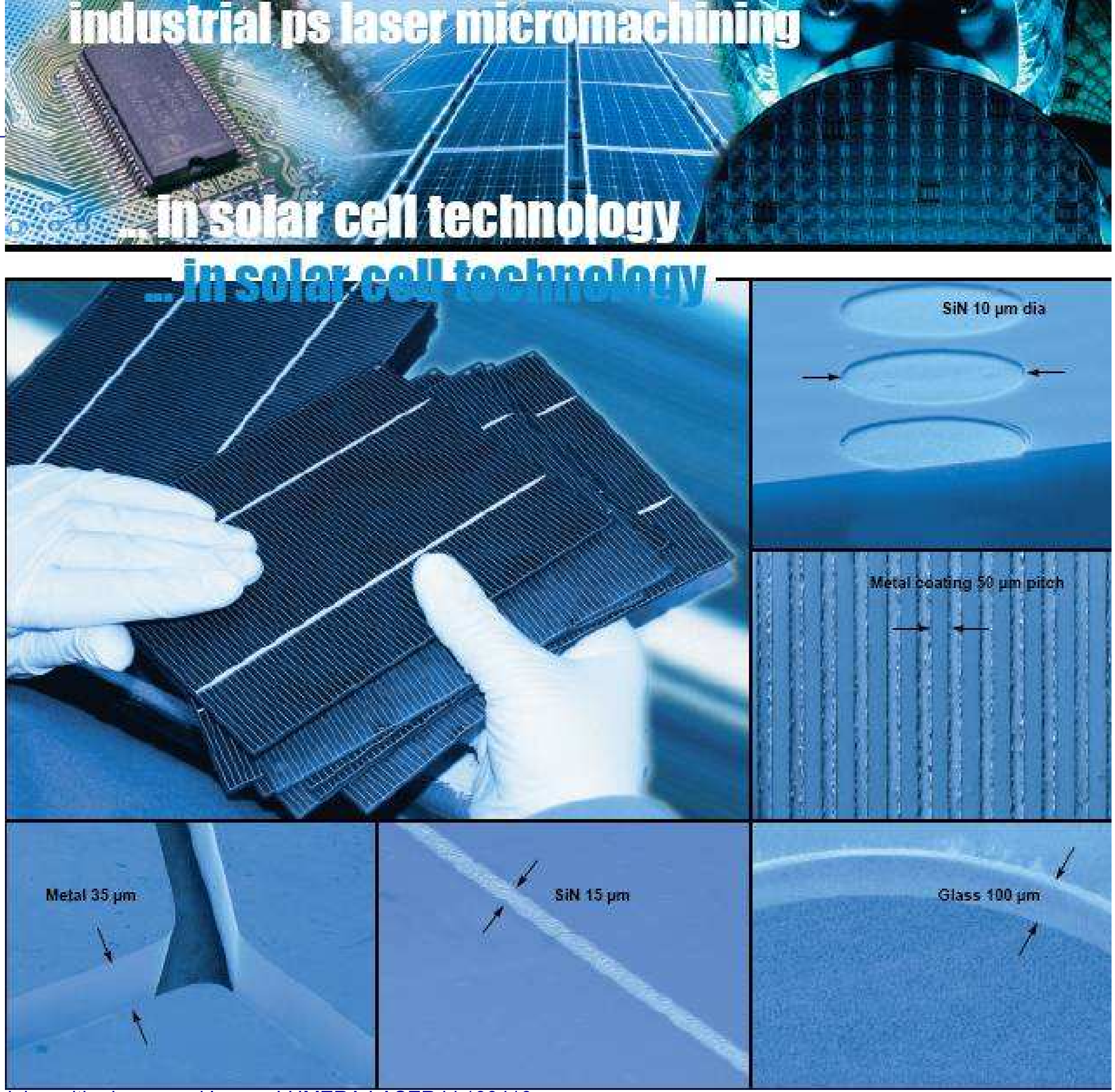
Applications and target industries

vias,
3D TSV,
MEMS
dicing,
memory
repair,
machining
difficult
materials
like
ceramics,
structuring
organic
coatings

