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SHAPING THE LIGHT

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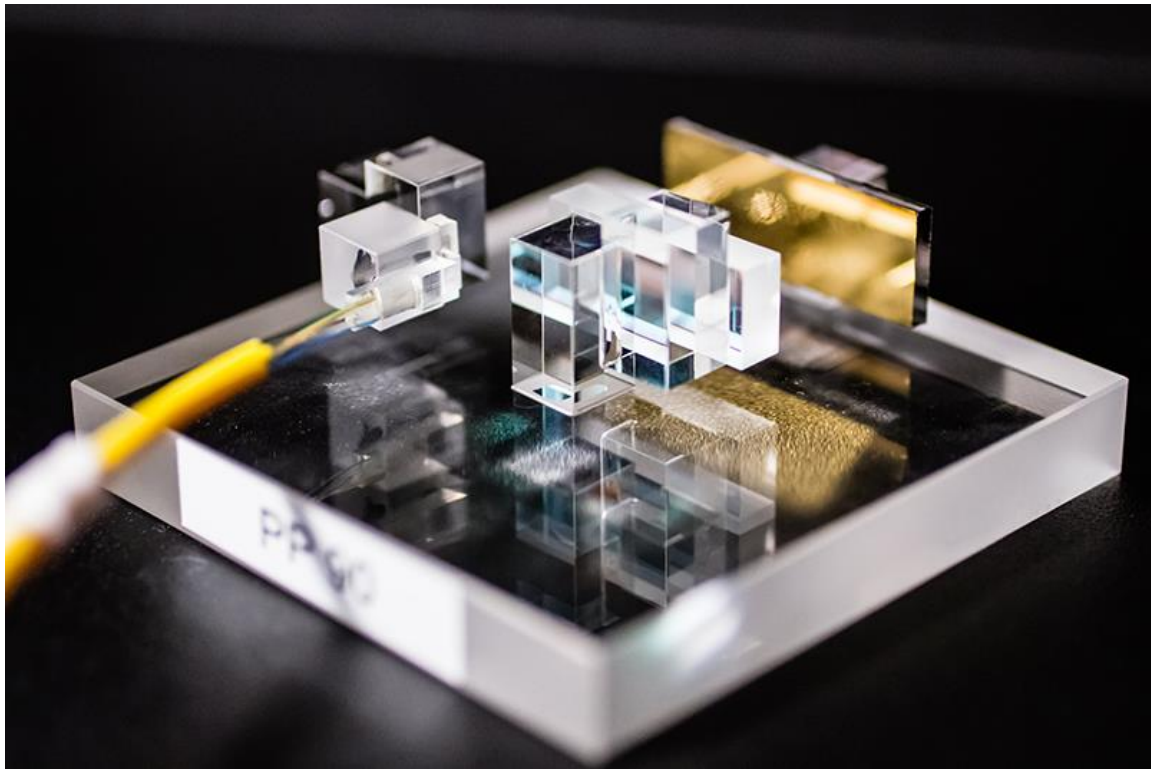
Macro-Processing and Micro-Processing Improvement Thanks to Multi-Plane Light Conversion Technology



EPIC meeting : Beam Shaping for Industrial Applications at LASYS

22 June 2022

Gwenn Pallier – Product Line Manager

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Cailabs, a deep-tech company

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Unique technology (MPLC)
and **expertise** in beam shaping

19
patent families

70%
export

70+ employees
(**20** PhDs)

16.6 M€
raised

20+ sales partners
worldwide

References:

SAFRAN

DLR

PRECITEC

Rexel

NEC

Amplitude

DGA

LZH
LASER ZENTRUM HANNOVER e.V.

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Canunda product line to improve laser-based processes

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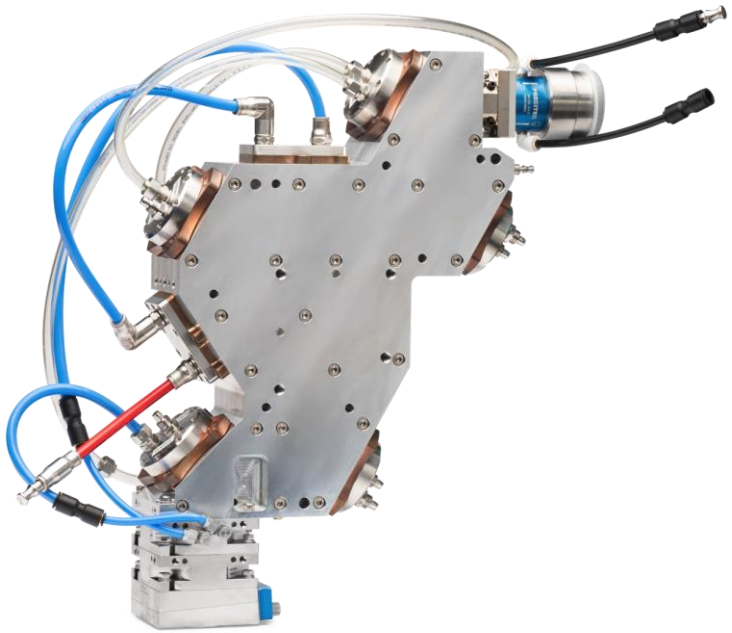
For **High-Power CW** lasers macro-processes

& for **Ultra-Short Pulse** lasers micro-processes :

CANUNDA HP



CANUNDA PULSE

CANUNDA SPLIT

CANUNDA AXICON

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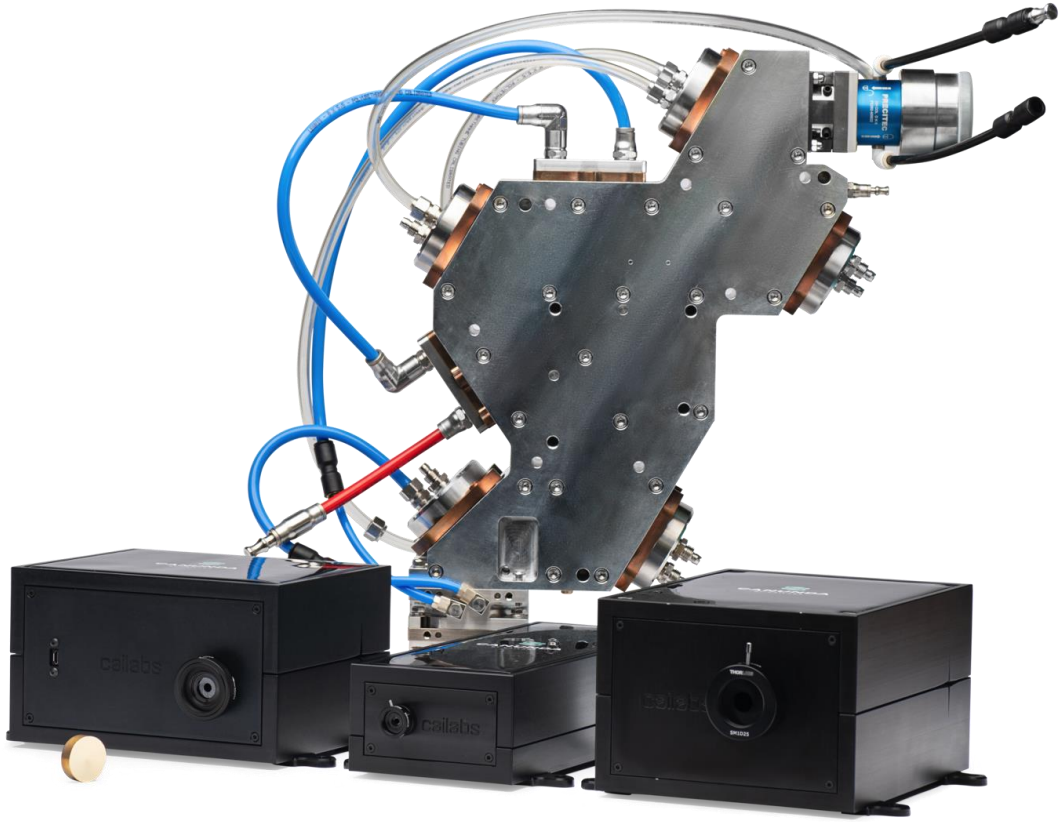
- **Some Ultra-Short Pulse applications of MPLC**
  - Micro chip welding
  - Fresnel-type mold drilling
- **Some High-Power applications of MPLC**
  - Automated Fiber Placement
  - Hybrid Laser Arc Welding of Steel



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How to generate a Top-Hat?
Many strategies can provide the same intensity profile

