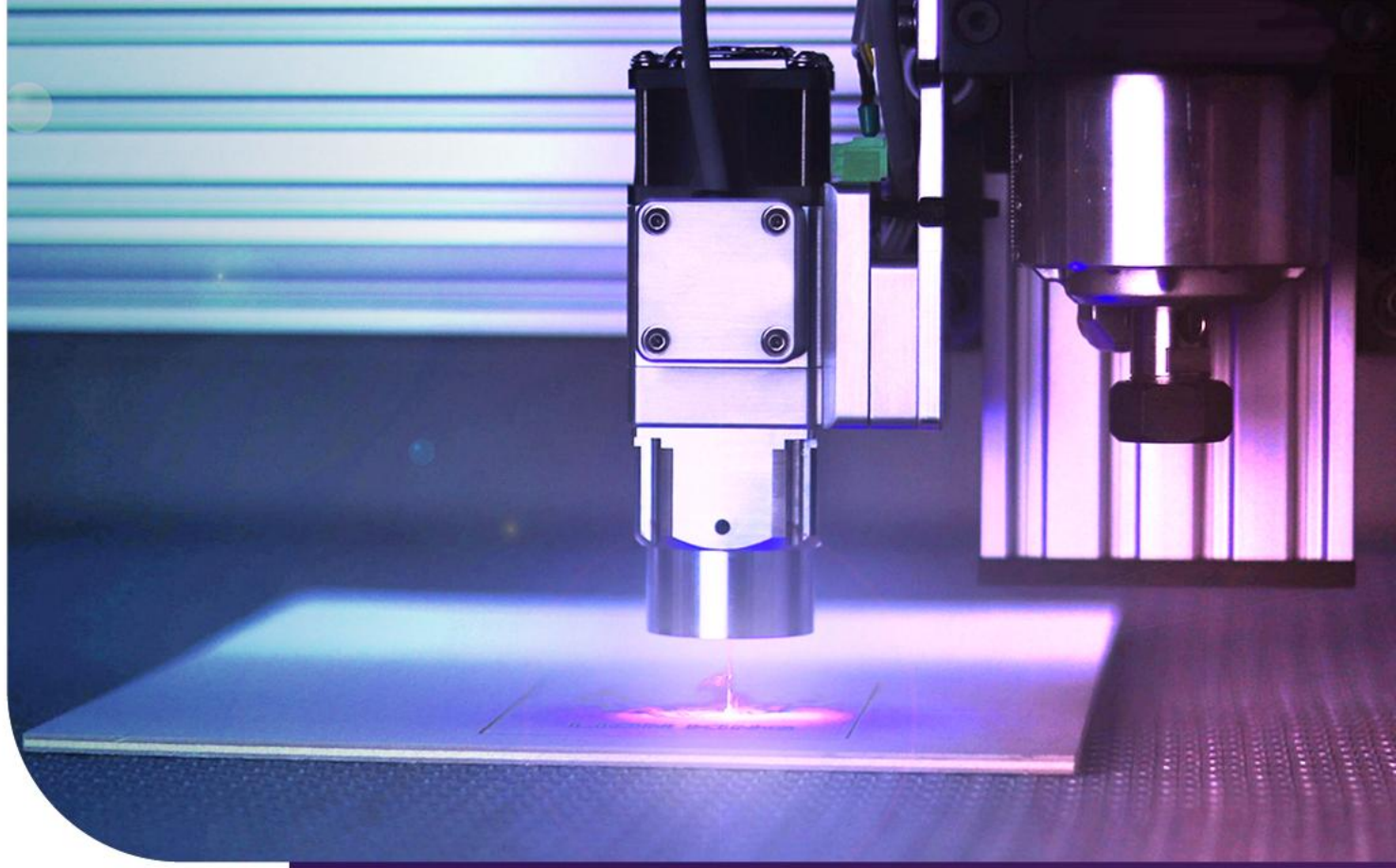
FLASH

Flexible Laser-Based Manufacturing



Introduction to Laser MircoJet® Technology

Jonathan Wood - Synova

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INDEX

- Introduction to Synova
- Laser MicroJet Technology
- Optics and Sensors
- Laser MicroJet® vs. Competing technologies
- Applications & Case Studies

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Introduction to Synova

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Introduction – Welcome to Synova SA

Headquarters

Our team in Duillier

Assembly hall

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Introduction – A Global Company

28

Years of experience in laser-machining

> 500

LMJ machines installed worldwide

40

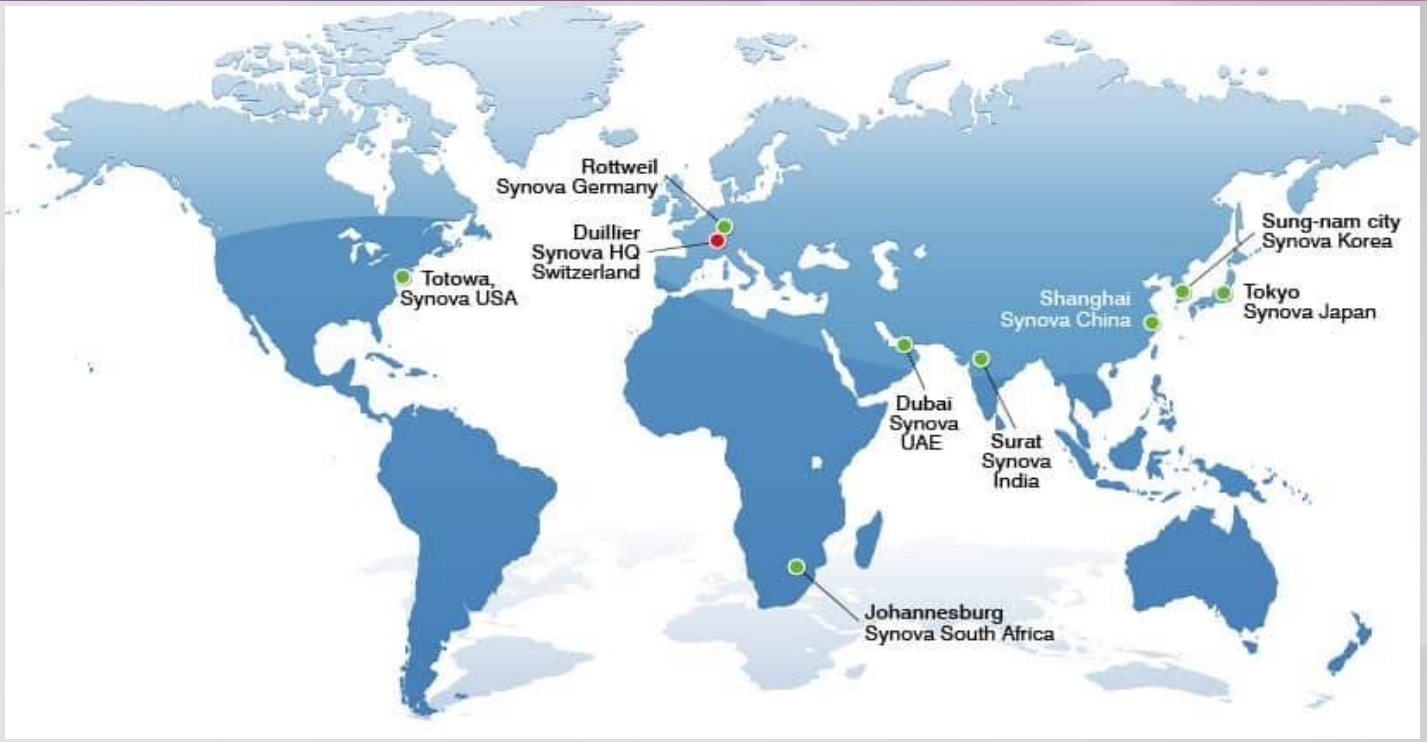
Million CHF invested in R&D

8

Global LMJ competence center

> 150

Patents



Headquarters in Switzerland

140 employees globally

Over 40 engineers

Production in Switzerland

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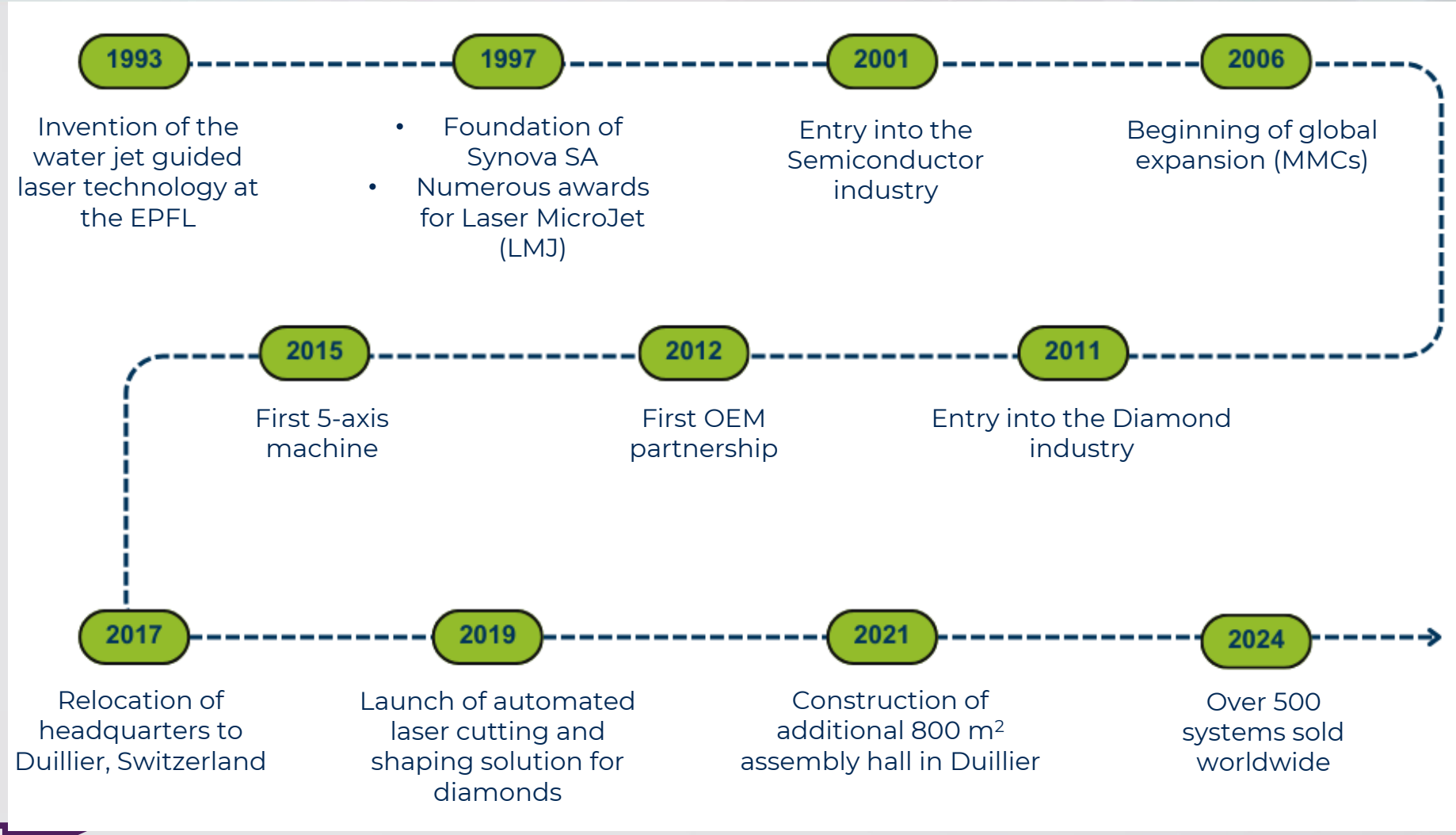
Introduction – History of Synonva SA



Introduction – History of Synonva SA

1993 → **1997** → **2001** → **2010** → **2015** → **2025**

Invention of the water jet guided laser technology at the EPFL

Foundation of Synova SA

Entry into the Semiconductor industry

Entry into the Diamond industry

Second generation of machine with 5 axis machine

Over 500 systems sold worldwide

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Laser MicroJet Technology

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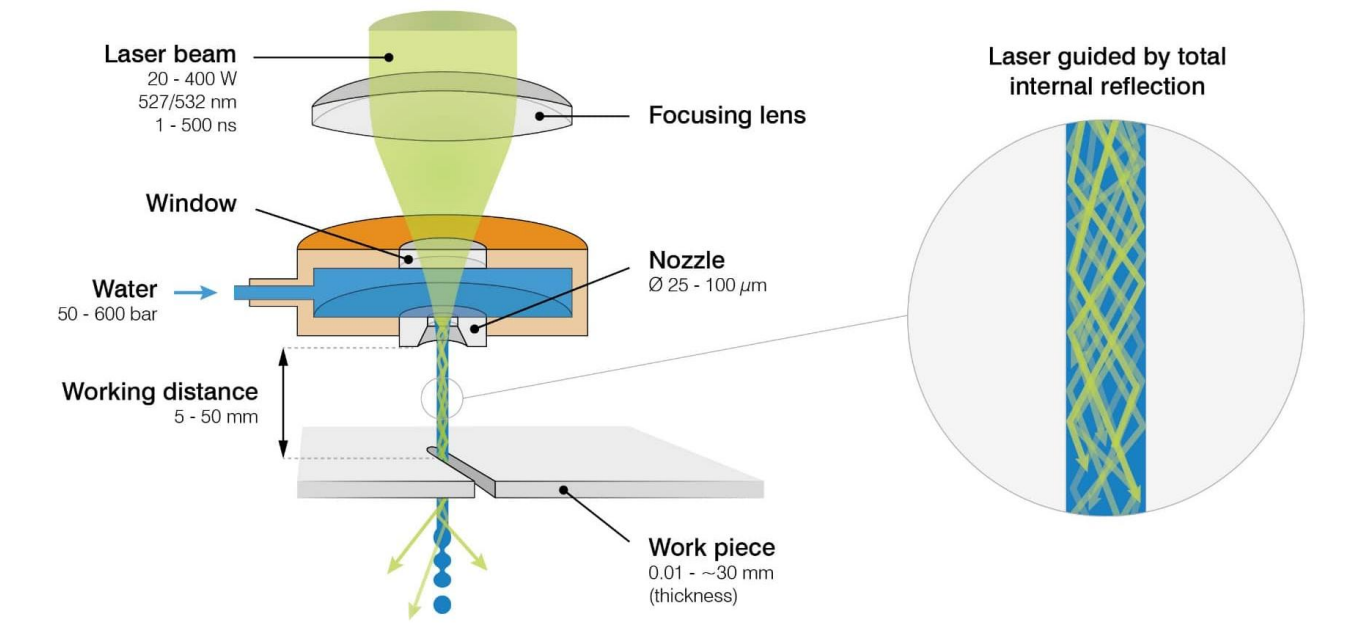
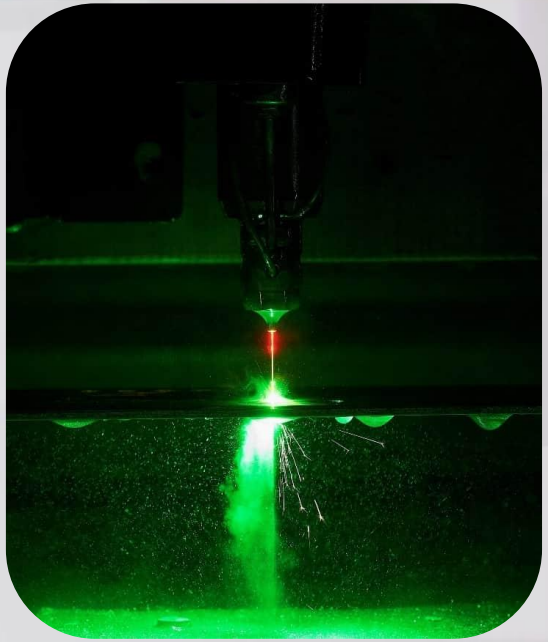
The Laser MicroJet® Technology