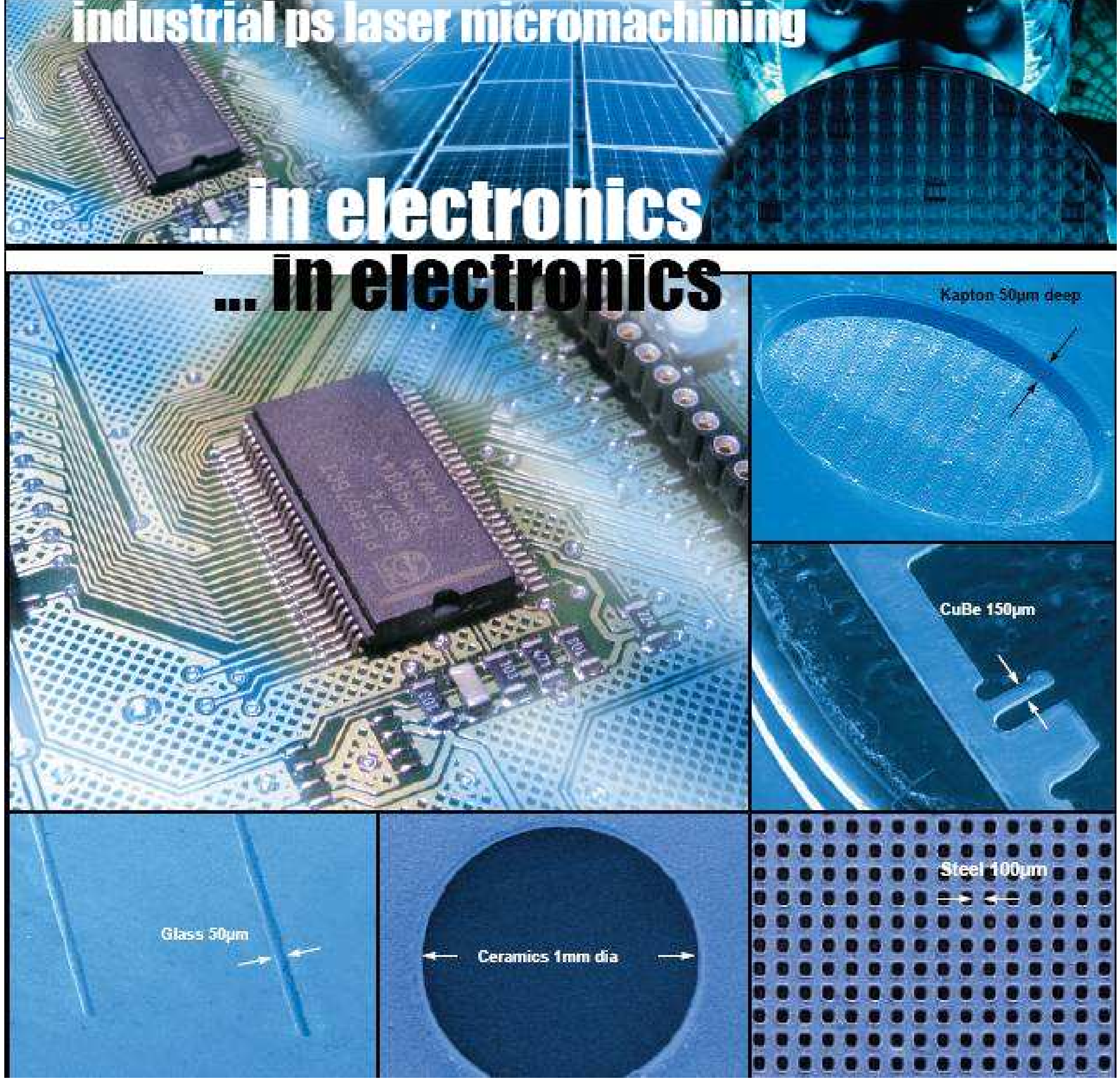


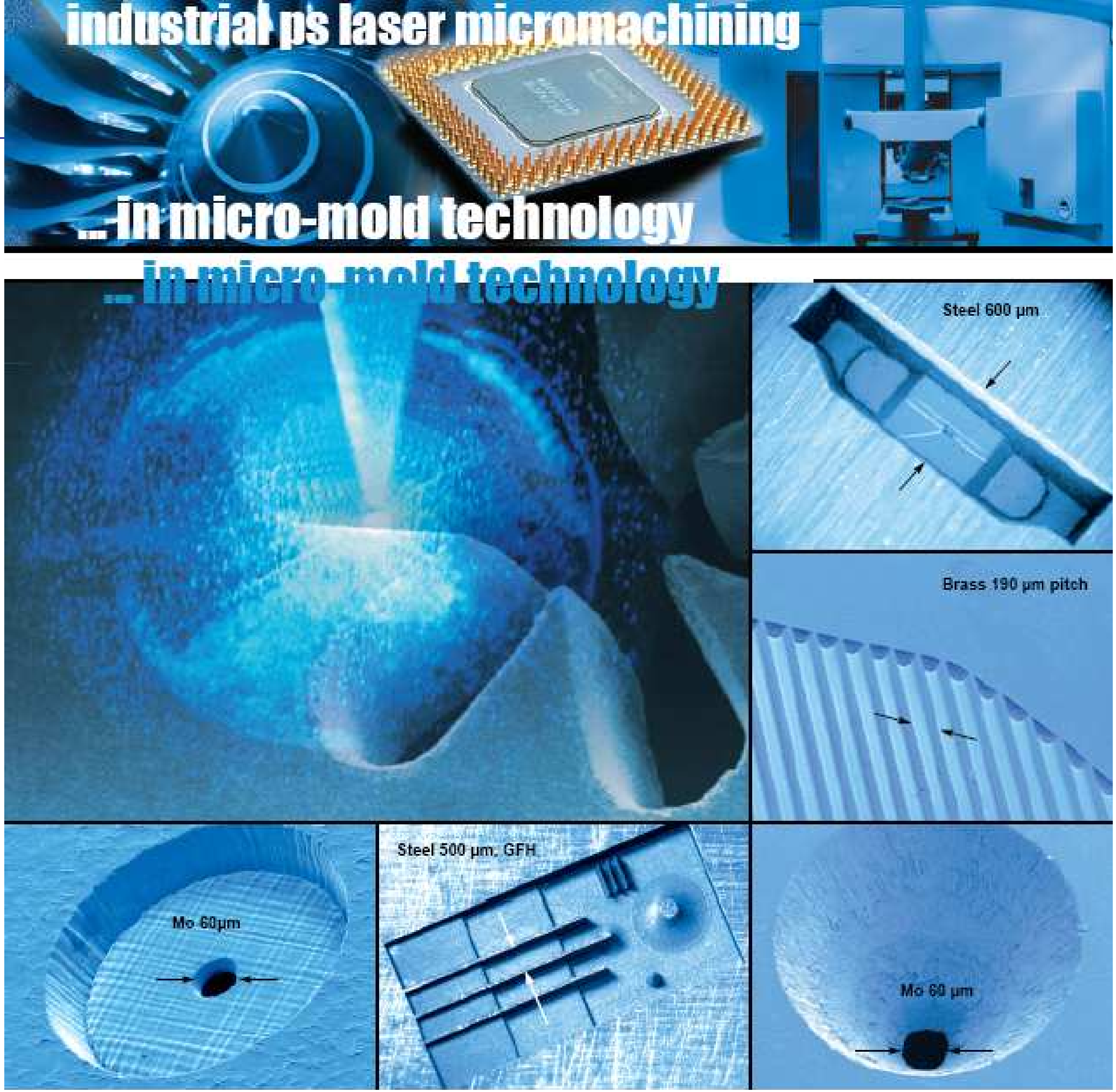
scribing or welding glass, structuring and repairing masks, structuring ITO/AZO and similar coatings