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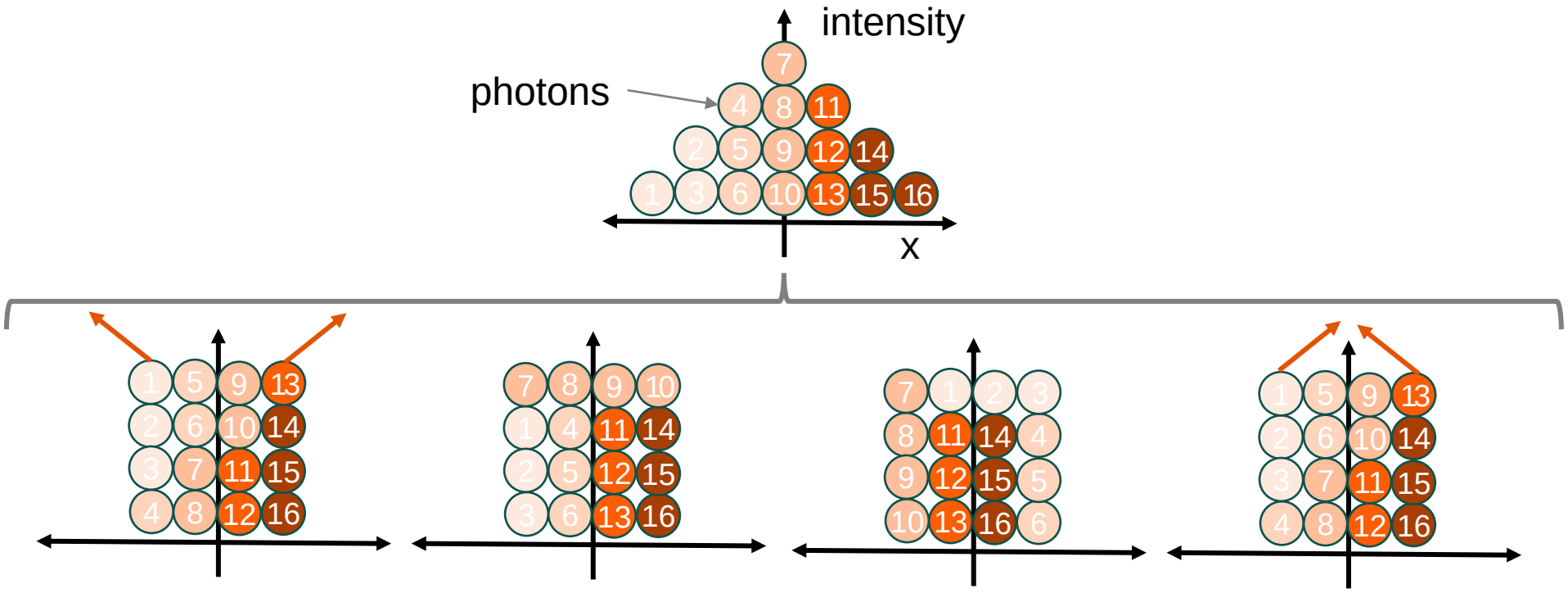
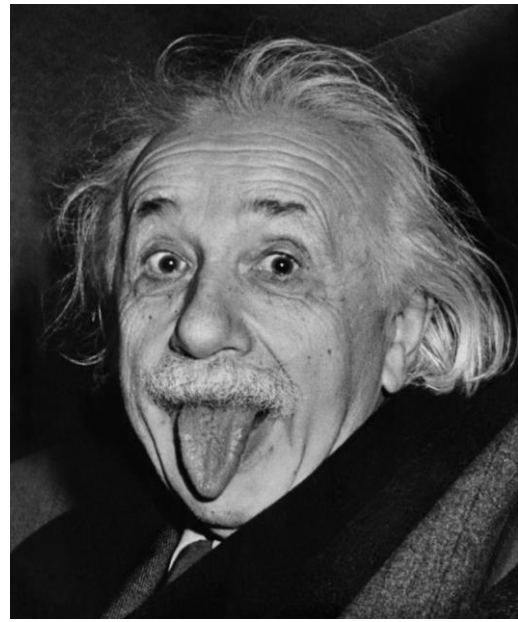
There are multiple ways to generate a top-hat :





In all cases you will see the same thing, though it is definitely not the same thing!

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How to generate a Top-Hat?
Multiple laws of optics can be used to do so

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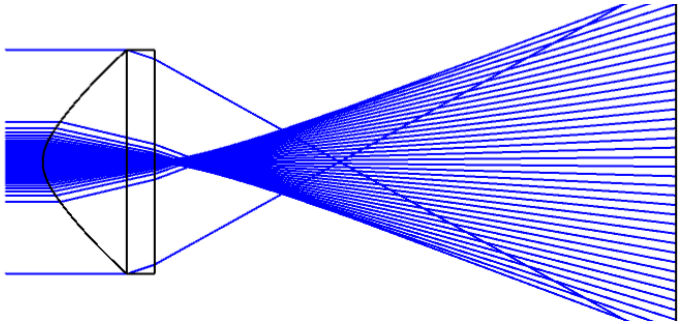
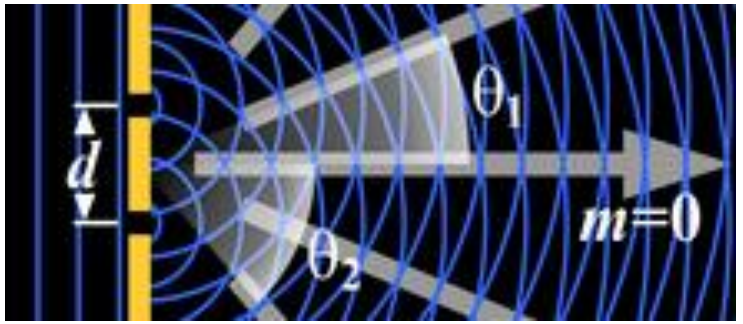
There are multiple ways to generate a top-hat :



Ray tracing

- Classical beam-shapers

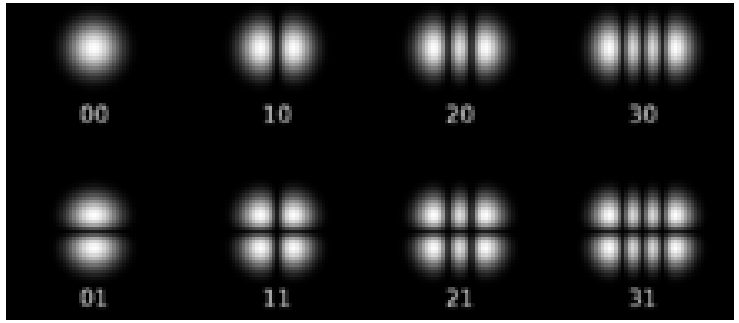
Light is tuned using Fresnel laws



Diffraction

- Diffractive Optical Eléments (DOEs)

Light is tuned using physical optics laws



Mode propagation

- Multi-Plane Light Conversion (MPLC)

Light is tuned using unitary mode transformation

Image credit to Wikipedia and Shape optics

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Multi-Plane Light Conversion
Cailabs' patented, flexible technology for complex light shaping

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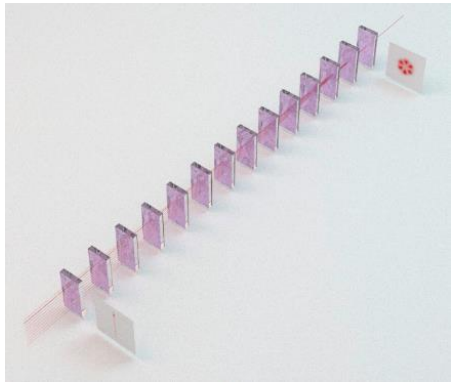
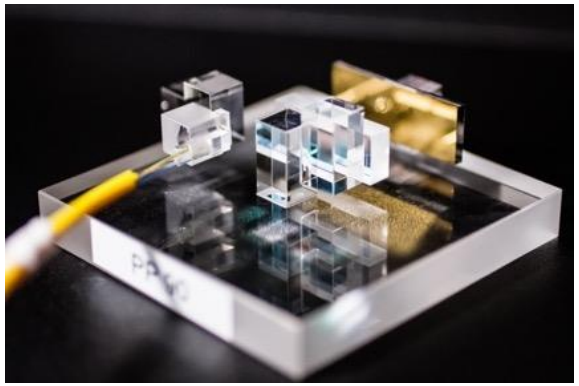
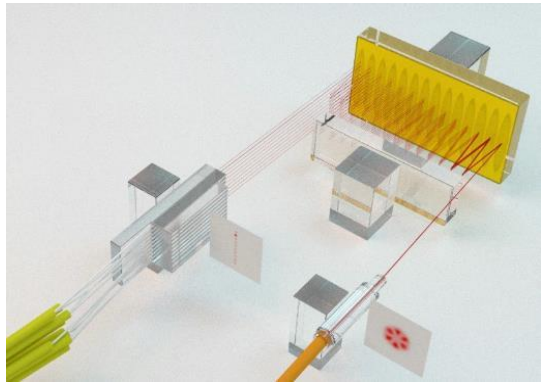
Multi-Plane Light Conversion (MPLC)

- **Free-form beam shaping** through succession of spatial phase profiles and propagation
- **Passive** beam shaping with **no intrinsic loss**
- **Reflective implementation**, can handle high power / energy
- **Multiple beams (free space or delivery fibered)** can be shaped **simultaneously**

➔ **A good candidate for high power or high energy shaping and combining!**







Labroille, G. et al., Optics Express, 22(13), 15599-15607.