- Hybrid method of machining which combines a green laser with a “hair-thin” water jet.
- The water jet precisely guides the green laser beam by means of total internal reflection.
- The LMJ solves all drawbacks of conventional high-power lasers and has several technological advantages

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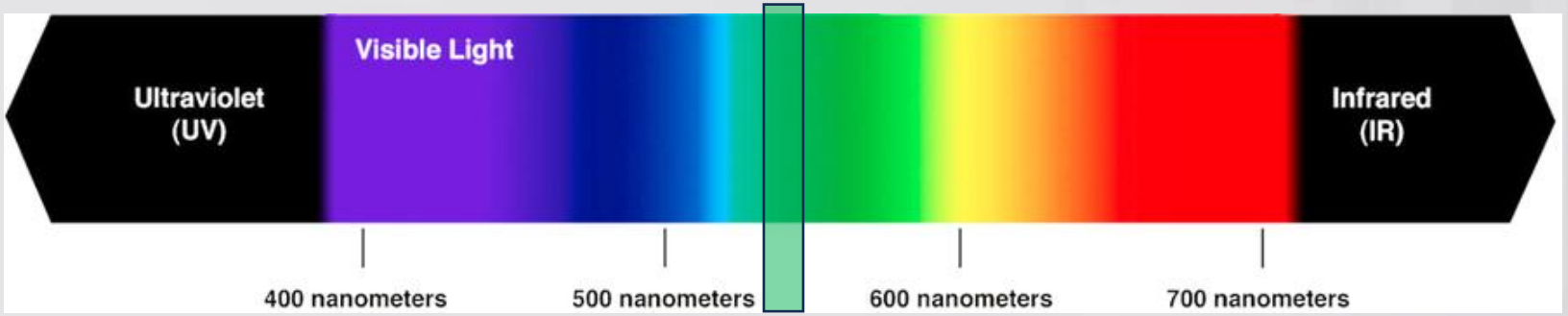
Why green laser light?

- The wavelength is the “colour” of the laser and corresponds to the energy of a photon.



Lasers in Synova have a wavelength of 515, 527 or 532 nm

Water absorption spectrum

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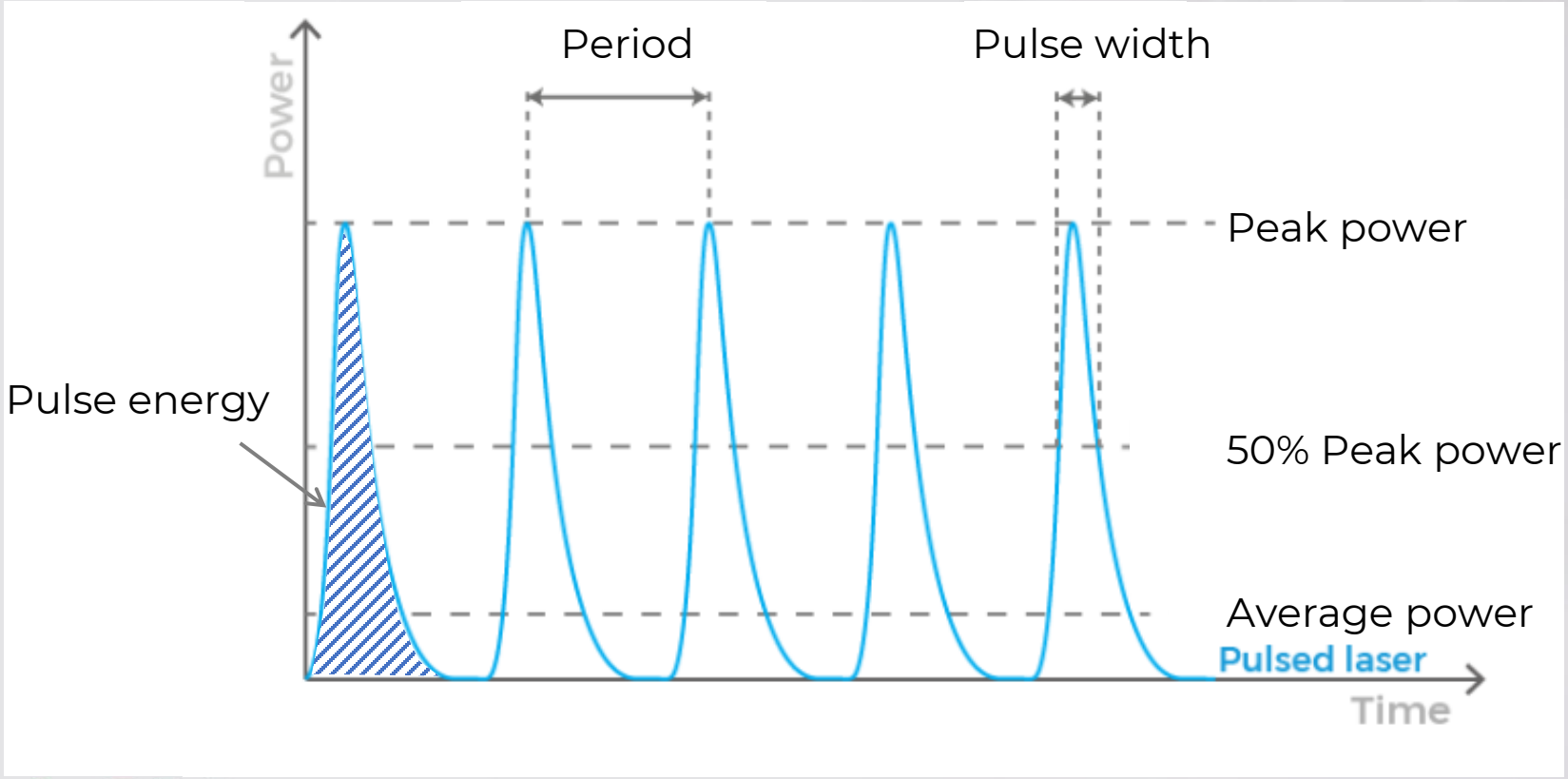
Key parameters for pulsed lasers

- In time, a pulsed laser is defined by its frequency, its pulsed energy and its pulse width.



Frequency = 1/period

Typical for Synova lasers:

Frequency = 10 kHz
Period = 100 µs
Pulse width = 100 ns
Pulse Energy = 5 mJ
Average Power = 50W
Peak power = 50 kW

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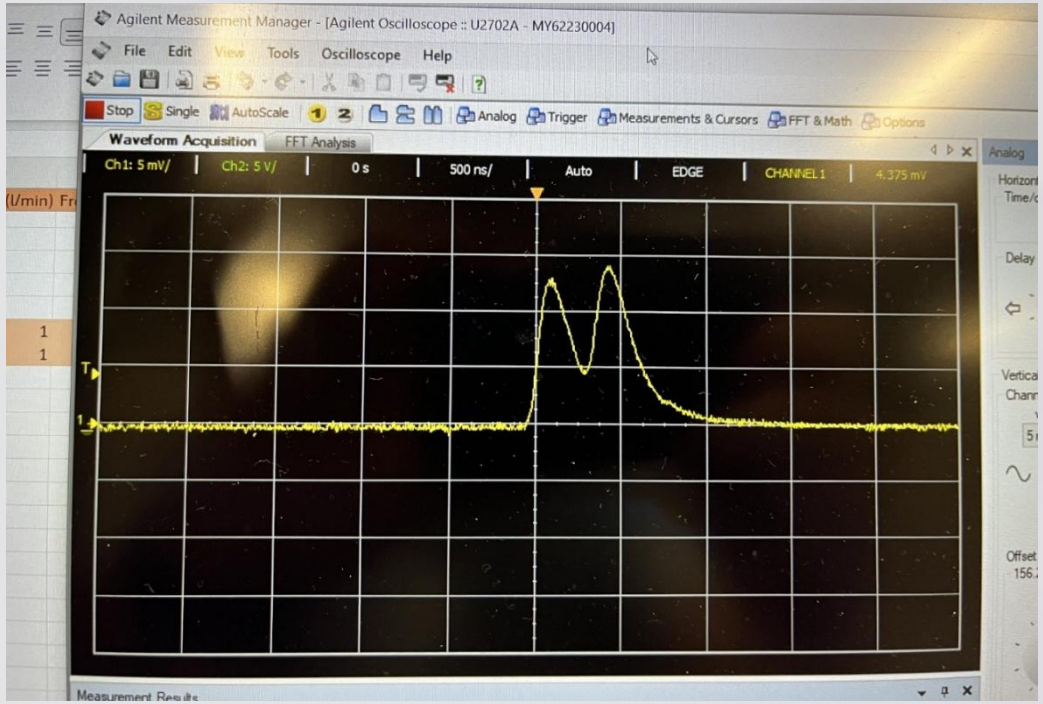
Dual lasers

- To increase the laser power, two lasers can be combined into one optical path. The “two lasers” is called “dual lasers”
- The delay between the two pulses can be adjusted very precisely.



Pulse as a function of time, “camelback” shape

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Optics & breakthrough sensor

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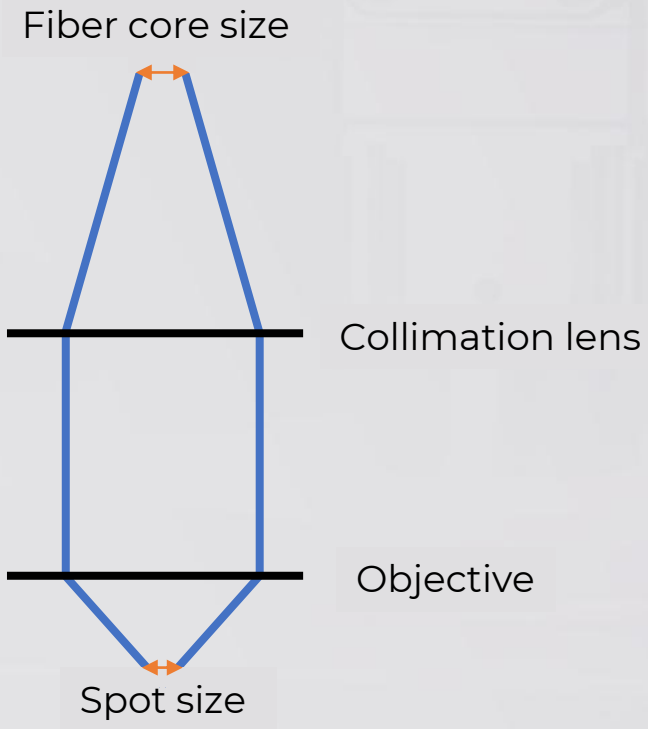
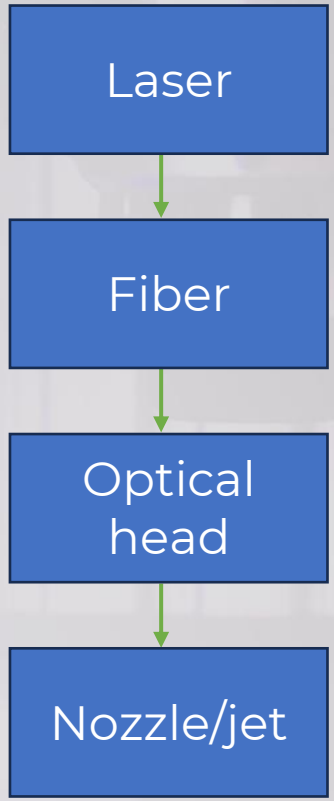
Optical line configuration

The optical line is composed of a laser, a fiber and an optical head and a nozzle.