ablation of dielectric coatings, doping selective emitters direct writing, drilling vias, EWT-holes, cutting thin material



via drilling, cutting flex boards, trimming organics, micro-parts like apertures

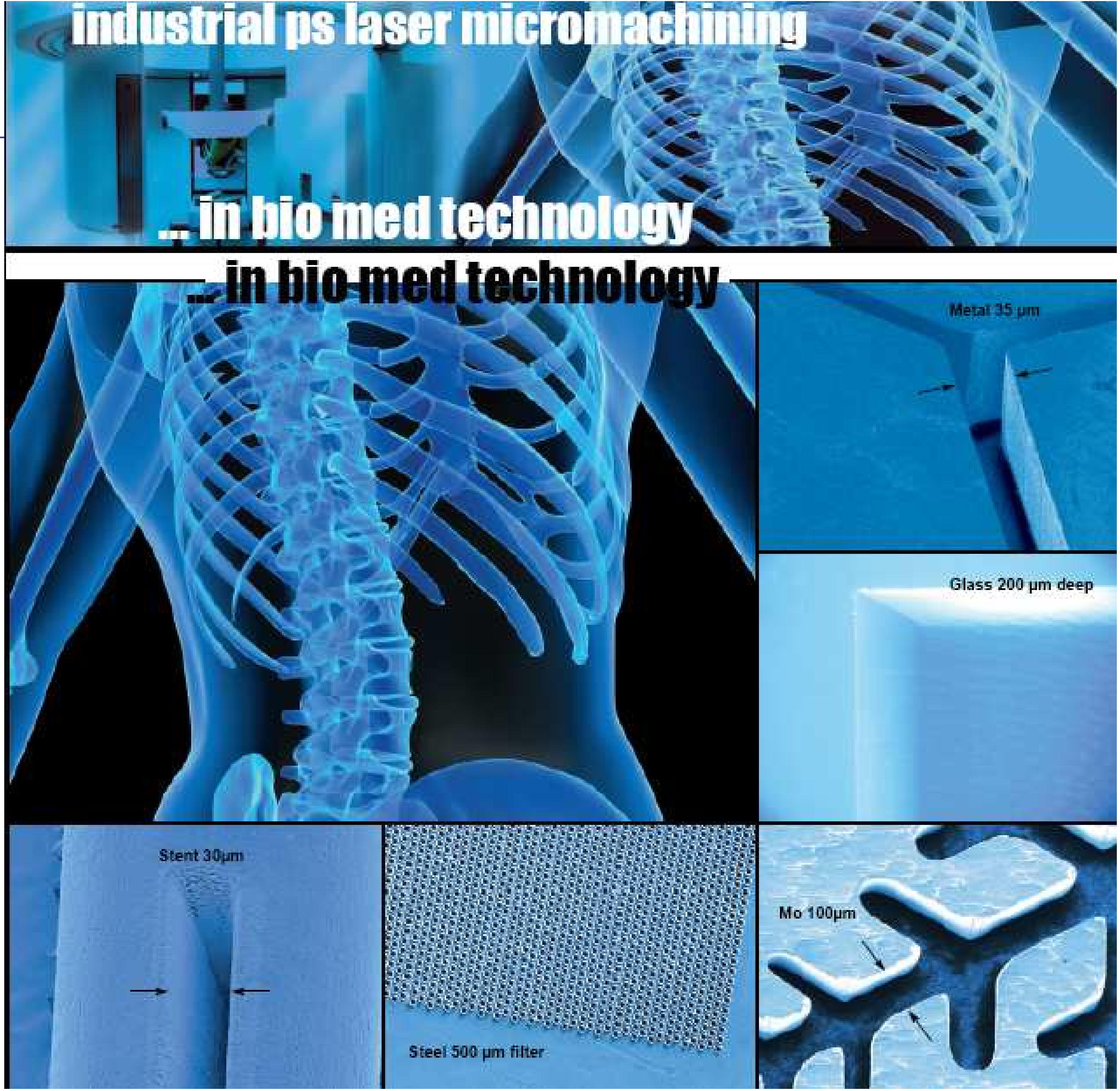




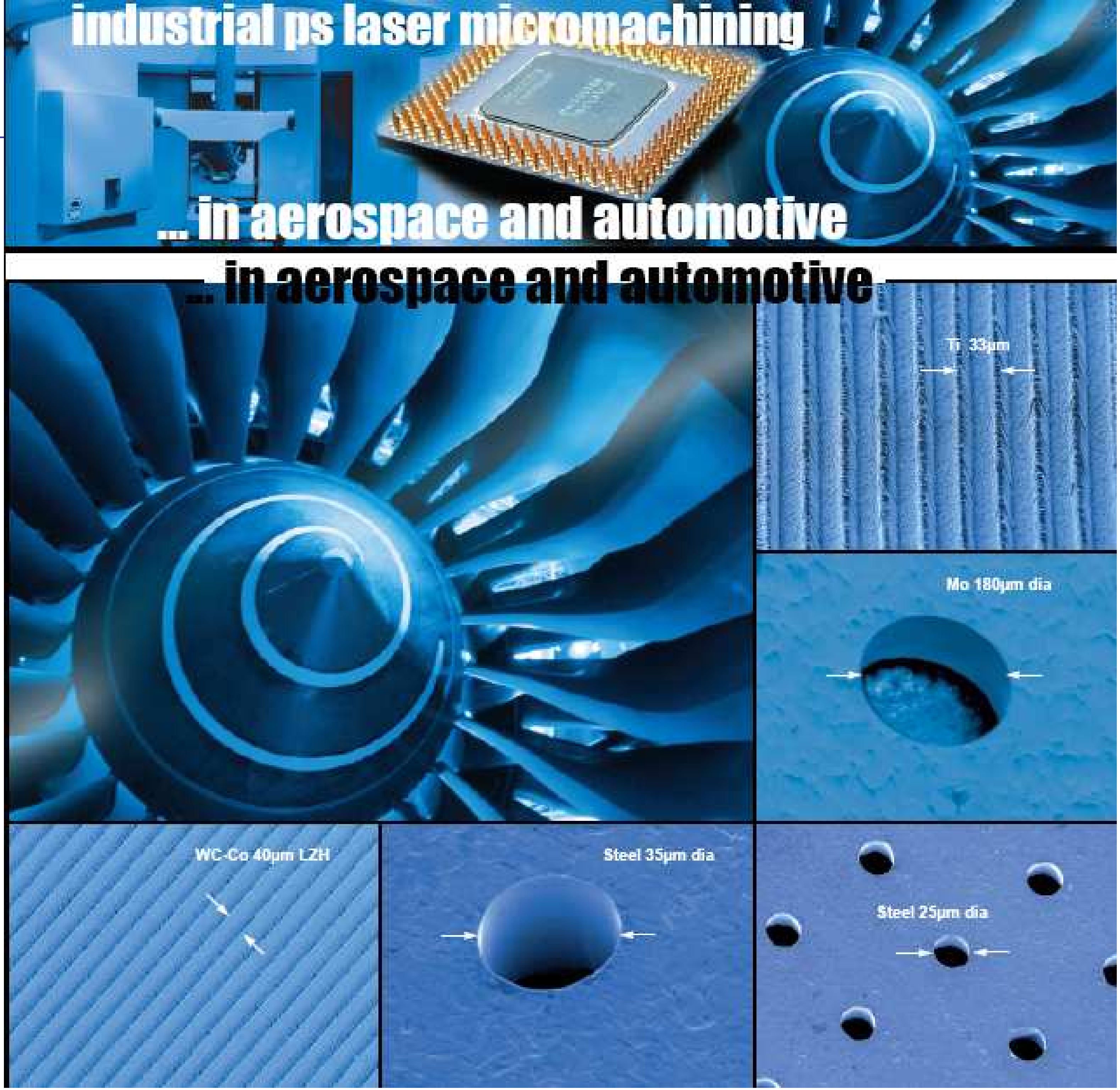
tough materials, just in time from CAD,

~10nm depth control, ~µm lateral resolution, 2.5D structures

stents,
filters,
lab-on-the-chip,
micro-implants,
surgical tools,
implant surface structures



holes, injection nozzles, grooves for friction reduction, machining tough brittle materials



Company status

- **Ownership:** founded 2000, since Aug. 2008 part of Aton group (~3 bil $)
- **Personnel:** ~60 +
- **Facility:** ~3000 m²; ~400 m² clean room; Application Lab, Job shop

- **Patents:** 8 Patent-Families, nat./ internat. (high RR EOM; 888nm pumping)

- **ISO 9001:** 2007

Company Status

- **Product:** industrial ps-laser RAPID series
  industrial ns-laser BLASE series
- **Net work:** global net of sales and service reps
- **Experience:** ~ 300 ps-lasers built