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- **Some Ultra-Short Pulse applications of MPLC**
  - Micro chip welding
  - Fresnel-type mold drilling
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  - Hybrid Laser Arc Welding of Steel

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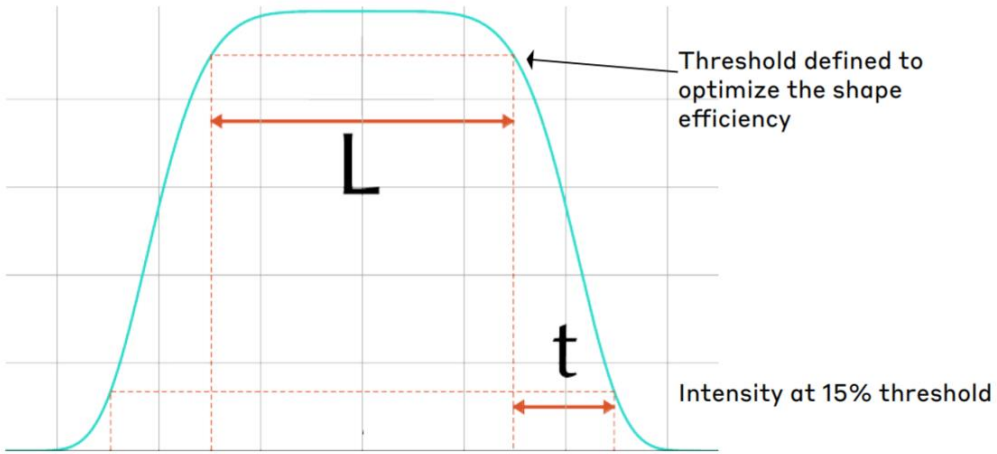
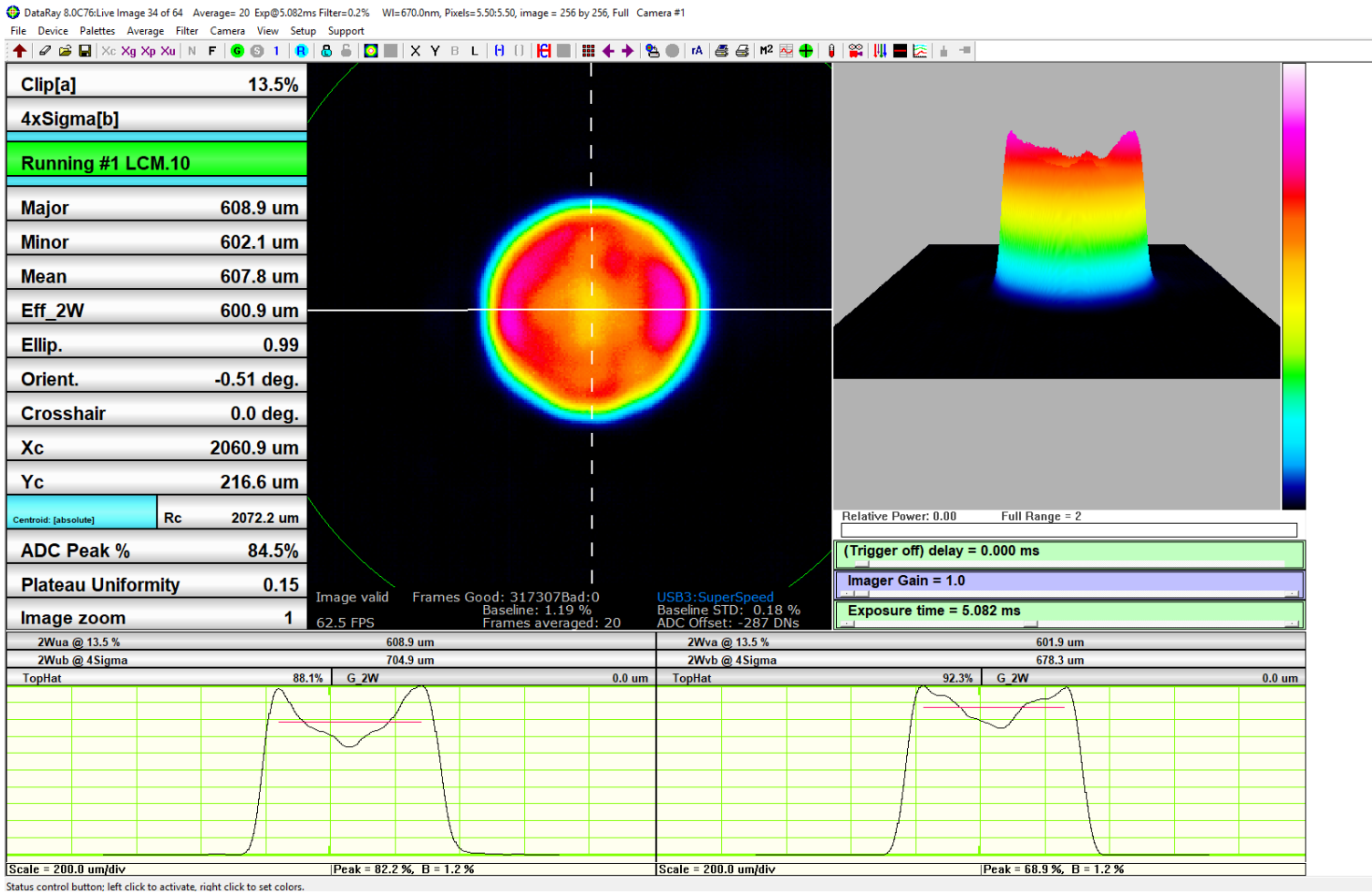
A tailored beam-shaping of high-quality
A tailored shape for an optimal process

Specific tailored shape :

- U-shape plateau
- Sharp edges :
  - t/L = 0,12
  - 15 times sharper than Gaussian beams





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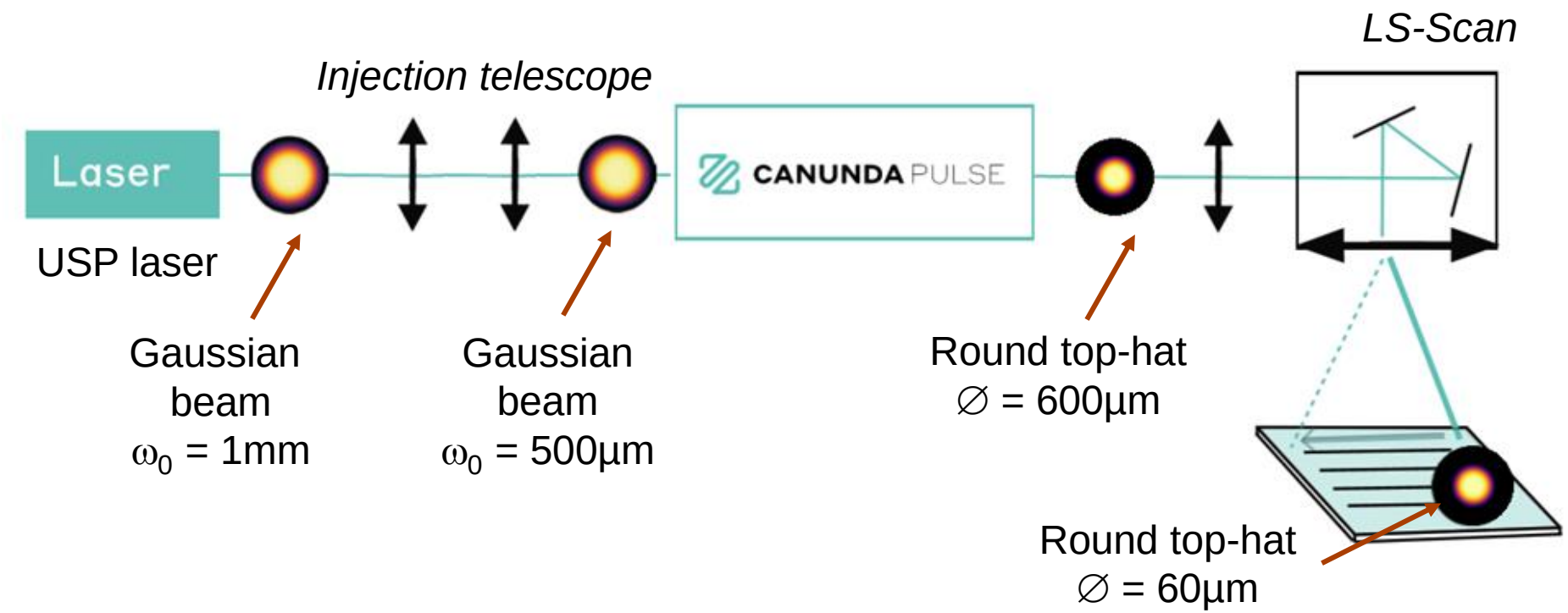
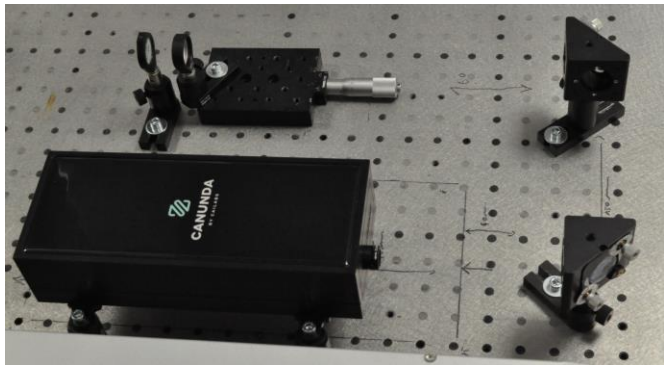
Microship welding with a standard set-up
Compatibility with a scanner and a F-theta