The optical head defines the magnification ratio: $\frac{fiber\ core\ size}{spot\ size} = \frac{f_{collimation}}{f_{objective}}$





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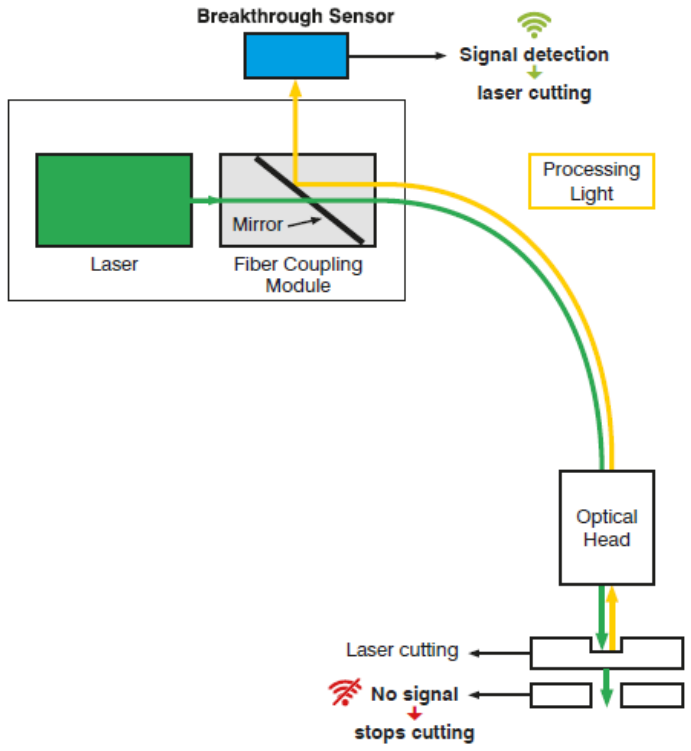
Optical line configuration: Breakthrough sensor

Breakthrough sensor detects when the laser has cut through the material to avoid unnecessary further passes and the laser microjet can automatically move on to the next task

Working principle



Key benefits

- **Early detection of process saturation**
- **Ideal for multilayer materials**
- **Reduce processing time up to 20%**
- **Avoid damage on opposite walls**

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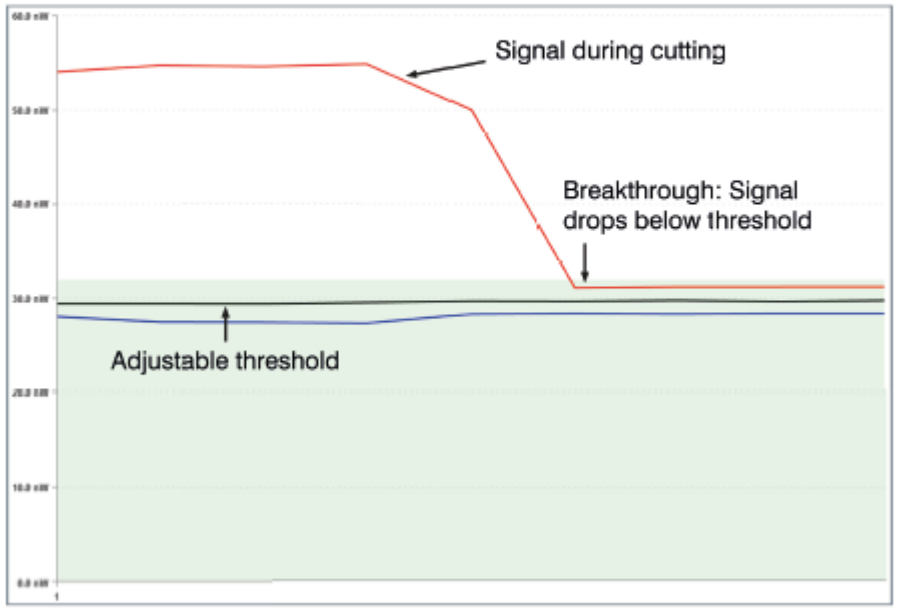
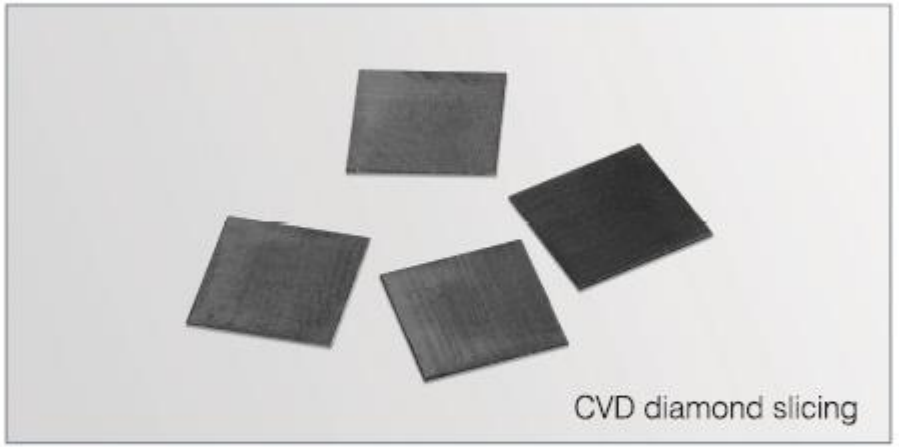
Breakthrough detection

HMI Visualization



Application example



- Breakthrough sensor reduces number of passes from 80 to 65.
- Overall time saving up to 20%.

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LMJ vs competing technologies

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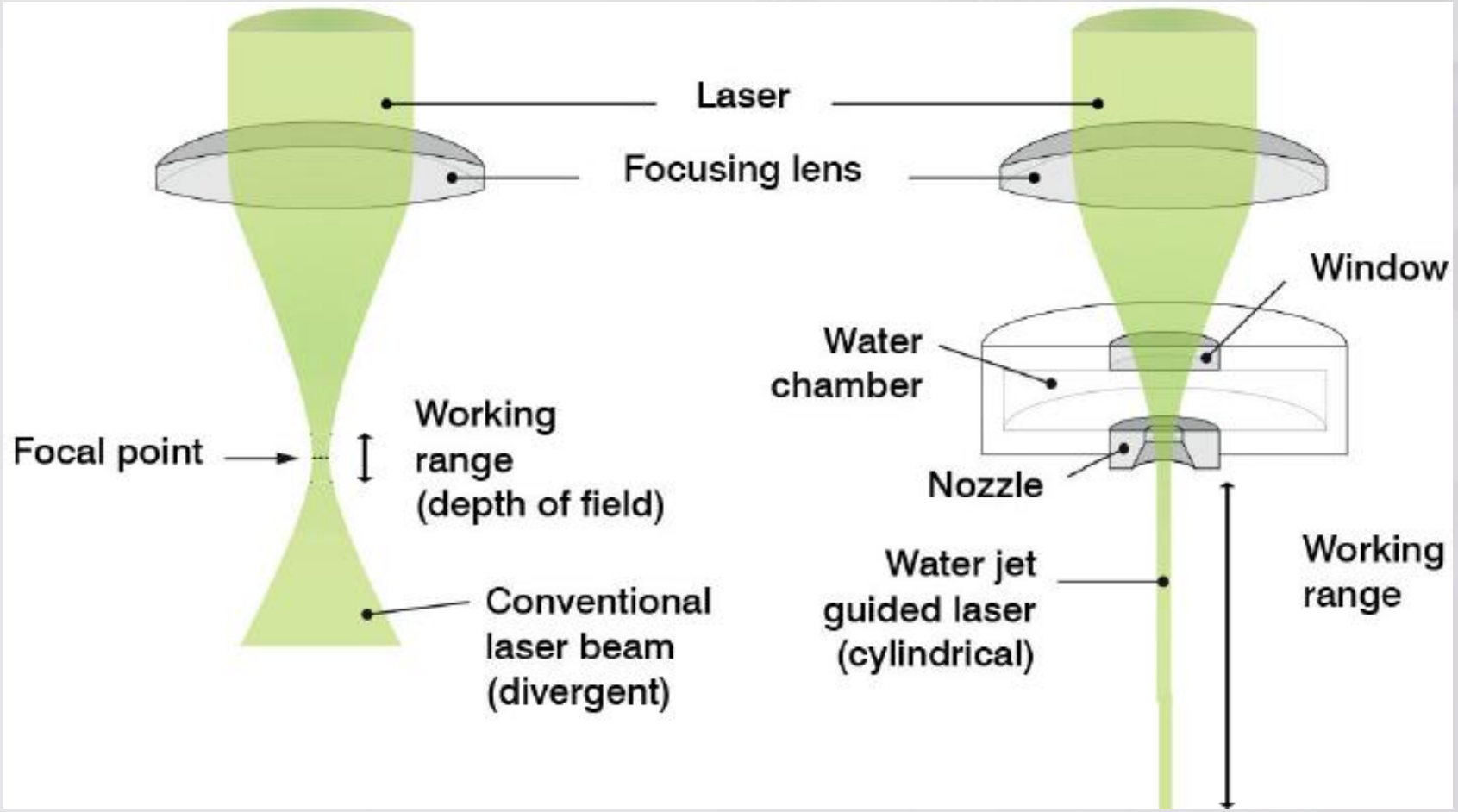
The Laser MicroJet® Technology

Conventional Laser

Laser MicroJet®



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The Laser MicroJet® Technology

Conventional Laser		Laser MicroJet®
Requires precise focus adjustment.		Possible to cut non-flat surfaces or variable thicknesses without focus adjustment.
Conical laser beam results in V-shaped cut.		Cylindrical waterjet results in parallel kerf walls.
Conical laser beam limits aspect ratio and maximum thickness.		High aspect ratio. We keep the nozzle size in the depth.
Heat-affected zone Limitation of the minimum thickness of the material.		Constant water-cooling avoids thermal damage and thermal dilatation of the sample during the cut.
Part of the molten material results in burrs and redeposition, especially for metal.		Ultrapure water prevents redeposition of molten material or contamination.

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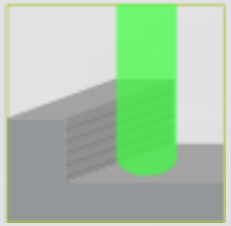
The Laser MicroJet® Technology

EDM wire			Laser MicroJet®
Only electrically conductive materials			All materials with enough absorption of the wavelength
Usual wire size Ø250µm Down to Ø50µm (very difficult)			Usual nozzle size Ø50µm Down to Ø25µm
Needs pre-hole to thread the wire.			Cut directly samples without preparation.
Cuts trough in one pass Needs bridge to make finishing passes Non-uniform quality			Mono or multi passes cutting Uniform quality, allow blind cut.

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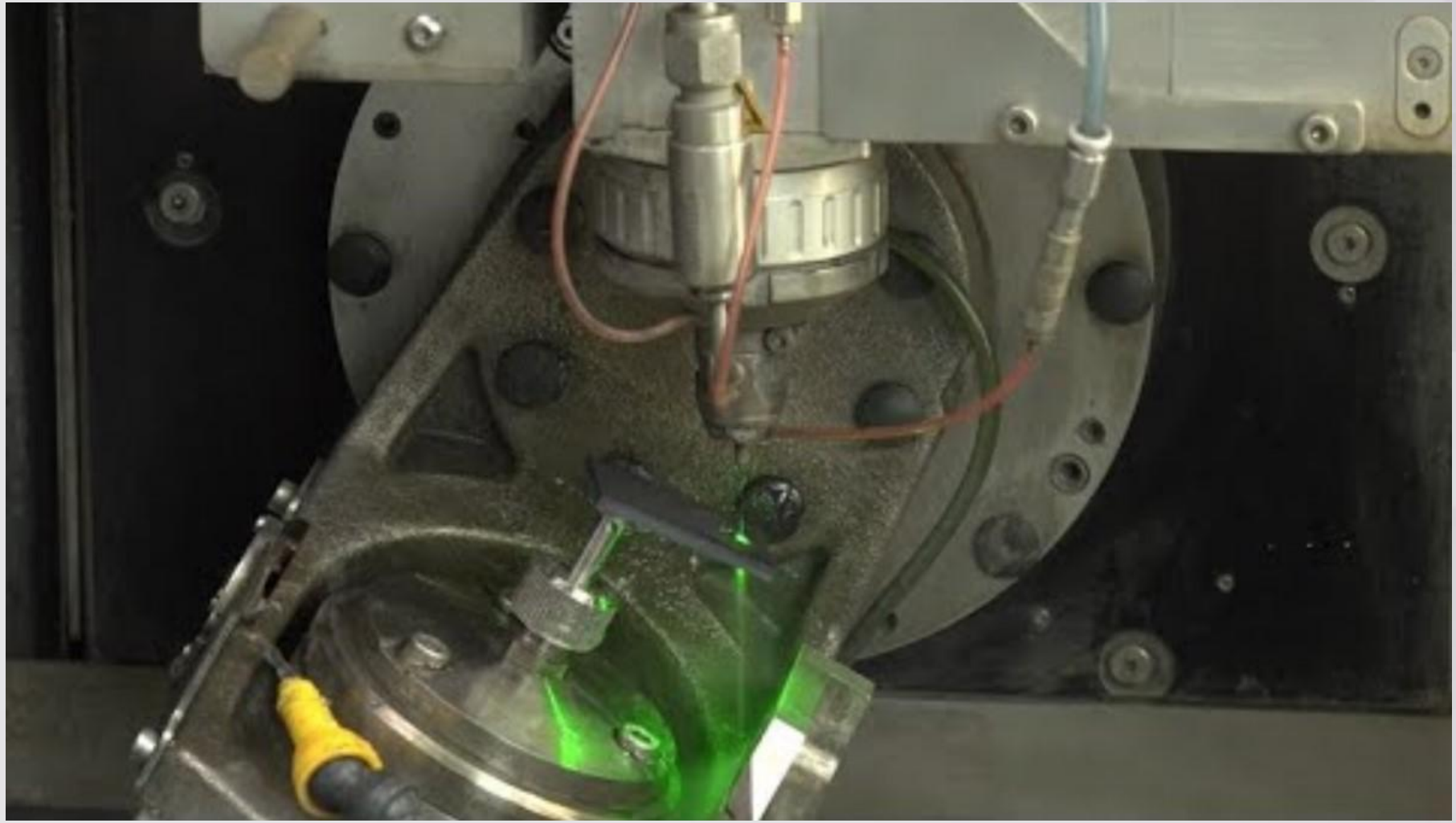
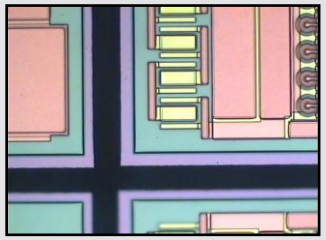
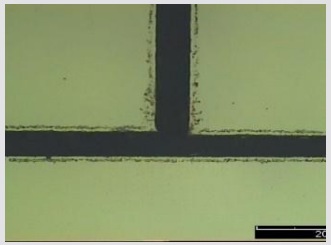
Example of Laser MicroJet®