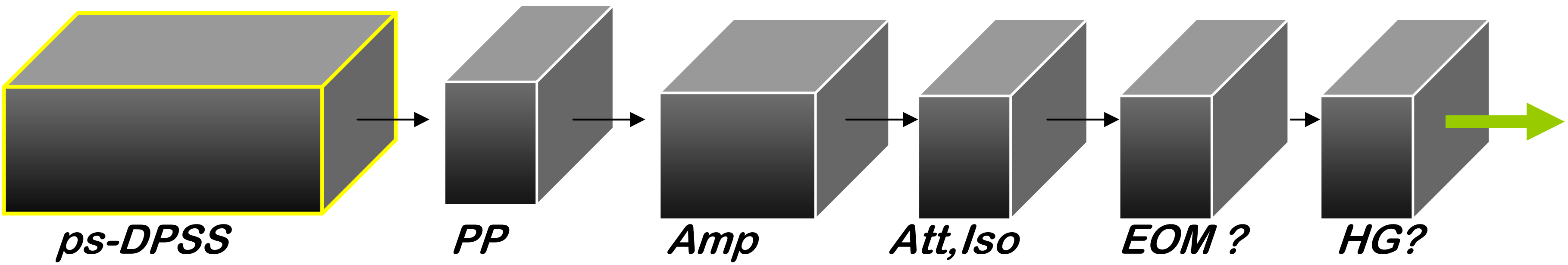
  ~ 7 mio h of operation

  ~ 700 samples processed

Products:

RAPID series of industrial ps-lasers

ps-laser RAPID series



Mode-locked seed laser: 50 MHz pulses, ~ 0.1 µJ

Pulse Picker: Picks 1 pulse (or more in burst mode) out of e.g. 100 pulses at 500 kHz