A **60µm tailored-shape beam** is generated with the following set-up:

- **Femtosecond Laser** up to **100µJ per pulse** @ 1030nm
- A **LS-Scan** and a 100mm **F-Theta lens**





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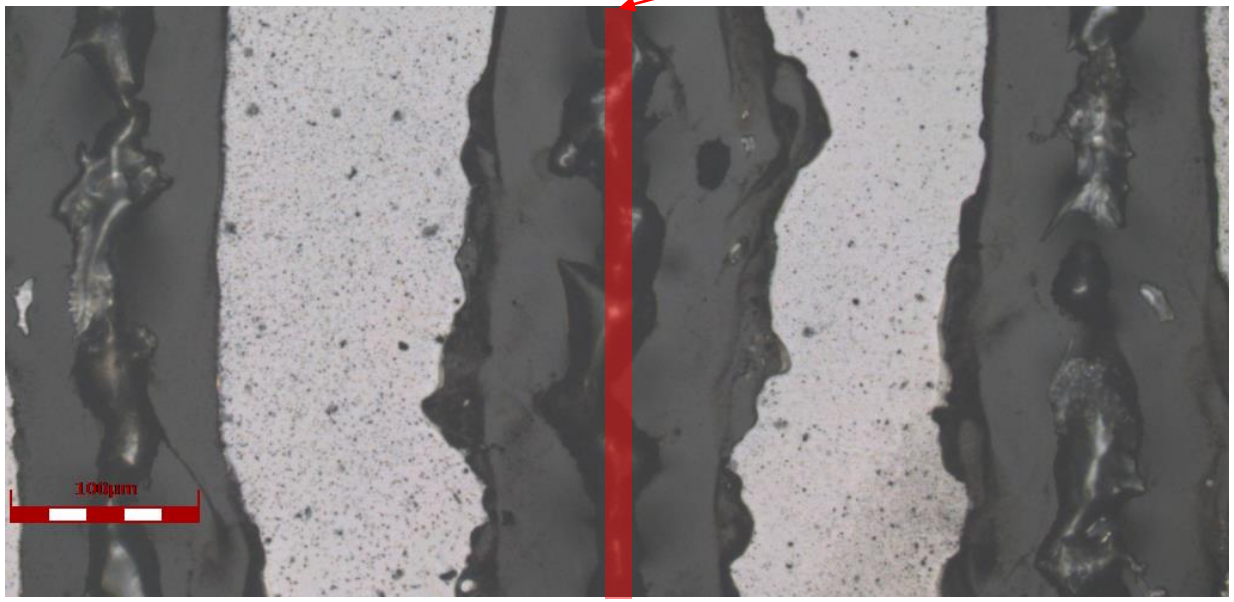
Quality improvement – Microscopic scale
Reduction of the weld seam

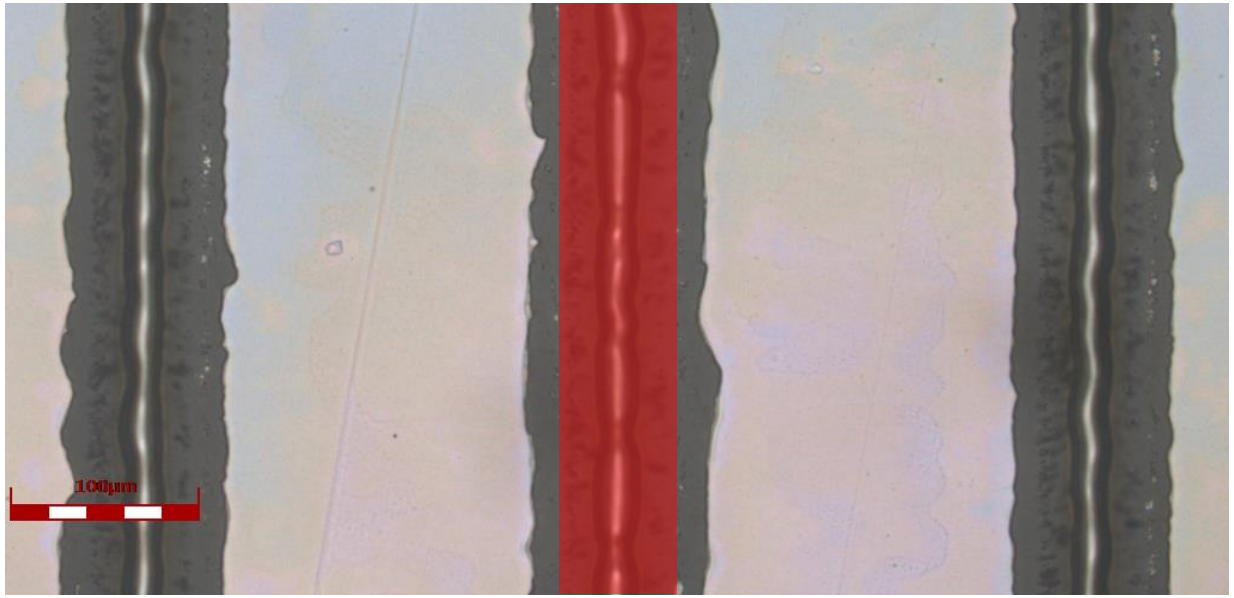
An optimal welding quality obtained for a **scanning speed 9 times higher** compared to Gaussian beam welding : **less than 20 seconds for microchip of 45x7,5 mm²**

The weld seam is reduced compared to Gaussian welding, and the esthetic of the seam is improved

Width of the laser line (in air)



Best welding seam Gaussian beam



Best welding seam with Top-hat beam

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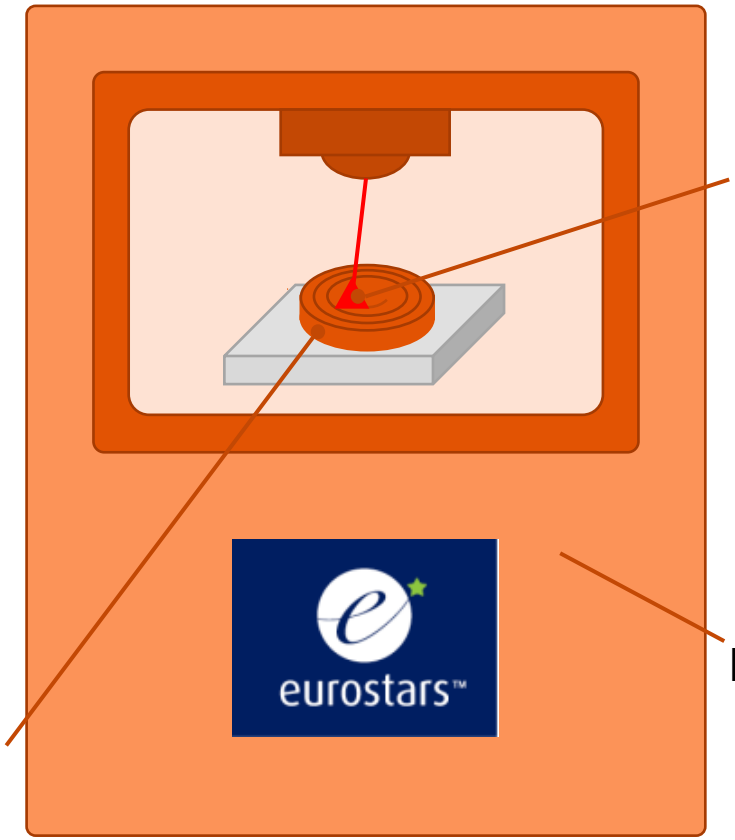
A machine to manufacture molds

Laser processes

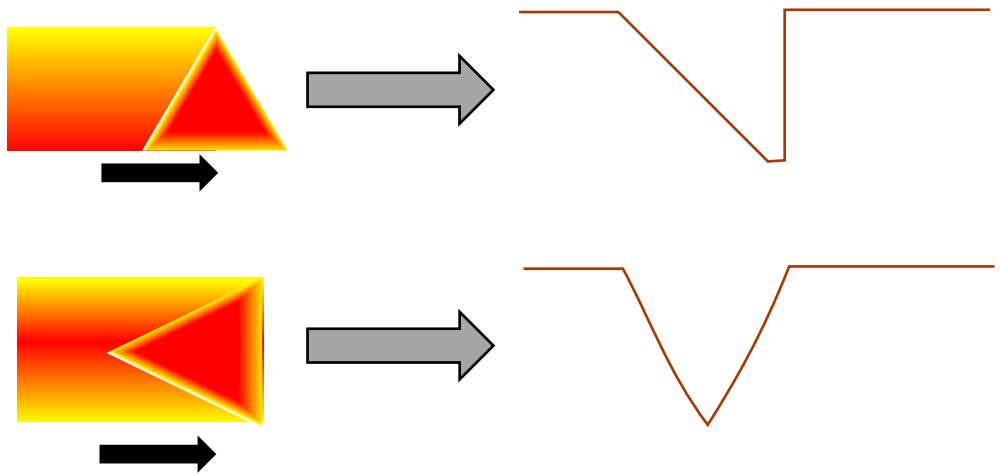
Beam shaping

Injection mold design

Micro-machining integration



- A **triangular shape** enables groove drilling with an adjustable angle.
- The **shape of the groove** depends on the relative angle between the triangle and the moving direction of the spot.
- The **position of the maximum depth** can be defined by the rotation of the triangle.