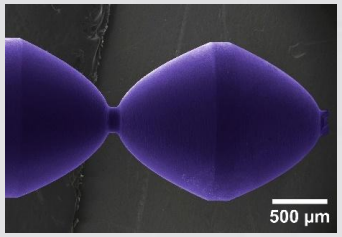
Application fields

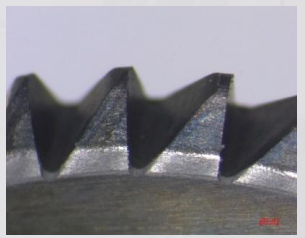
Semiconductor



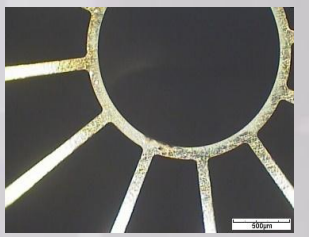
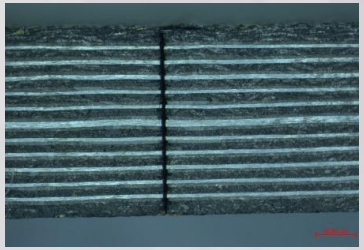



Diamond for jewelry & industry

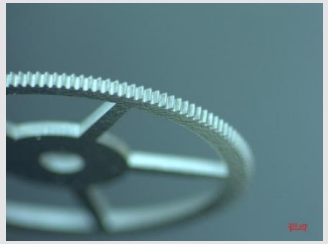





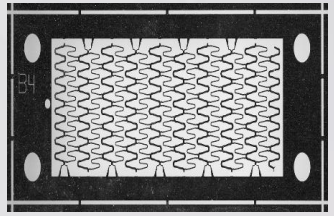
Aerospace - Defense

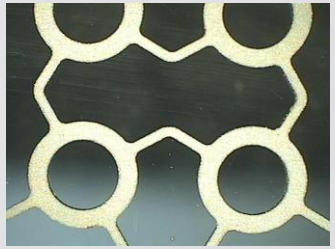




Watchmaking

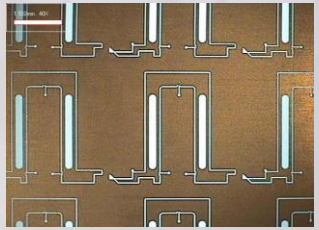



Medical

Other Industries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Synova machines

3-4-axis machines for 2D shapes

LCS-150

Working volume:
125x200x100 mm

LCS-303

Working volume:
300x300x100 mm

LCS-800

Working volume:
690x630x100 mm

3-5-axis machines for 3D geometries

LCS-50 (3 and 5-axis)

Working volume:
50x50x50 mm

LCS-305 (5-axis)

Working volume:
240x380x380 mm

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Flexible Laser-Based Manufacturing

Applications & case studies

Flexible Laser-Based Manufacturing

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Applications & case studies

1. **Capability recap**
2. **Materials**
   - Thin sheet
   - Laminates
   - Composites
   - SiC_f/SiC
   - Polycrystalline Diamond
3. **Applications**
   - Drilling
   - Cutting
   - Micromachining
   - Turning

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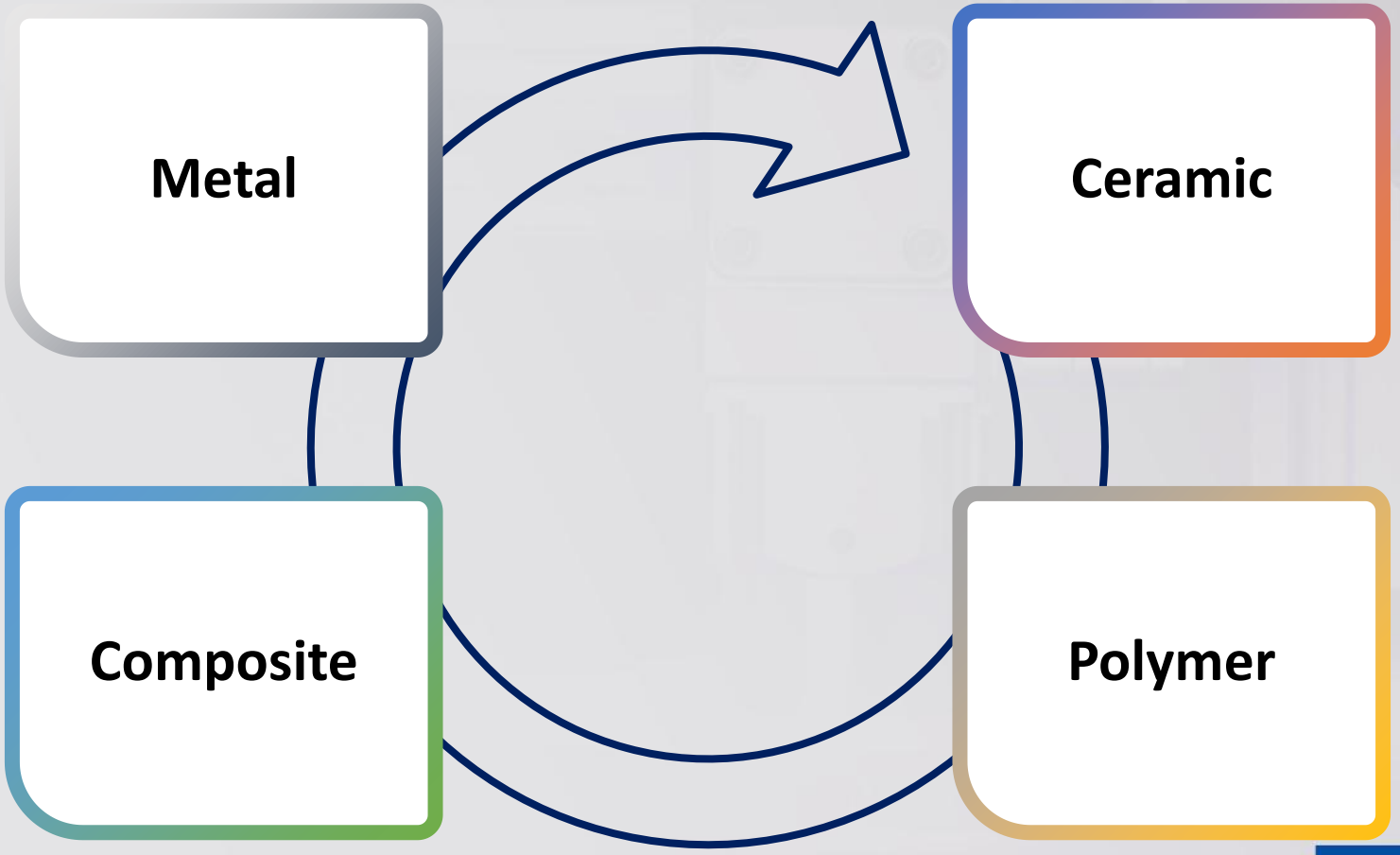
Capability recap



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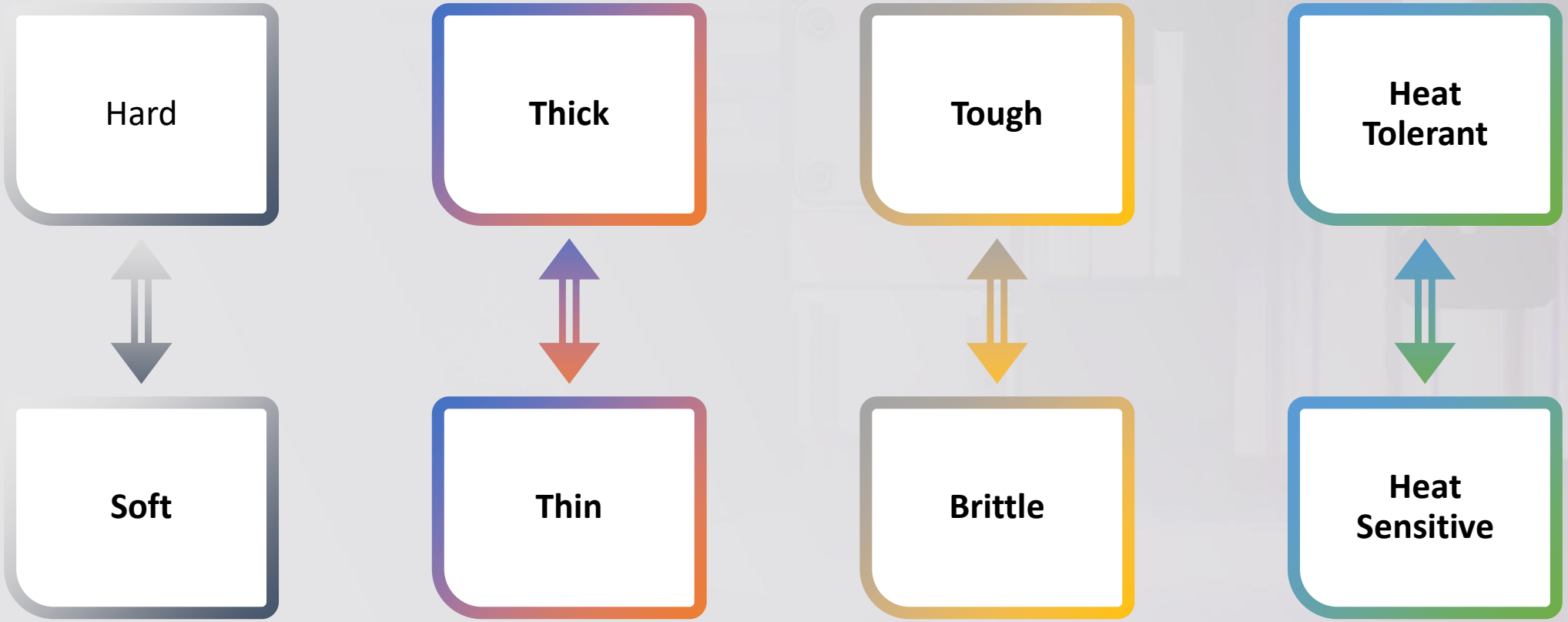
Capability recap



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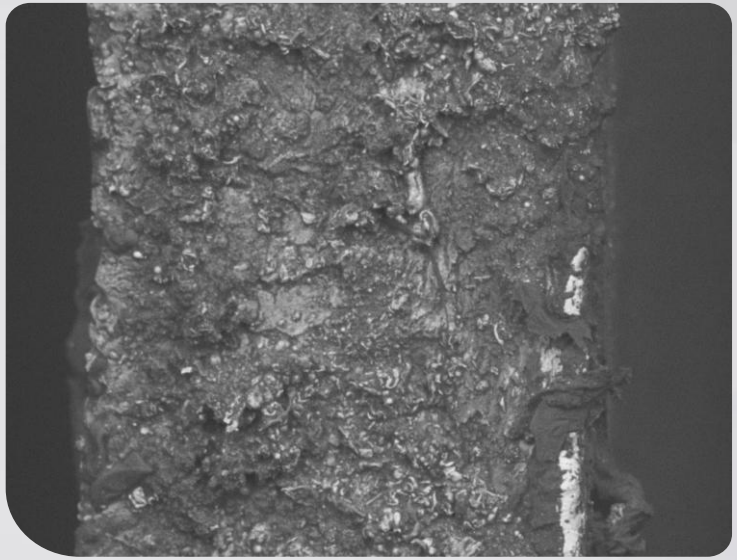
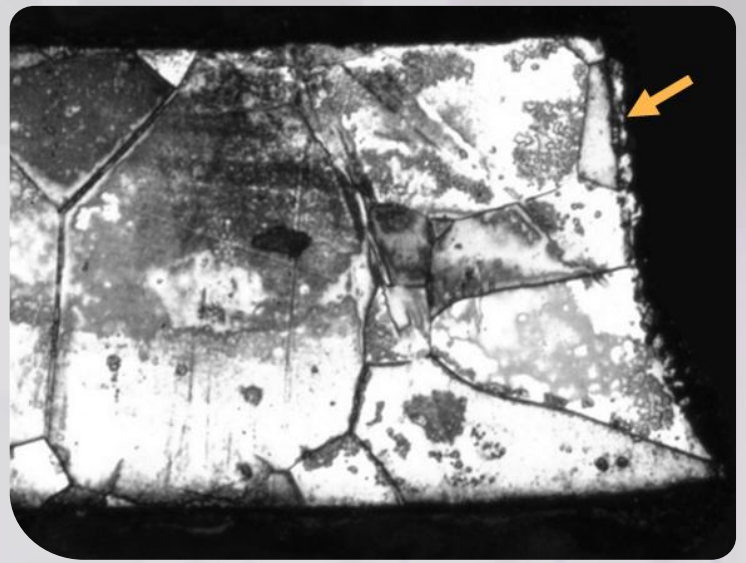
Materials