Transient amplifier: amplifies pulse energy up to ~ 200 µJ

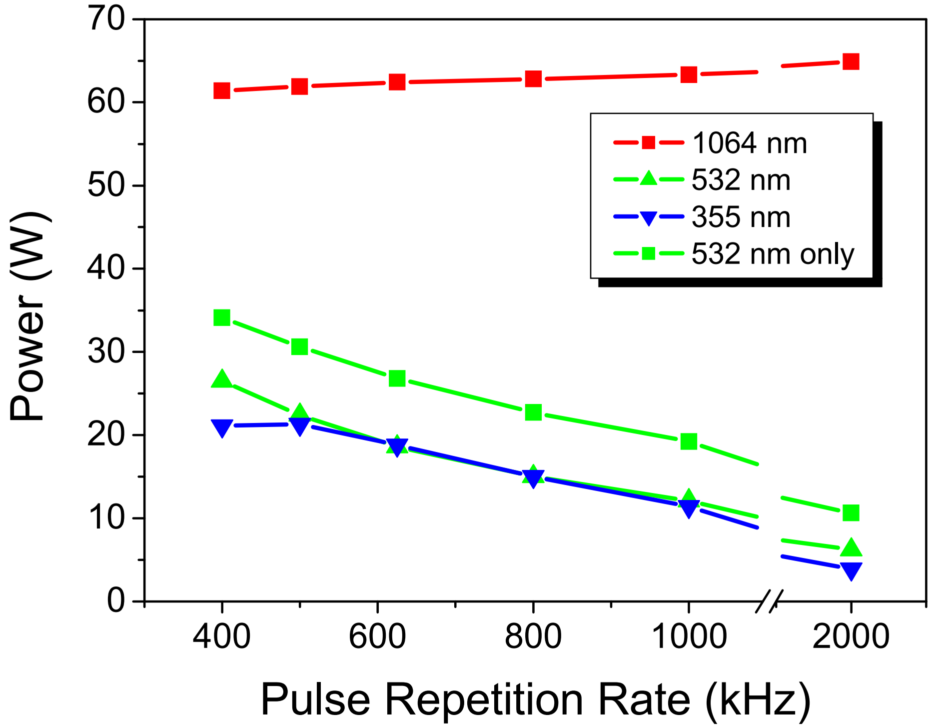
Attenuator, Isolator

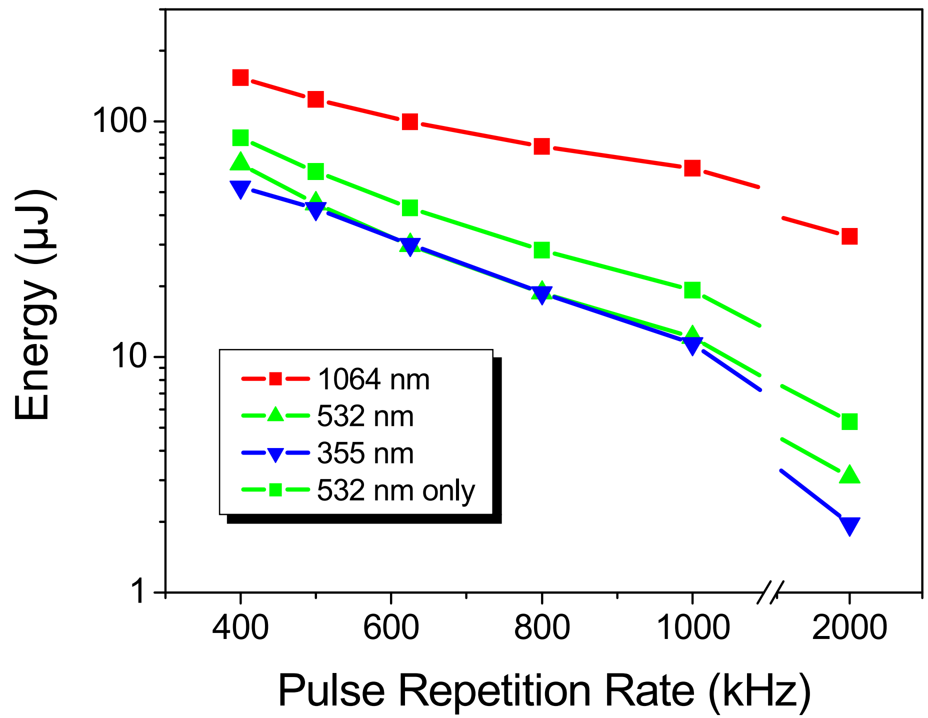
Option: External EOM Pulse Picker

Option: Harmonic Generator: converts IR pulses to green and UV 532nm, 355nm (266nm); with 0-air generator

HYPER RAPID 50

typical data





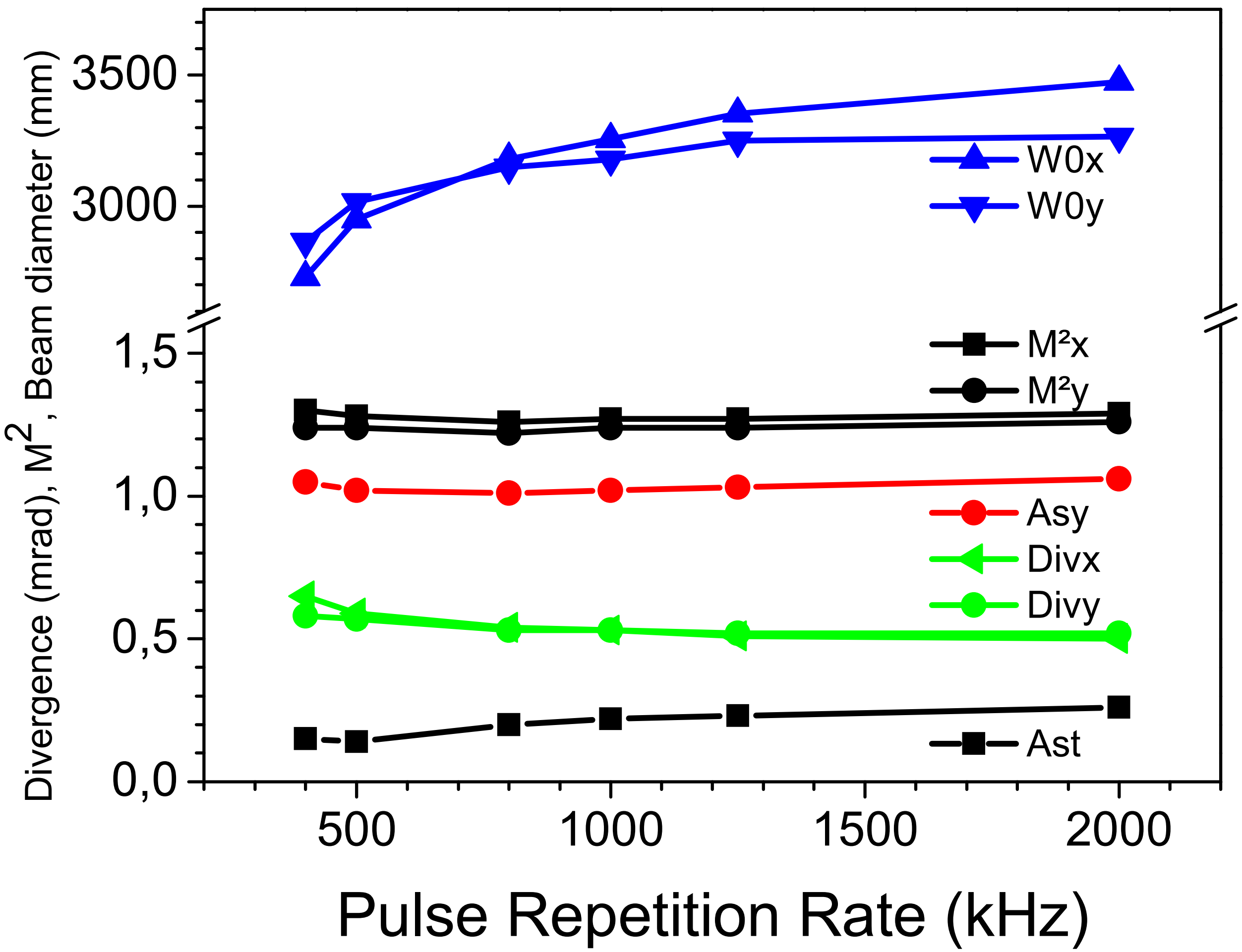
PRF: 400 – 1000 kHz (opt. 2MHz), E: 125 – 50 μJ; $M^2<1.5$