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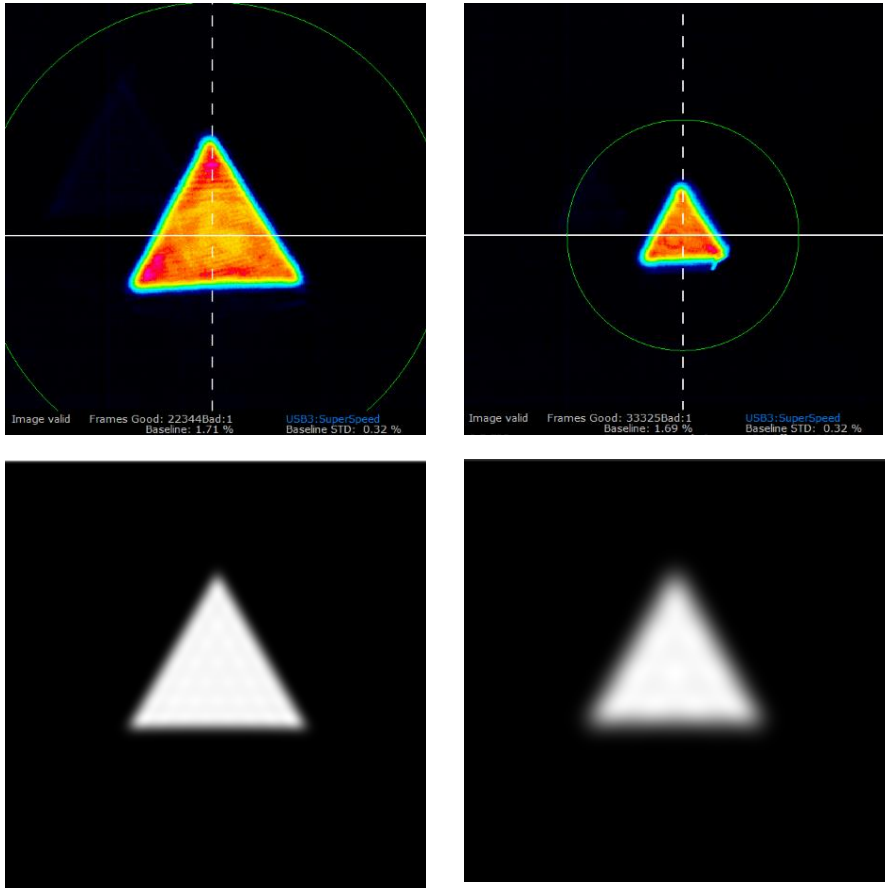
A high quality optical system

A triangular high quality beam shaping

- 500 µm and 1000 µm width output of module
- 10 and 20 µm width in the process plane
- 20 µm triangle : sharpness 0.1 / DOF 20 µm
- 10 µm triangle : sharpness 0.2 / DOF 9 µm



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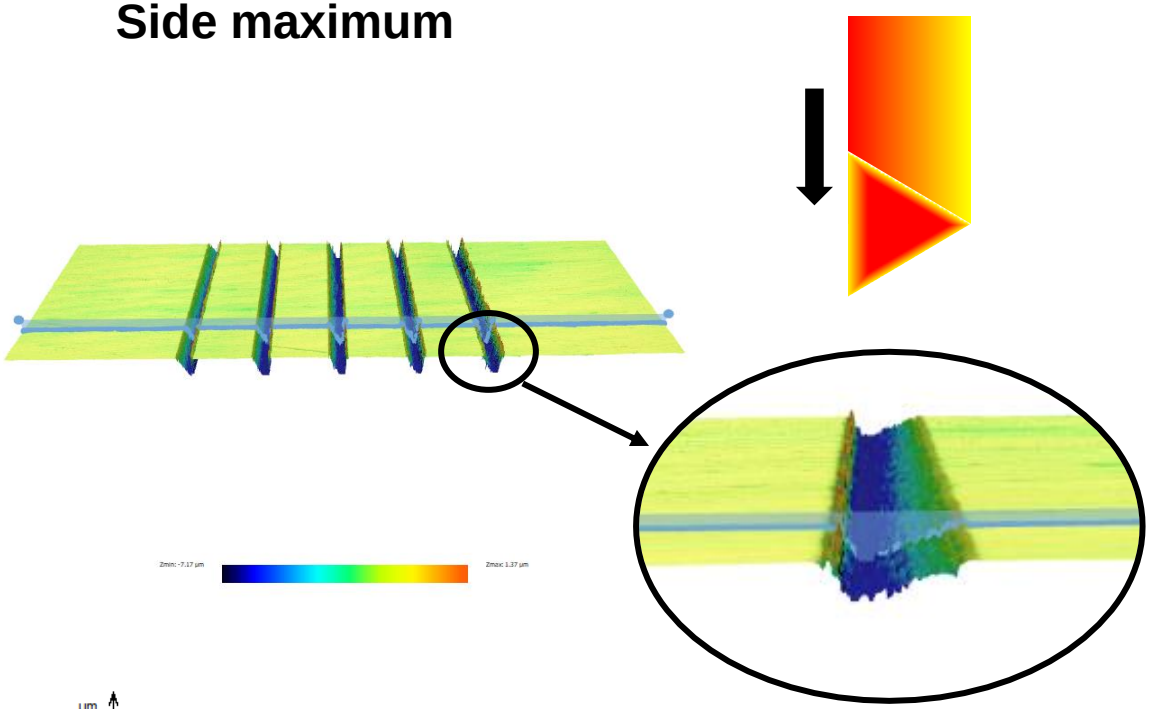
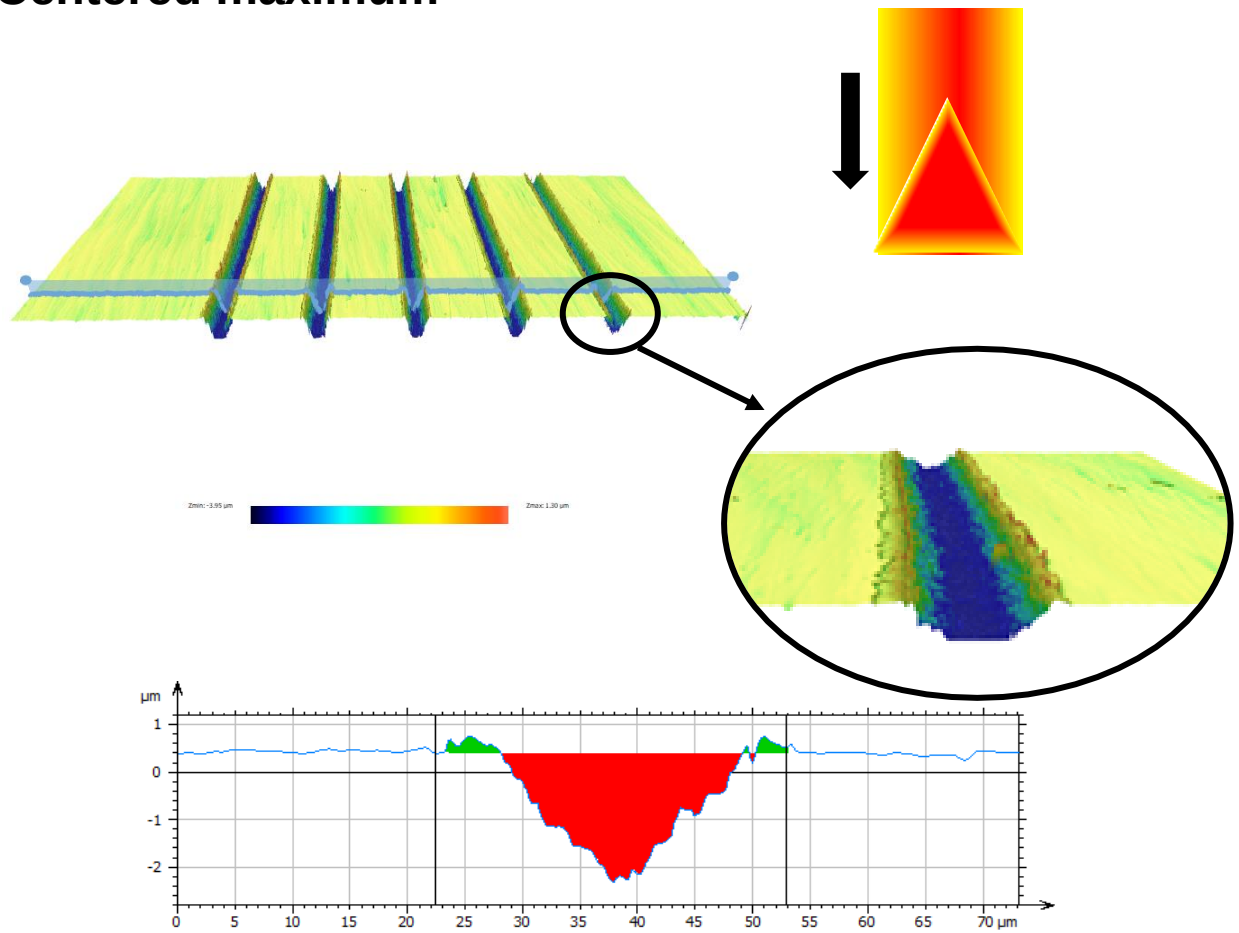
Maximum depth adjustment position tuning