Thin Sheet Cutting

Single pass cutting

0.2 mm thick steel





100 µm

Frequency	20 kHz
Average Power	61 W
Jet Pressure	150 bar
Scan Speed	10 mm/s
Linear Energy	6.1 J/mm

https://doi.org/10.1016/j.procir.2024.08.162

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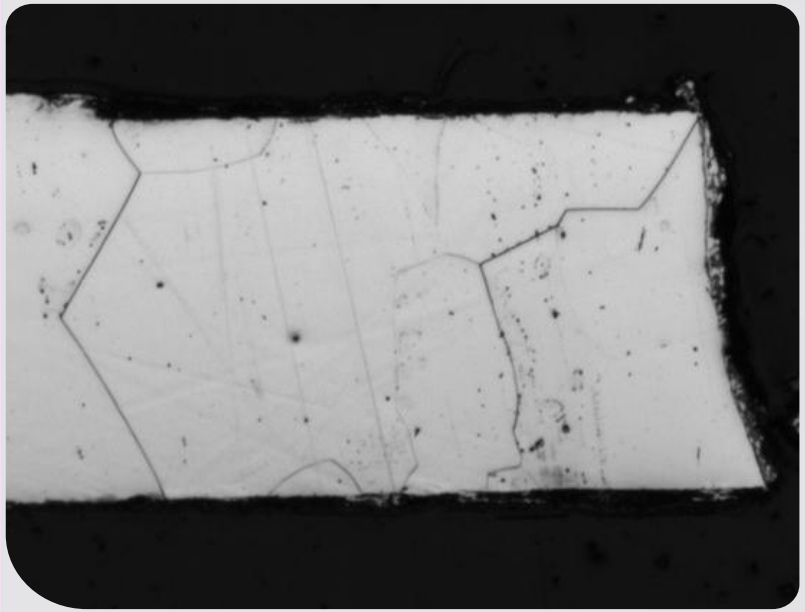
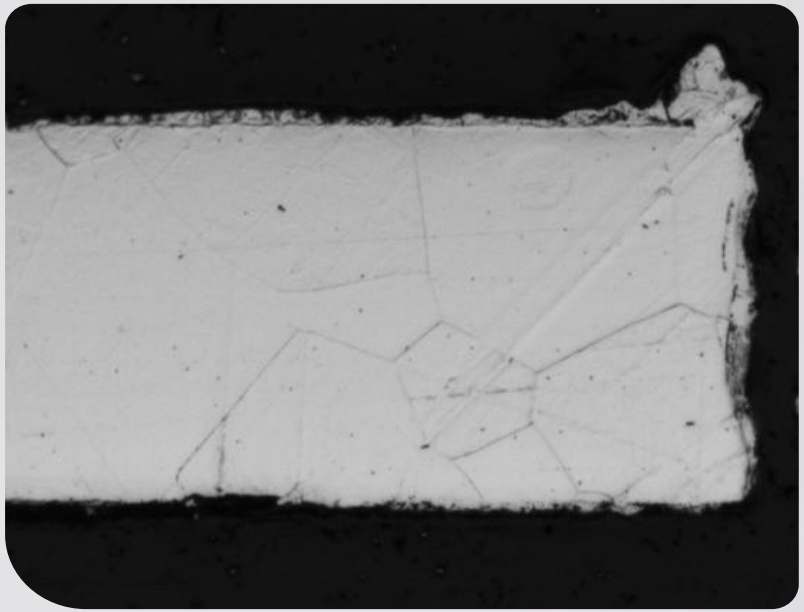
Materials

Thin Sheet Cutting

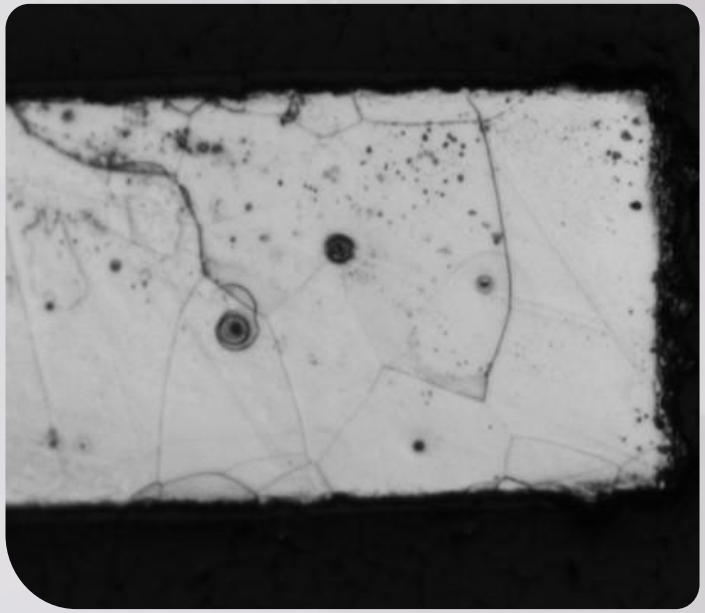
Comparison to other cutting methods.



WJGL
0.6 m/min



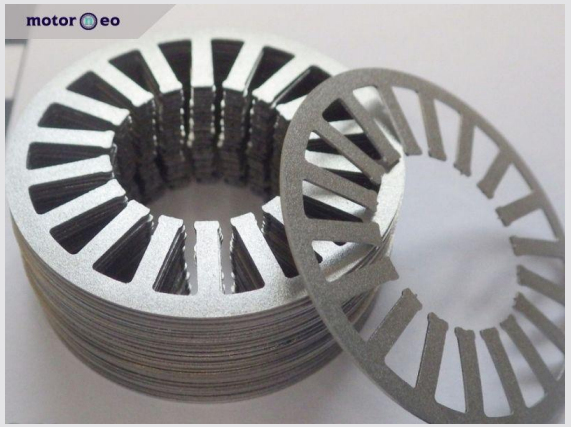
Remote Laser Cutting
18 m/min

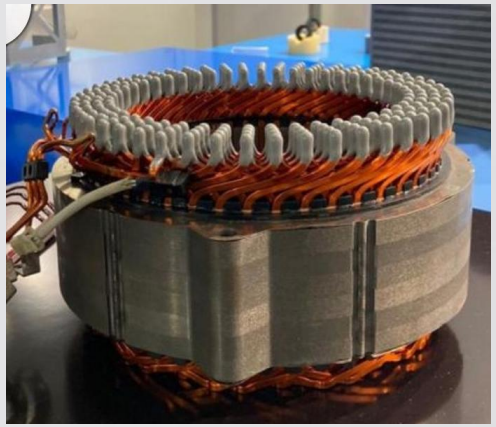


Wire-EDM
0.2 m/min

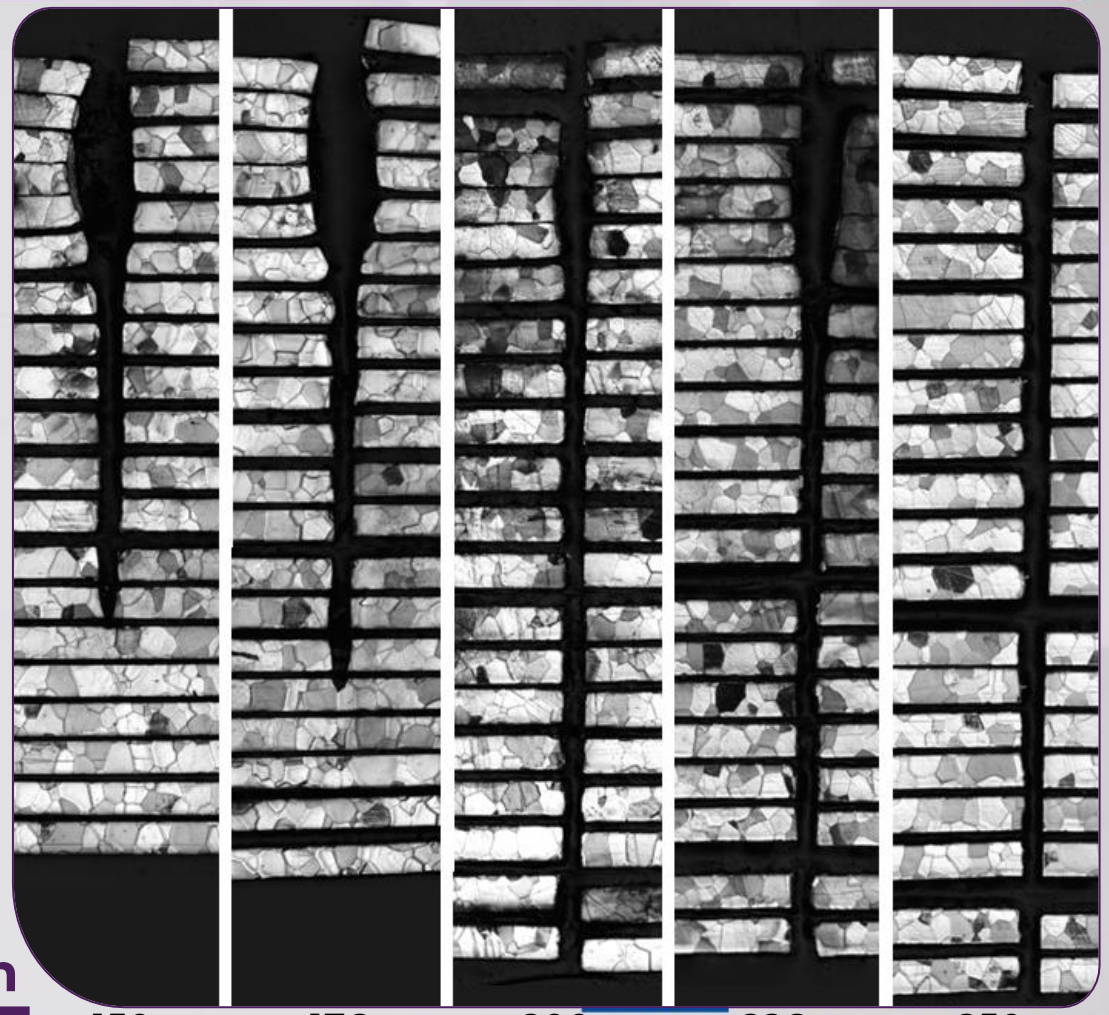
Materials

Laminations





Frequency	20 kHz
Average Power	159 W
Jet Pressure	150 bar
Scan Speed	10 mm/s
Effective cutting speed	3.33 mm/s



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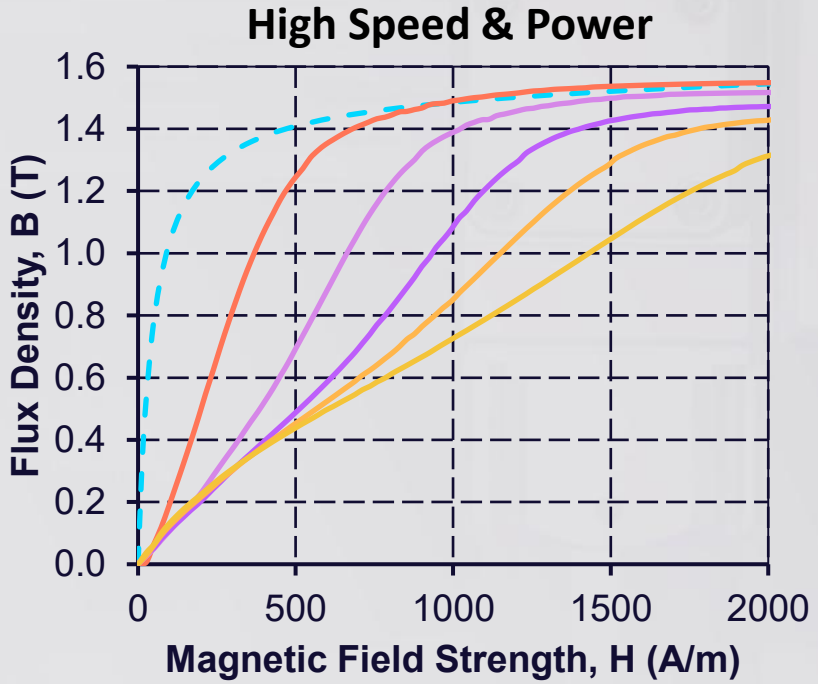
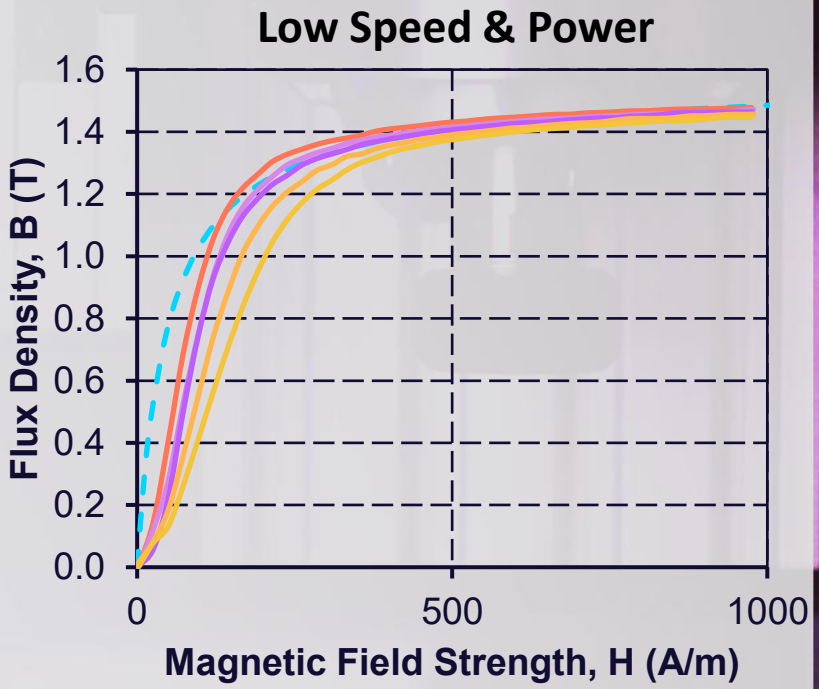
Materials

Laminations





Reference
0 Slit
1 Slit
2 Slit
3 Slit
4 Slit

	Pulse Frequency kHz	Scan Speed mm/s	Average Power W		Avg. Power (total) W
High Speed	40	40	74	96	170
Low Power	20	10	61	0	61