1064 nm: 50 W @ 1 MHz

532 nm: 25 W @ 400 kHz

355 nm: 16 W @ 400 kHz

HYPER RAPID 50



Beam diameter

M²

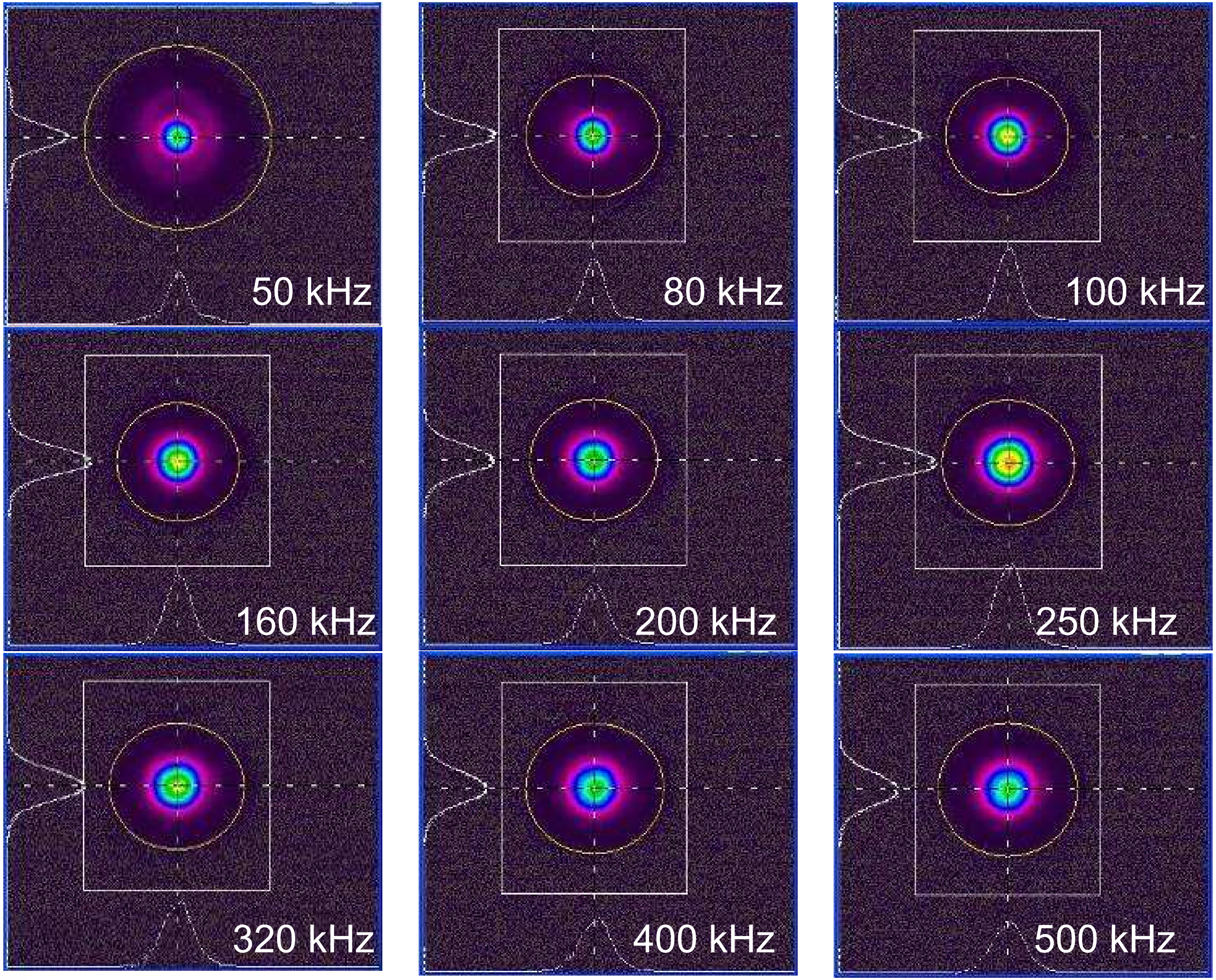
Asymmetrie

Divergence

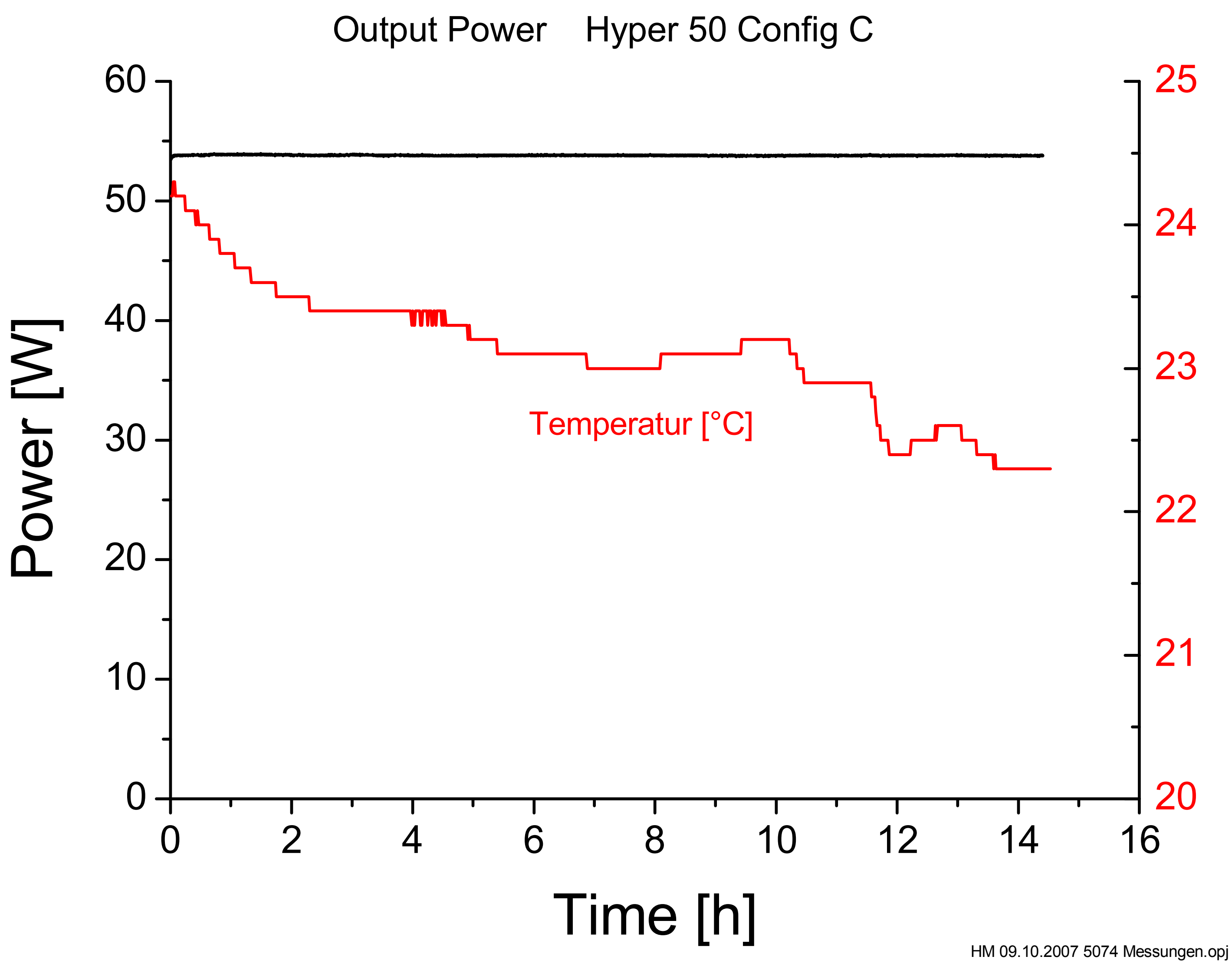
Asigmatism

⇨ **almost ideal beam with low variance vs. PRF**

Mode profile vs PRF



HYPER RAPID 50 : P vs T



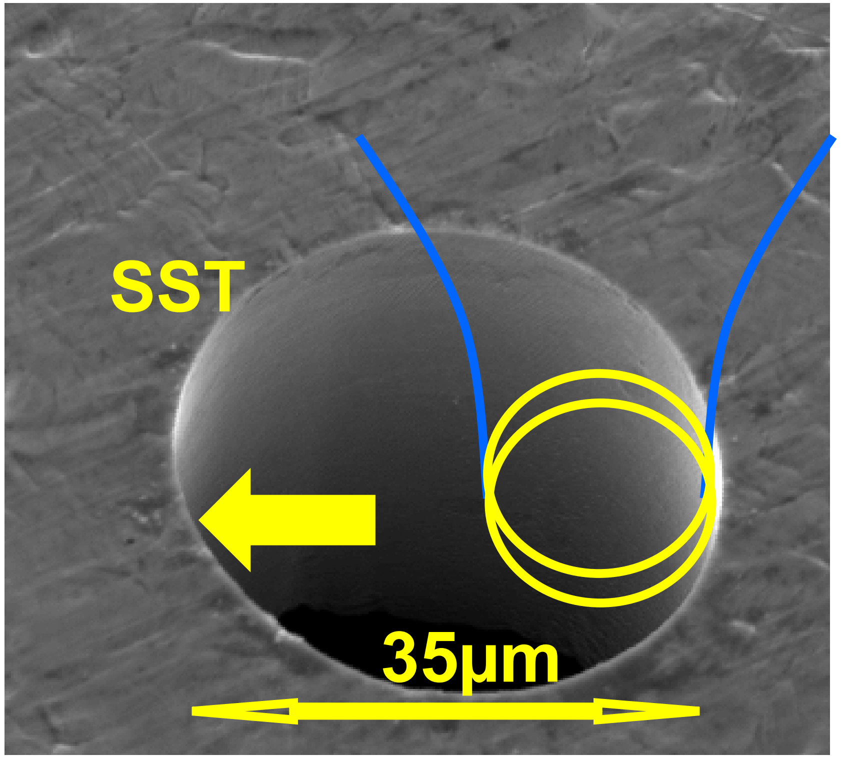
micro machining with ps-laser!

REMEMBER:

1. high resolution
2. high quality
3. any material, same universal laser
4. high removal rate:

   up to 60mm³/min with 50W, with high RR up to 2MHz , with burst-mode
5. low TCO

   in 24-7-use ~0.2€/min



Resolution

z: ~10-100nm / pulse

x, y : <µm

THANK YOU

FOR YOUR ATTENTION!

www.LUMERA-LASER.com

Klimt@LUMERA-LASER.com