Side maximum



Centered maximum



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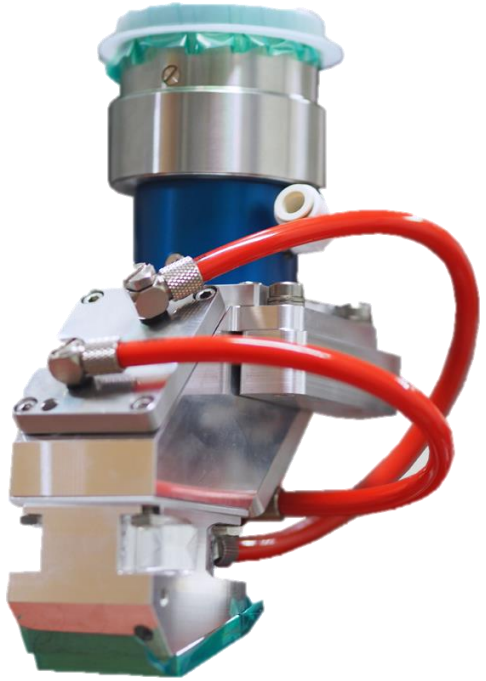

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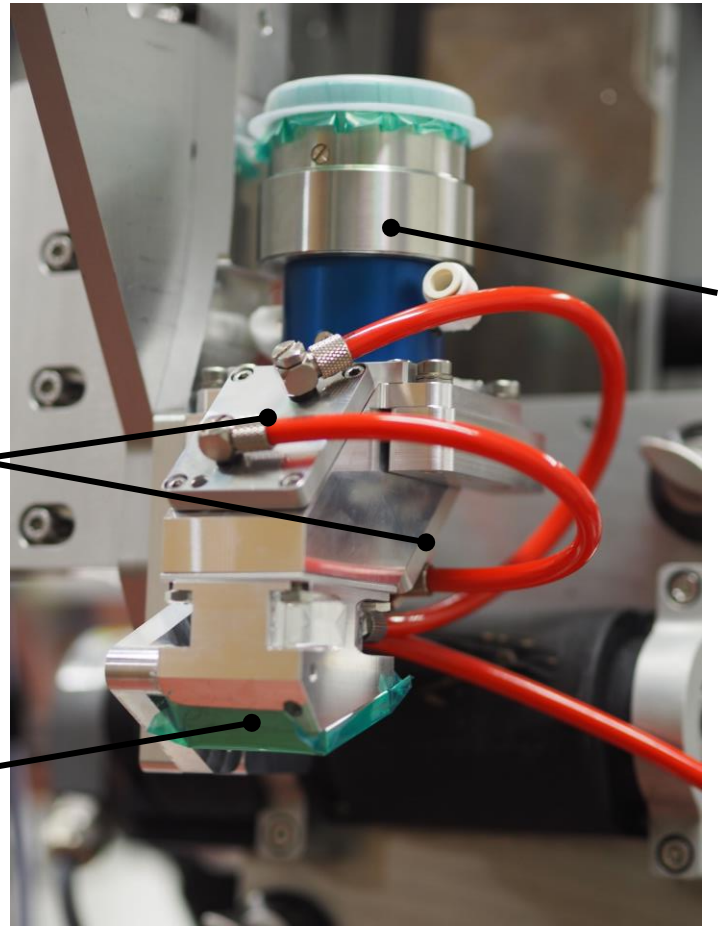
A laser head in an industrial environment

A fully integrated design with only reflective optics



A compact system

- Weight : 1 kg (including connector)

Integrated in an industrial environment

- Diode laser from Laserline LDM-6000 (100mm.mrad, 1000µm fiber diameter)
- Ready to use with no optical adjustment

Providing a rectangular top-hat : <3% homogeneity

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Composite Fiber Placement process tests
A high compactness laser-head

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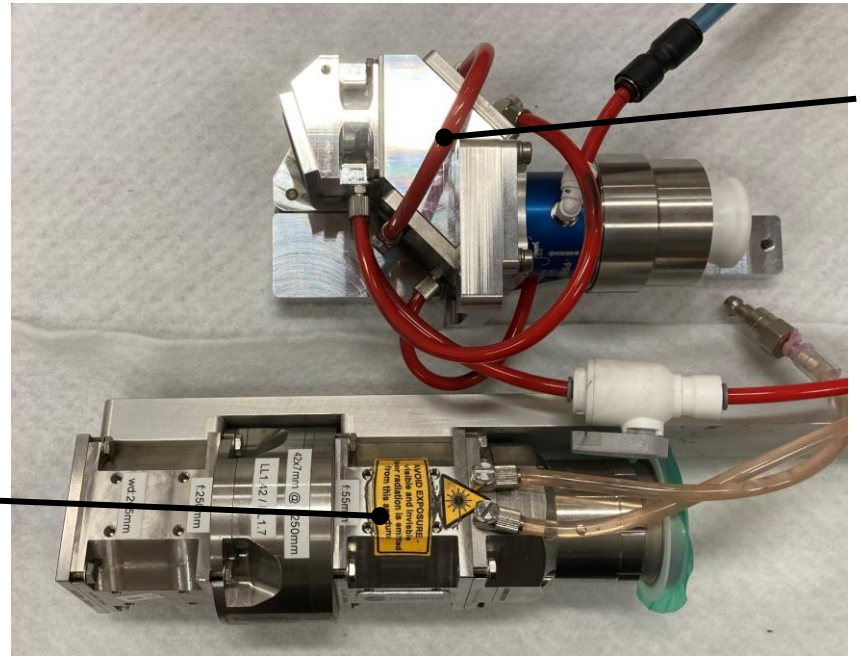
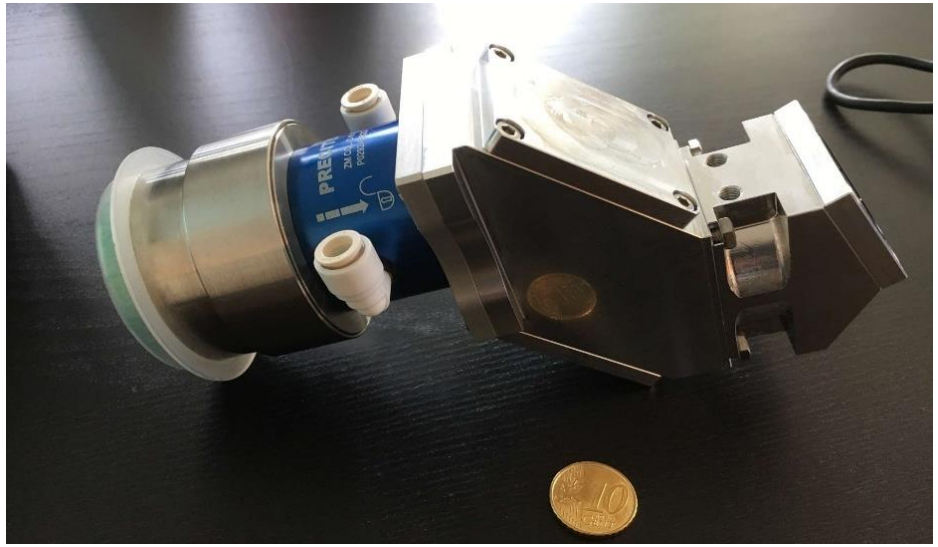
The compact laser head is fitting well the composite fiber placement machine and integrated on the robot arm. It enables drapping of **highly curved parts.**

The beam-shaper is **2,5 times more compact** compared to previous solutions.