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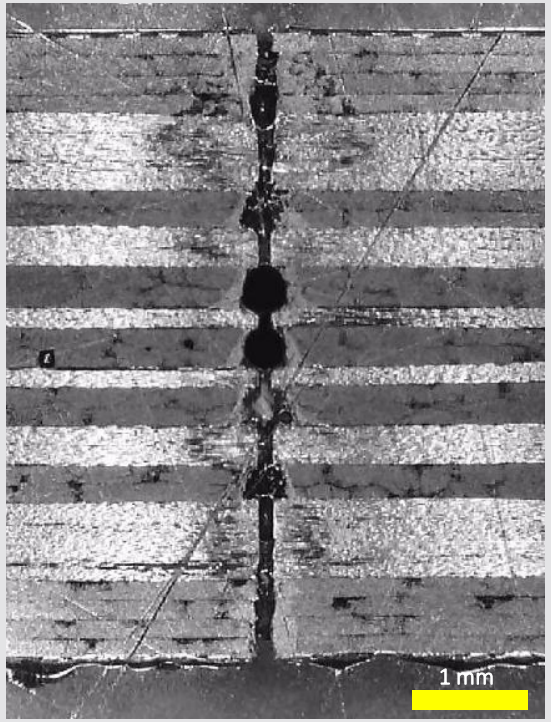
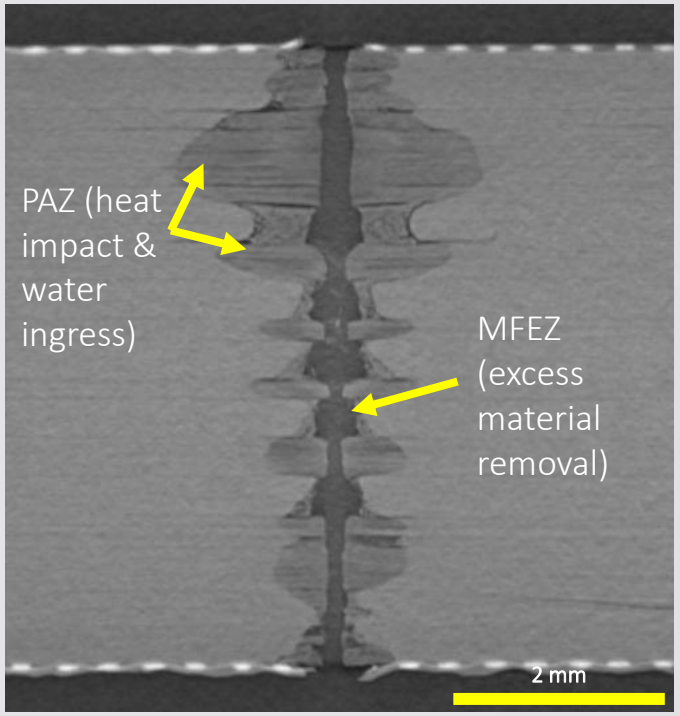
Materials

Composites – 6 mm CFRP

167 W, 400 bar



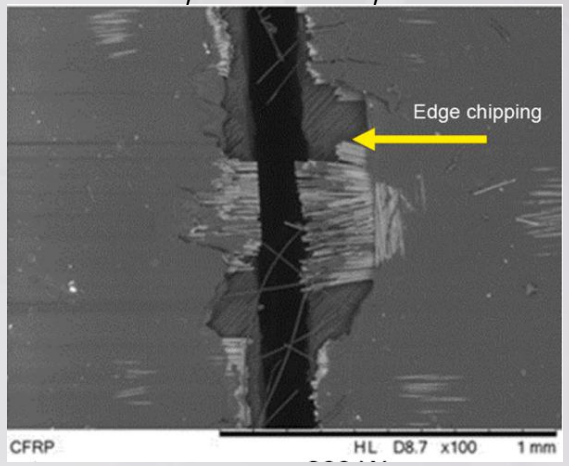
Optical

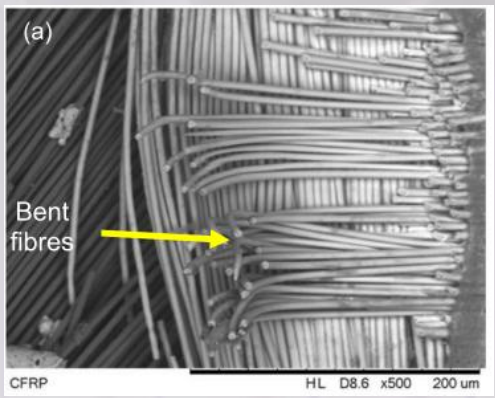


XCT

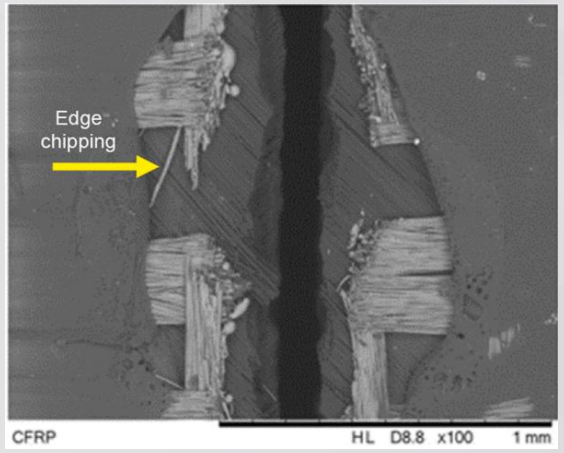
240 W, 400 bar, 16 kHz

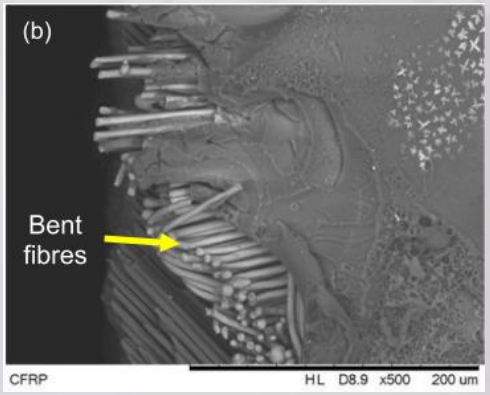
Cut Entrance





Cut Exit





https://doi.org/10.1016/j.optlastec.2023.110460

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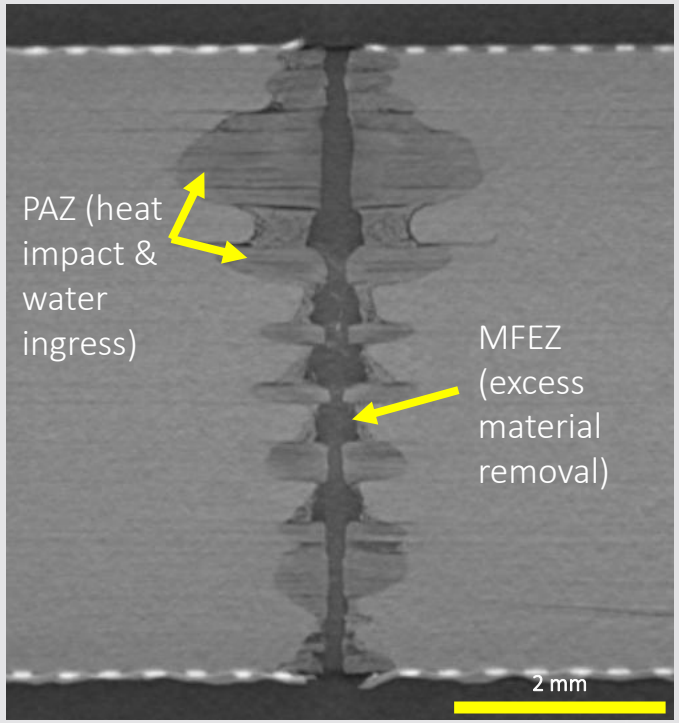
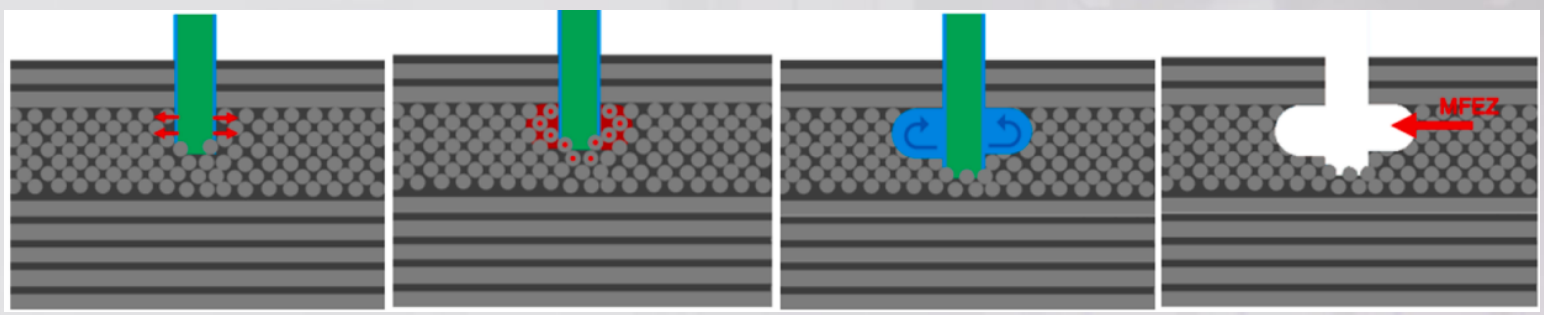
Materials

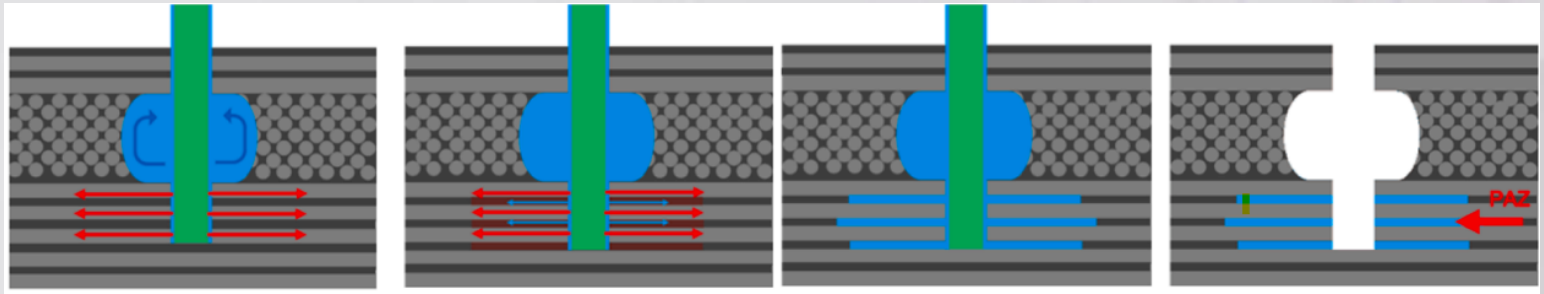
Composites – 6 mm CFRP



Matrix-fibre erosion zone formation



Process affected zone formation



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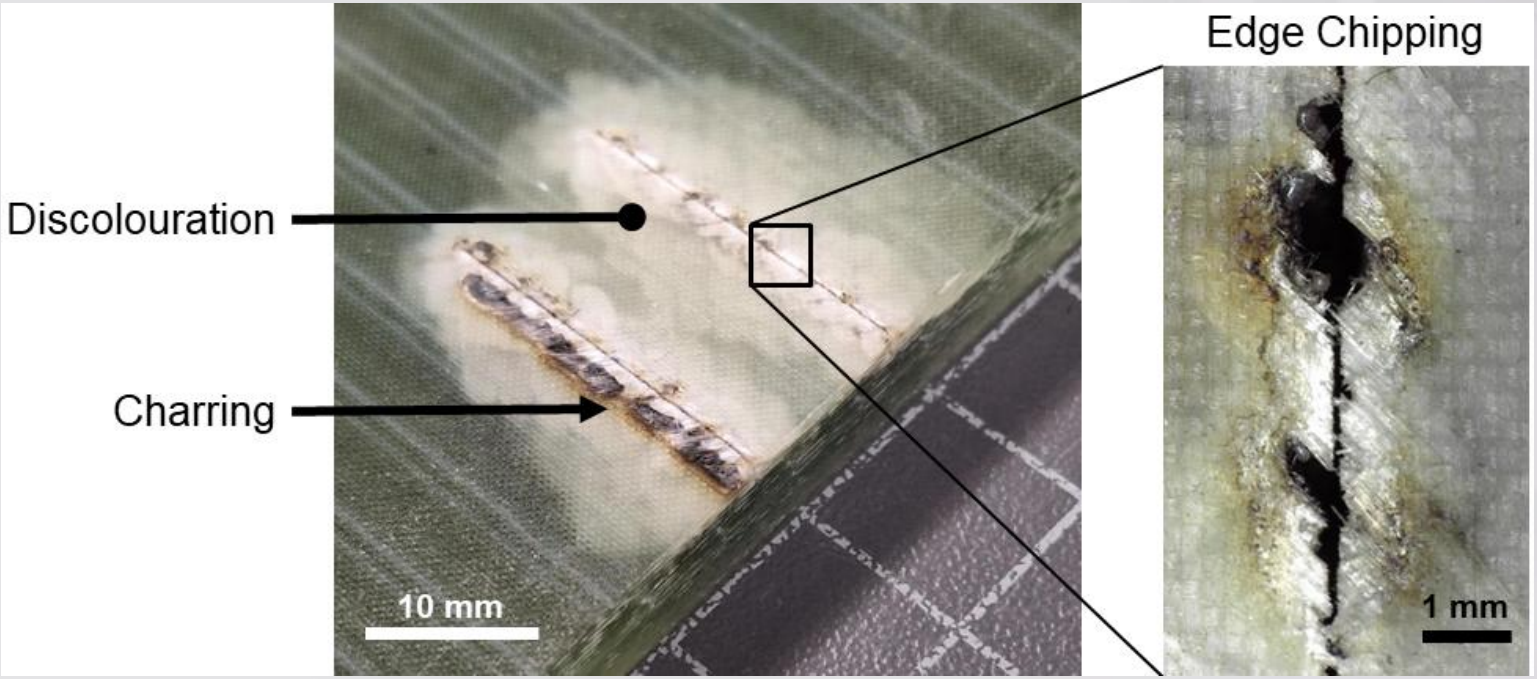
Materials