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Composite Fiber Placement process tests
High quality drapping

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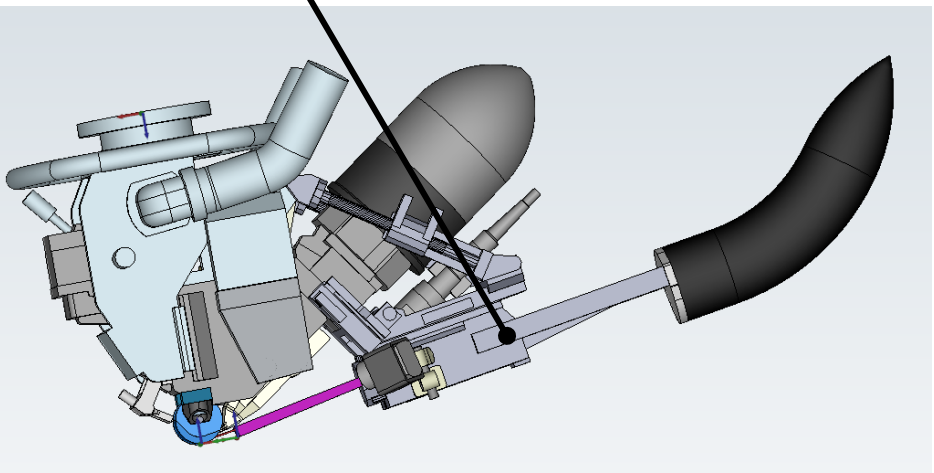
Lower volume of the optics allows the manufacture of **more complex parts**

reference



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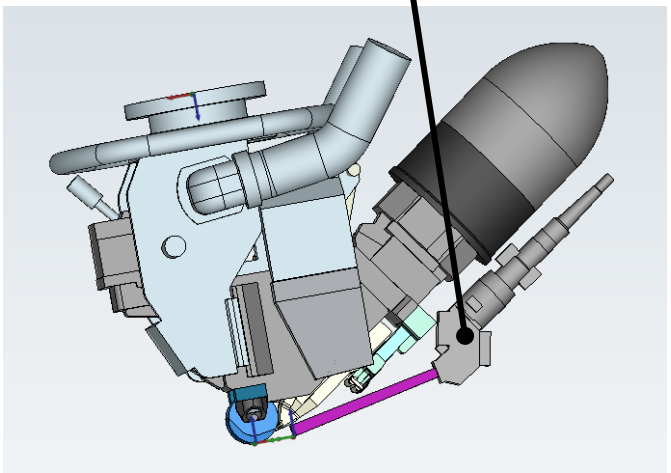

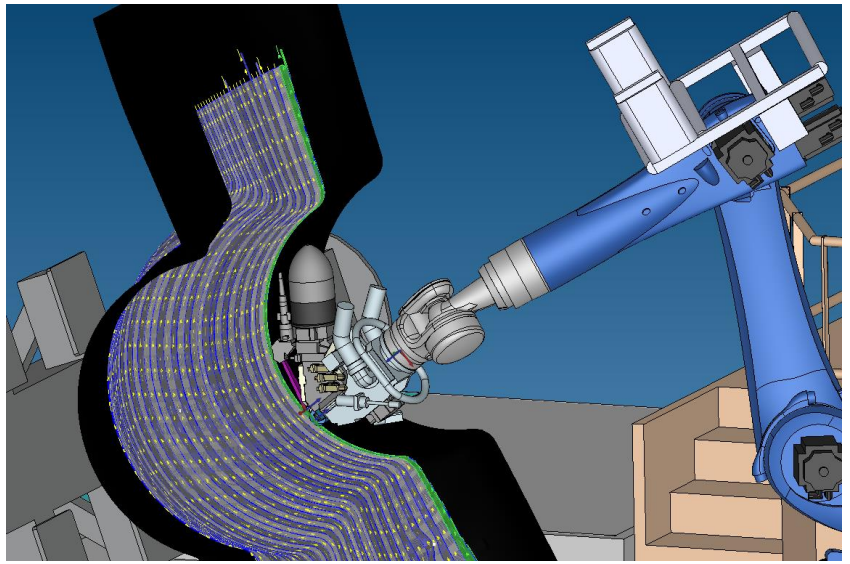

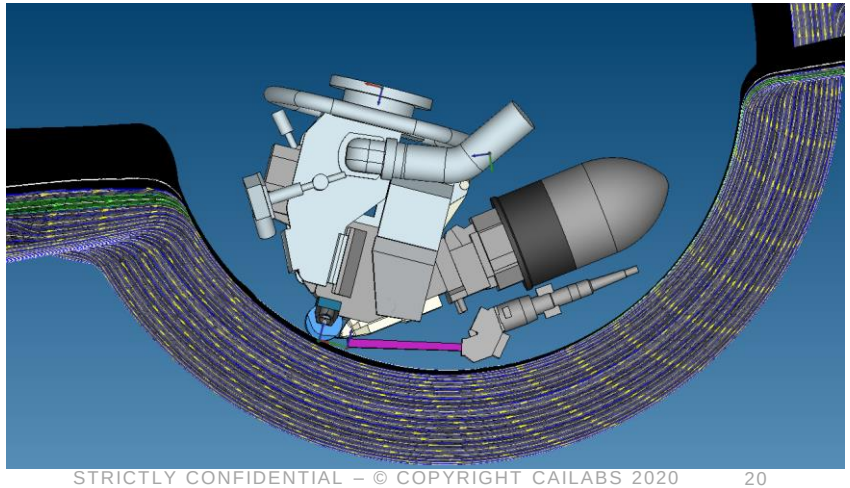

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INSTITUT MAUPERTUIS
TECHNOLOGIES INDUSTRIELLES INNOVANTES

- Some Ultra-Short Pulse applications of MPLC
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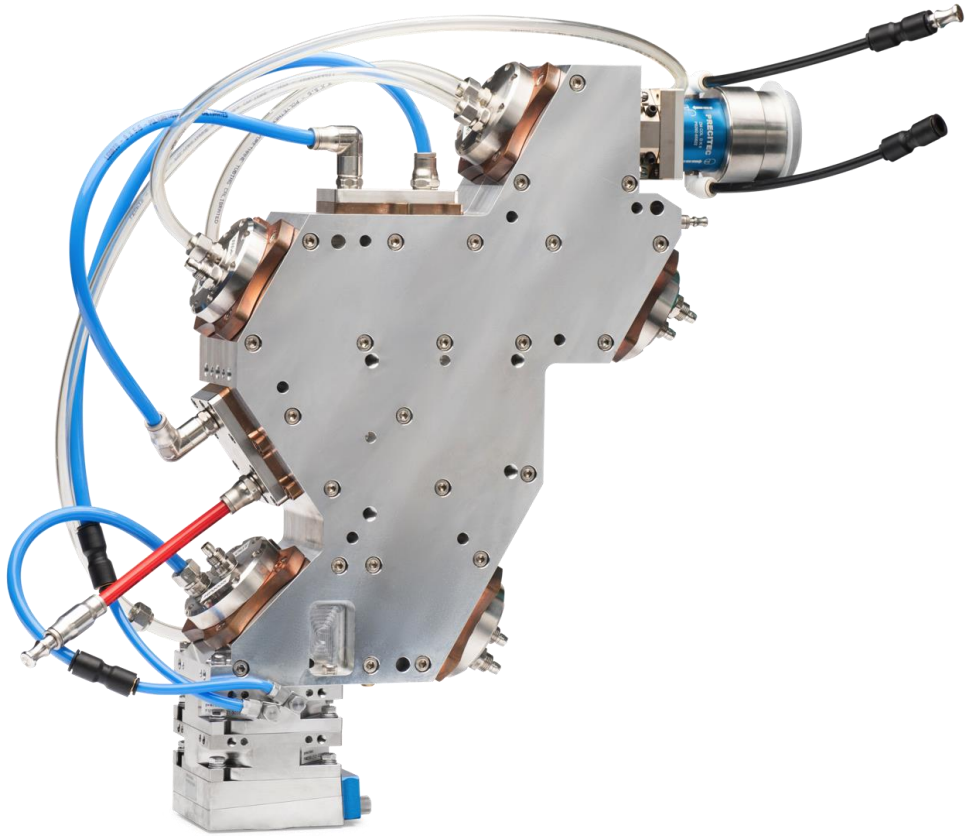