Composites – 7.5 mm GFRP

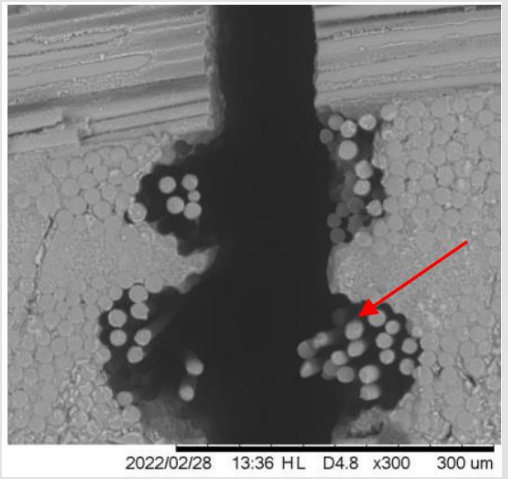


https://doi.org/10.21203/rs.3.rs-4630208/v1

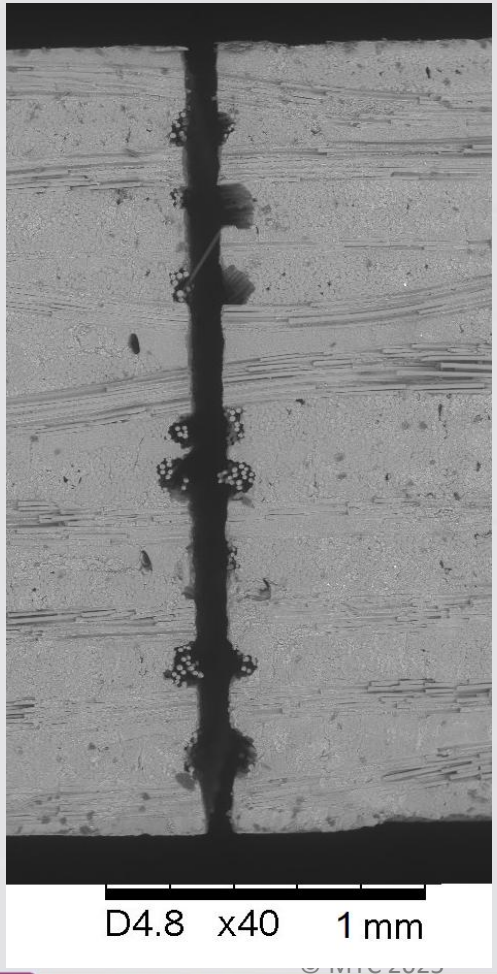
Materials

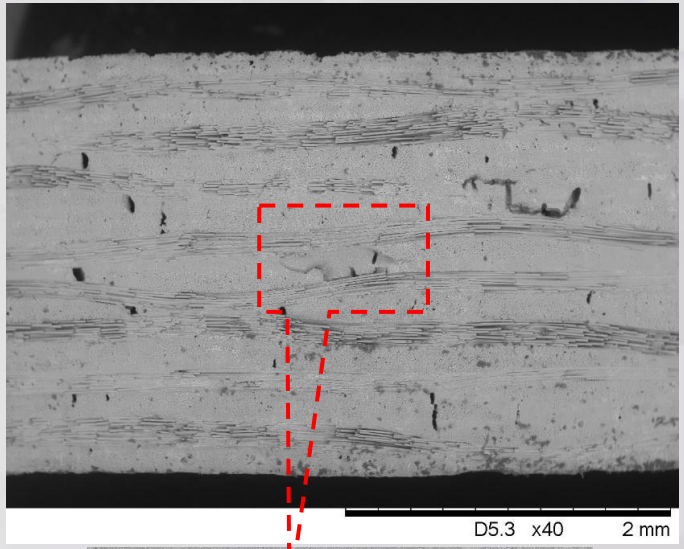
Ceramic Matrix Composites – 2 mm SiC/SiC

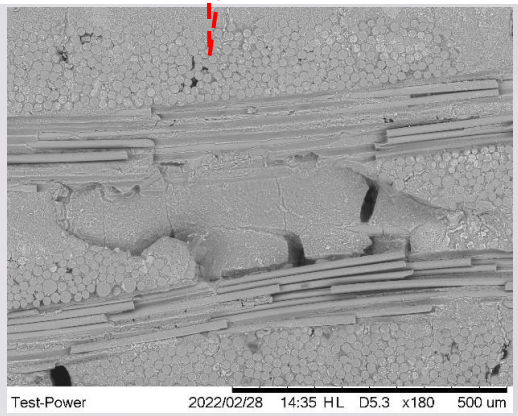
Proceedings of LPM2022 – the 23rd International Symposium on Laser Precision Microfabrication



Frequency	22 kHz
Average Power	49 W
Jet Pressure	300 bar
Scan Speed	70 mm/s
Effective cutting speed	3.33 mm/s







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Materials

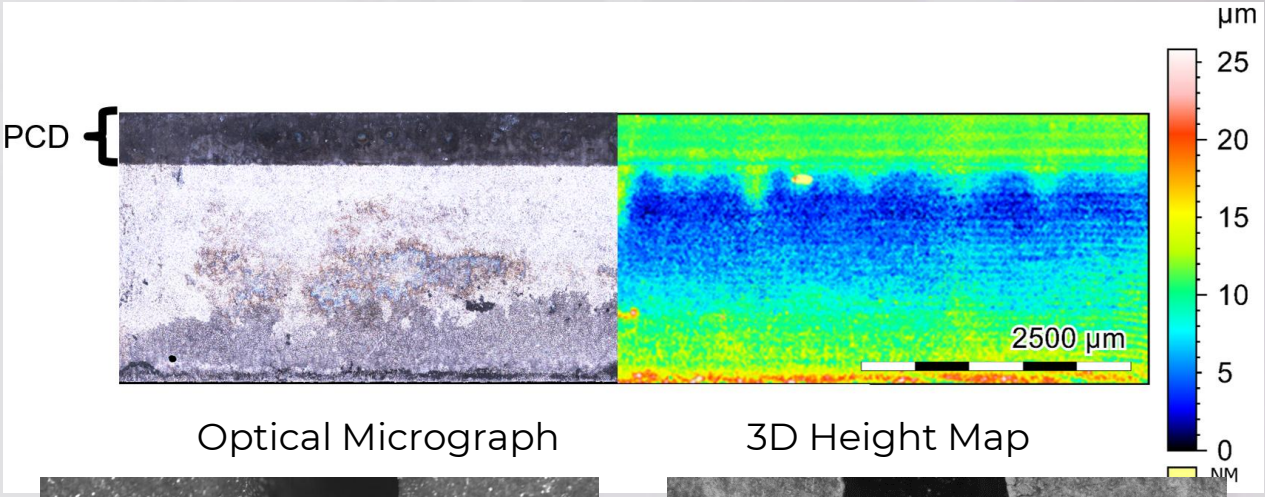
Polycrystalline Diamond & Tungsten Carbide

0.5 mm PCD layer on 2.1 mm WC/Co

Used in cutting tools

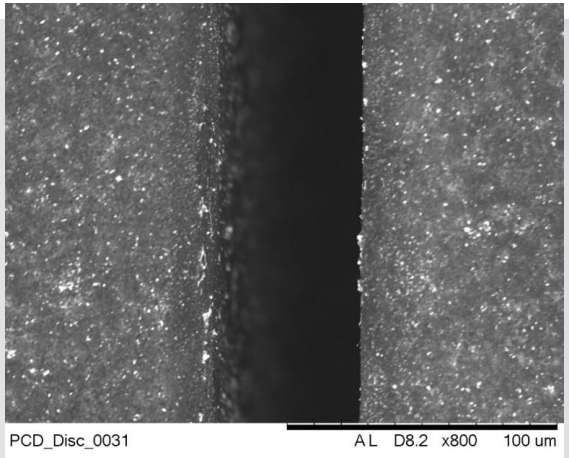
PCD of interest in quantum sensing applications

Frequency	8 kHz
Average Power	73 W
Nozzle Diameter	50 µm
Jet Pressure	300 bar
Scan Speed	5 mm/s

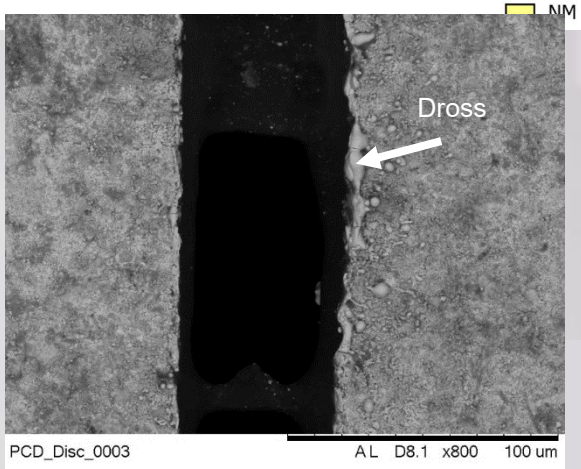


Optical Micrograph

3D Height Map



Entrance



Exit

https://doi.org/10.1007/s00170-025-16387-w

Applications

Drilling

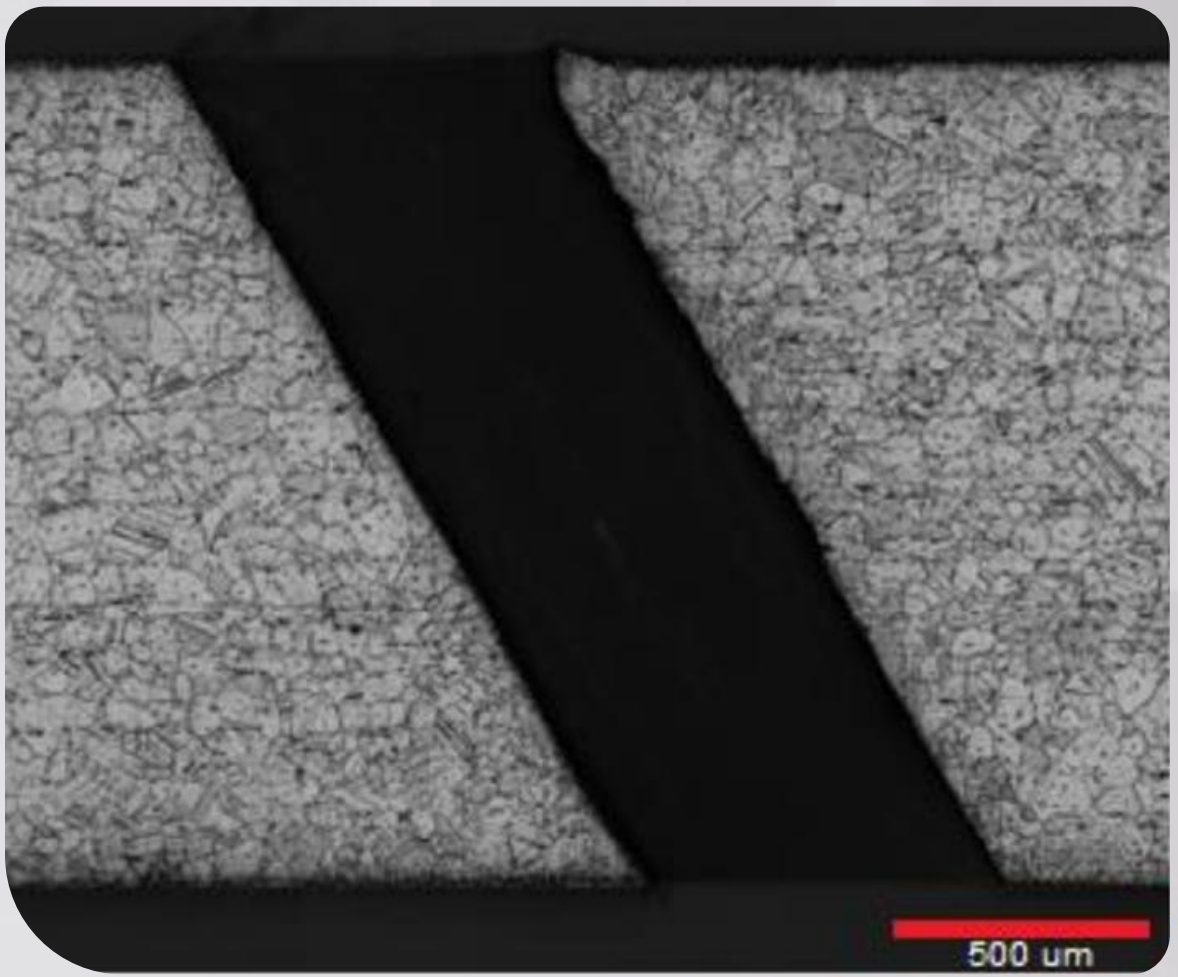
60° Angled holes through 1.6 mm thick nickel alloy

Aerospace interest

Thermal-barrier coated metal, MMC, CMC, Shaped holes

Much improved quality compared to ms drilling

Frequency	20 kHz
Average Power	163 W
Jet Pressure	200 bar
Scan Speed	20 mm/s
Drilling time	2.98 s



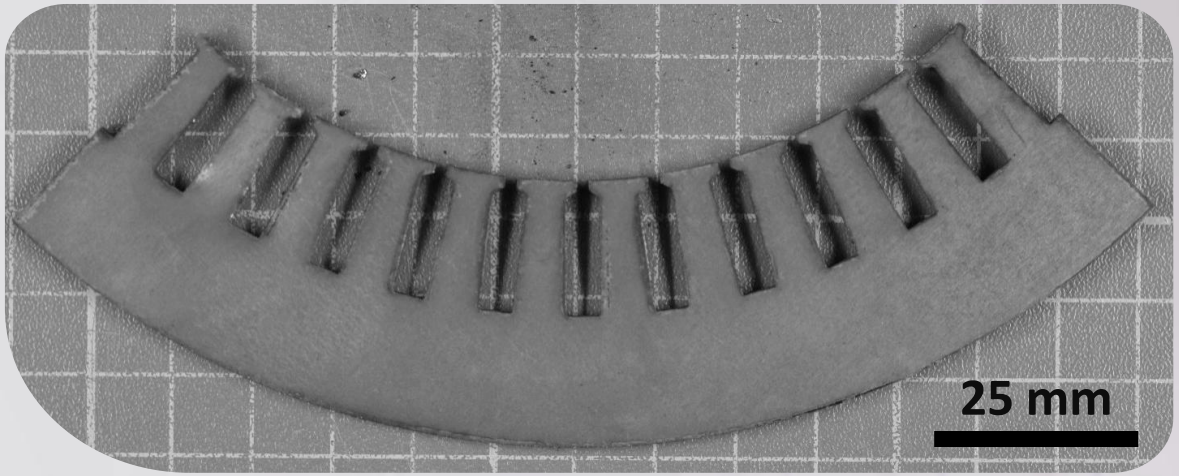
https://doi.org/10.1016/j.procir.2022.08.118

Applications

Cutting

Prototyping complex shapes

Low damage / high quality cutting



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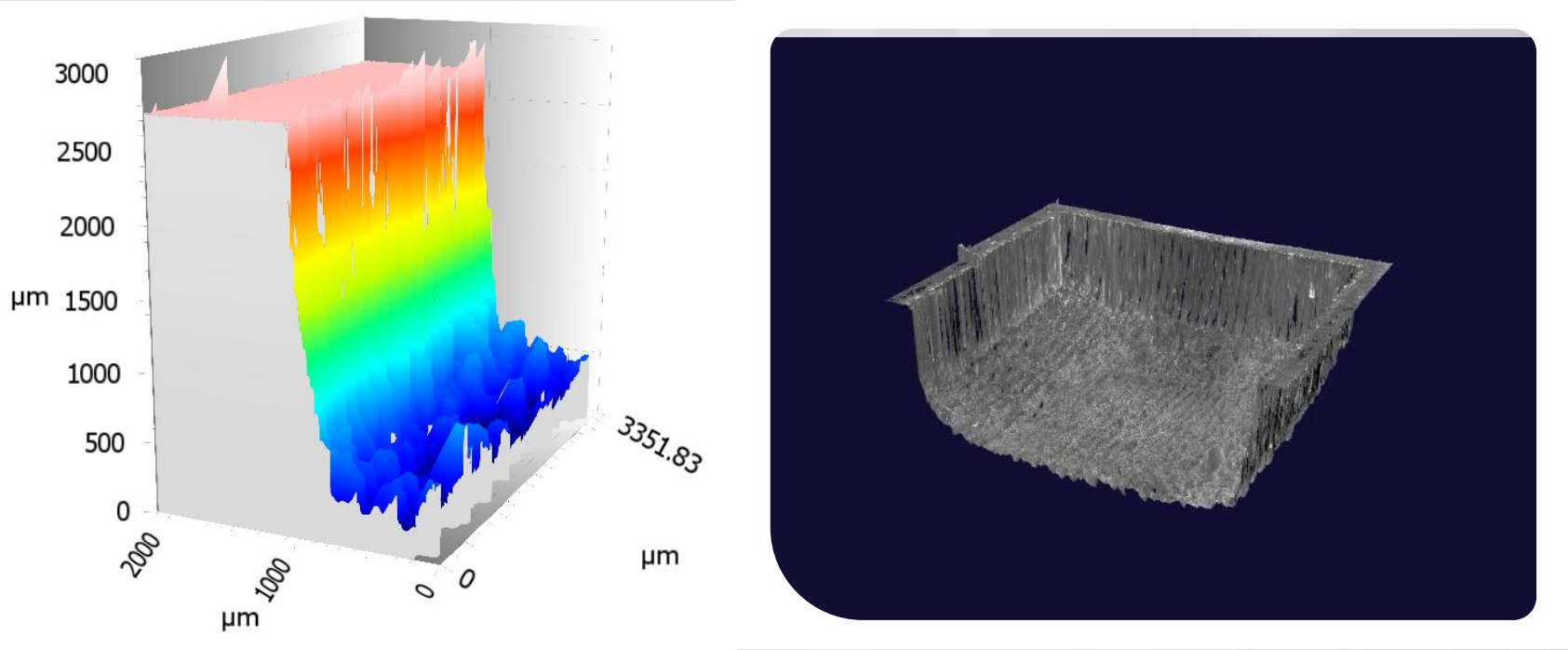
Applications

Micromachining

- Nearly taper free
- No burr
- Sharp internal corners
- Comparable MRR to EDM



https://doi.org/10.1007/s00170-025-16479-7

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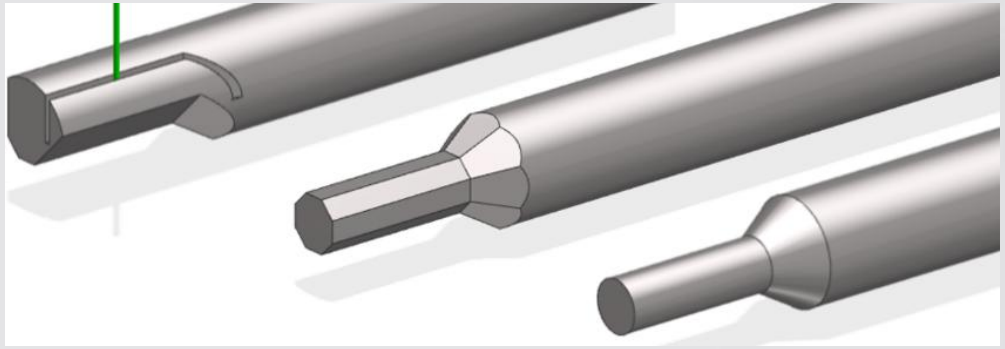
Co-funded by the European Union

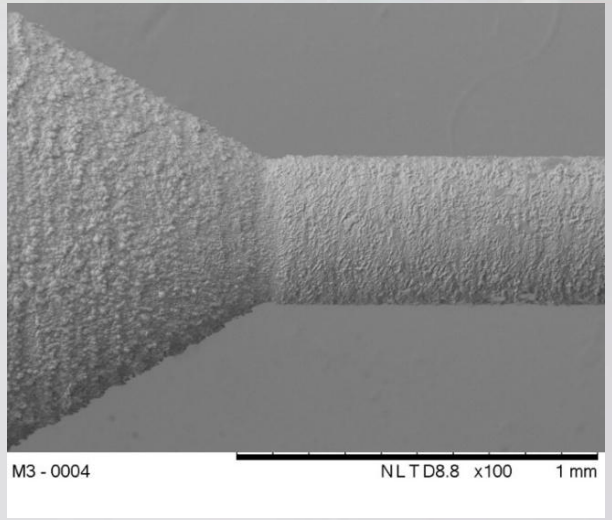
Applications

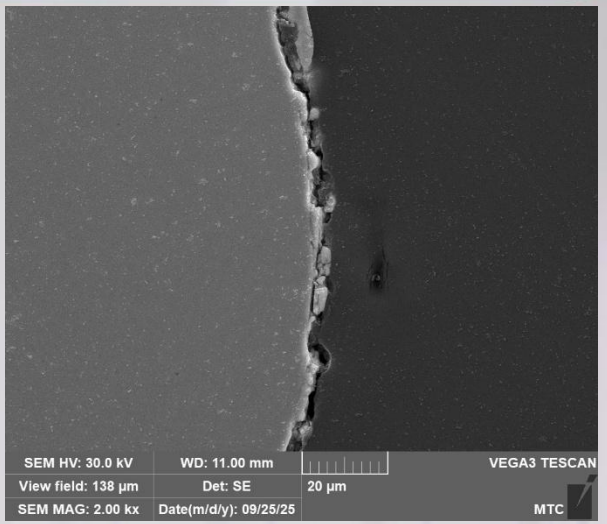
Turning

Two-stage processing

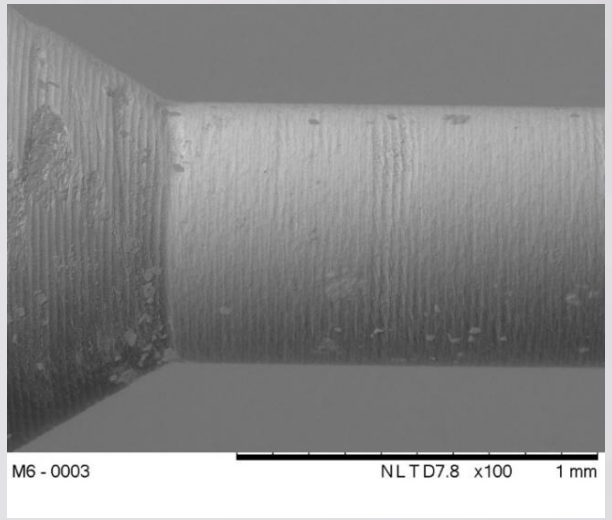


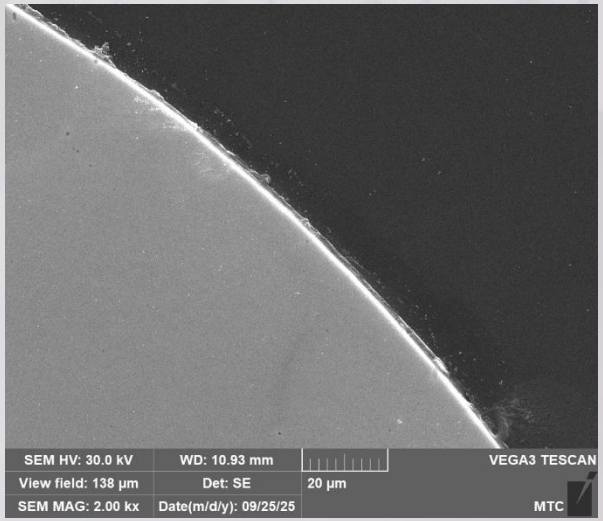
High power





Low power





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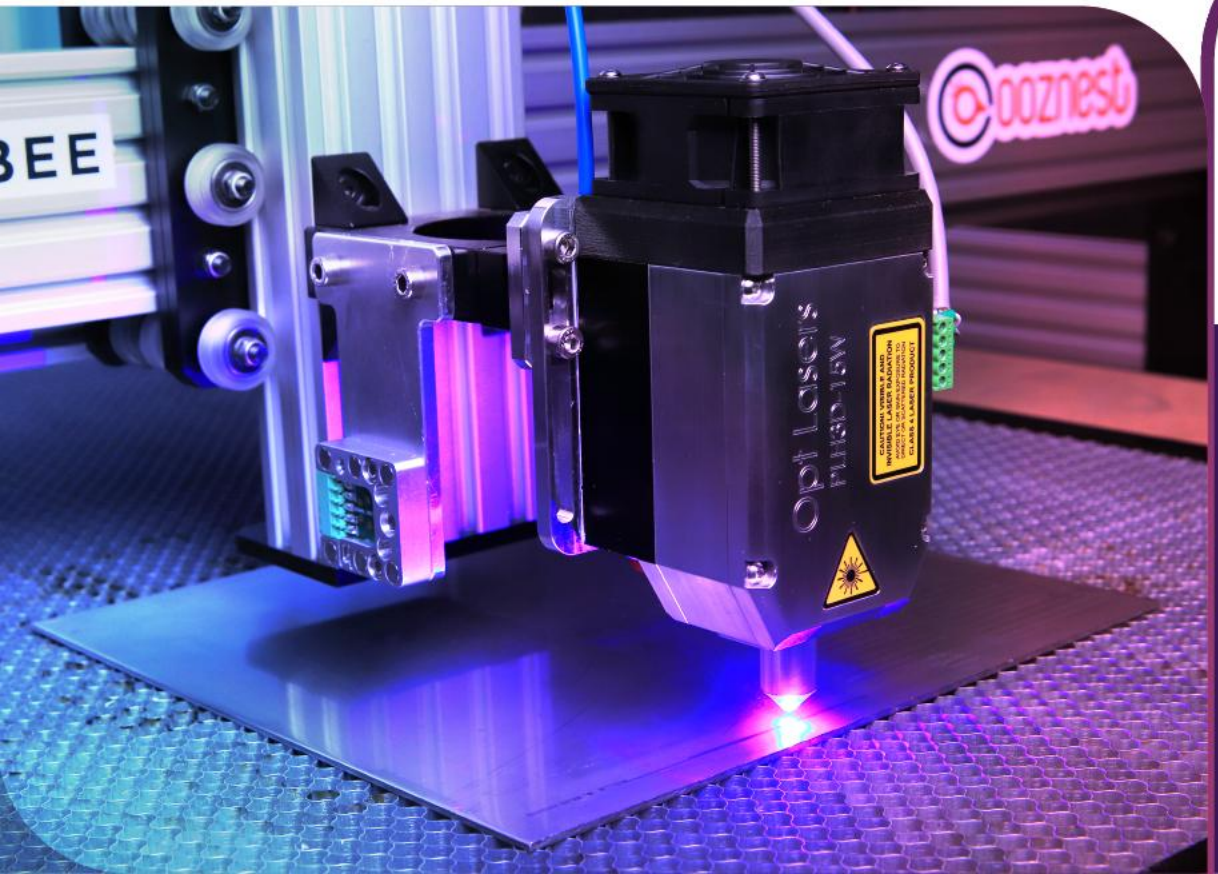
Flexible Laser-Based Manufacturing

Any Question?



"If there are any questions or if something needs further explanation, please, **don't hesitate to ask**!"

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