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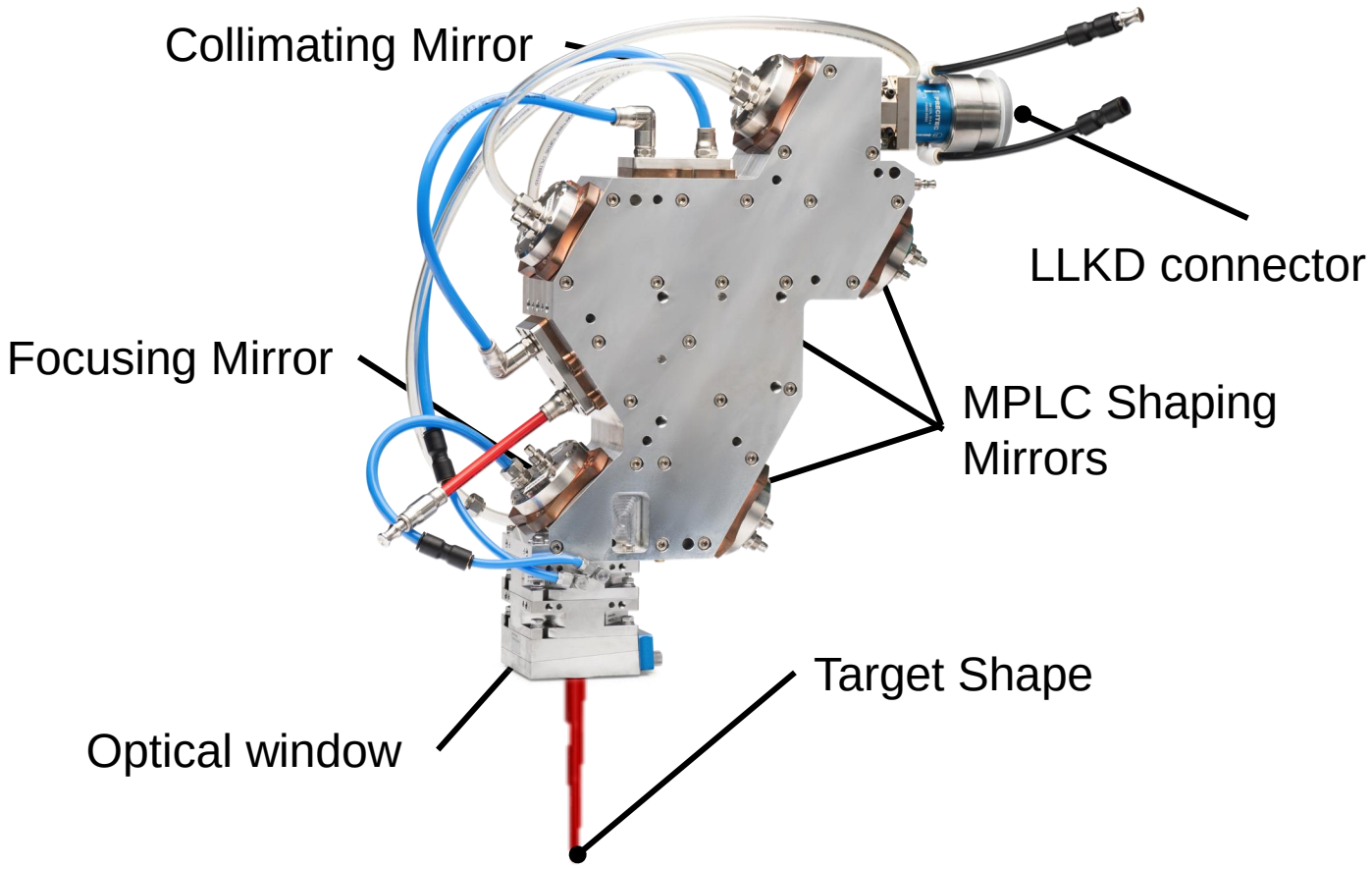
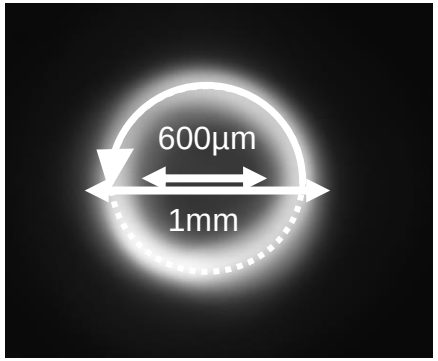
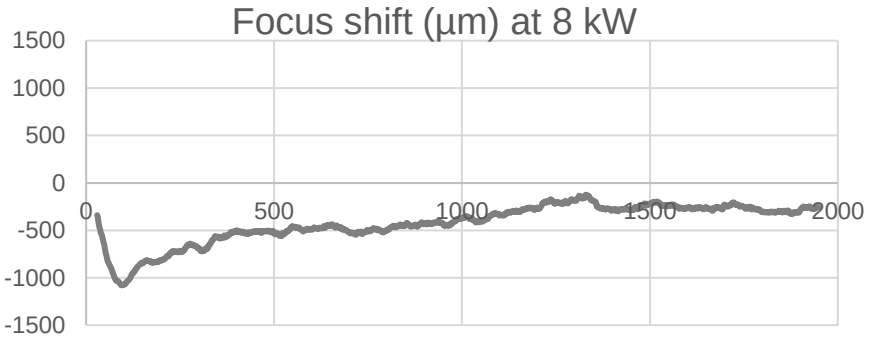
Beam shaping in a laser head
A fully integrated design with only reflective optics



An annular high quality beam shaping



A stable operation up to **16kW with a reduced focus shift (<1mm)**



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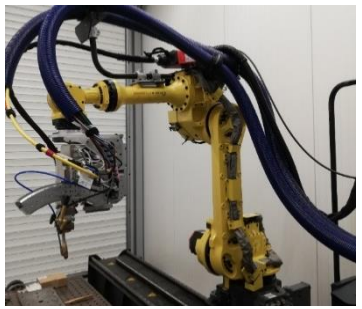
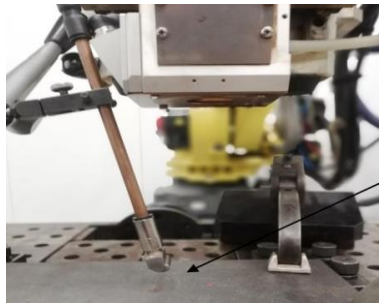
Hybride Laser Arc Welding process tests
A laser-head already compatible with arc welding

In order to increase the penetration depth, the Laser head has been **combined with Arc Welding.**

Welding tests on **S355 steel** plates (**t=28mm**)

- **16kW** input laser power, **0.8m/min** welding speed
- **Arcal Force** (82% Ar – 18%CO_2) shielding gas
- G3Si Ø1,2mm wire metal, 2mm wire-laser distance
- Compressed air @ 0,2MPa for plasma suppression

16 kW laser @1.03µm	6 axis robot on rail system	Plasma Plume suppression
		

S355 Steel welding

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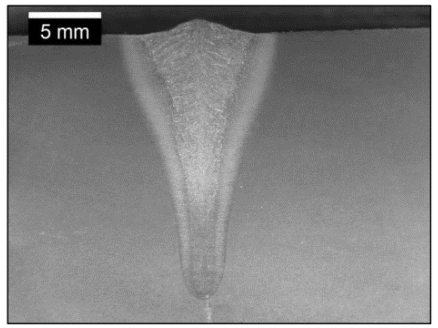
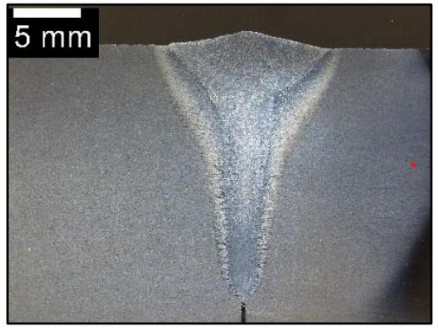
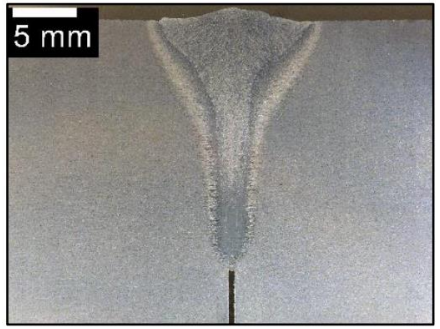
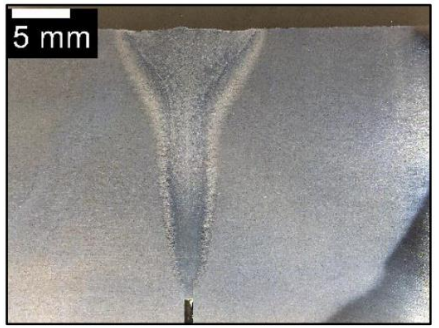
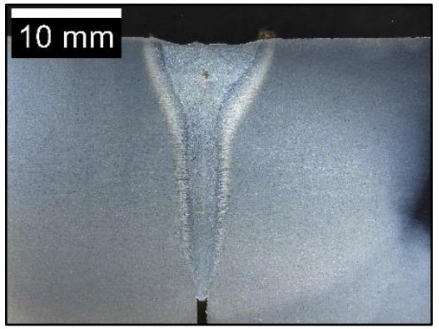
But joint HLAW process tests
Capability to weld up to 0,7mm gap

HLAW with a **0 to 1 mm** gap : A gap tolerance **up to 0.7 mm – x9 process speed vs. Arc alone**

0,0mm gap	0,3mm gap	0,4mm gap	0,7mm gap	1mm gap
				
Depth of penetration: 18.0mm	Depth of penetration: 19.0mm	Depth of penetration: 19.5mm	Depth of penetration: 23.3mm Undercut: 0.22mm	Depth of penetration: 24.0mm Porosity Ø0.42mm Undercut: 0.7mm
Compliant	*Compliant*	*Compliant*	*Compliant*	*Non-Compliant*

Macro examinations of welds

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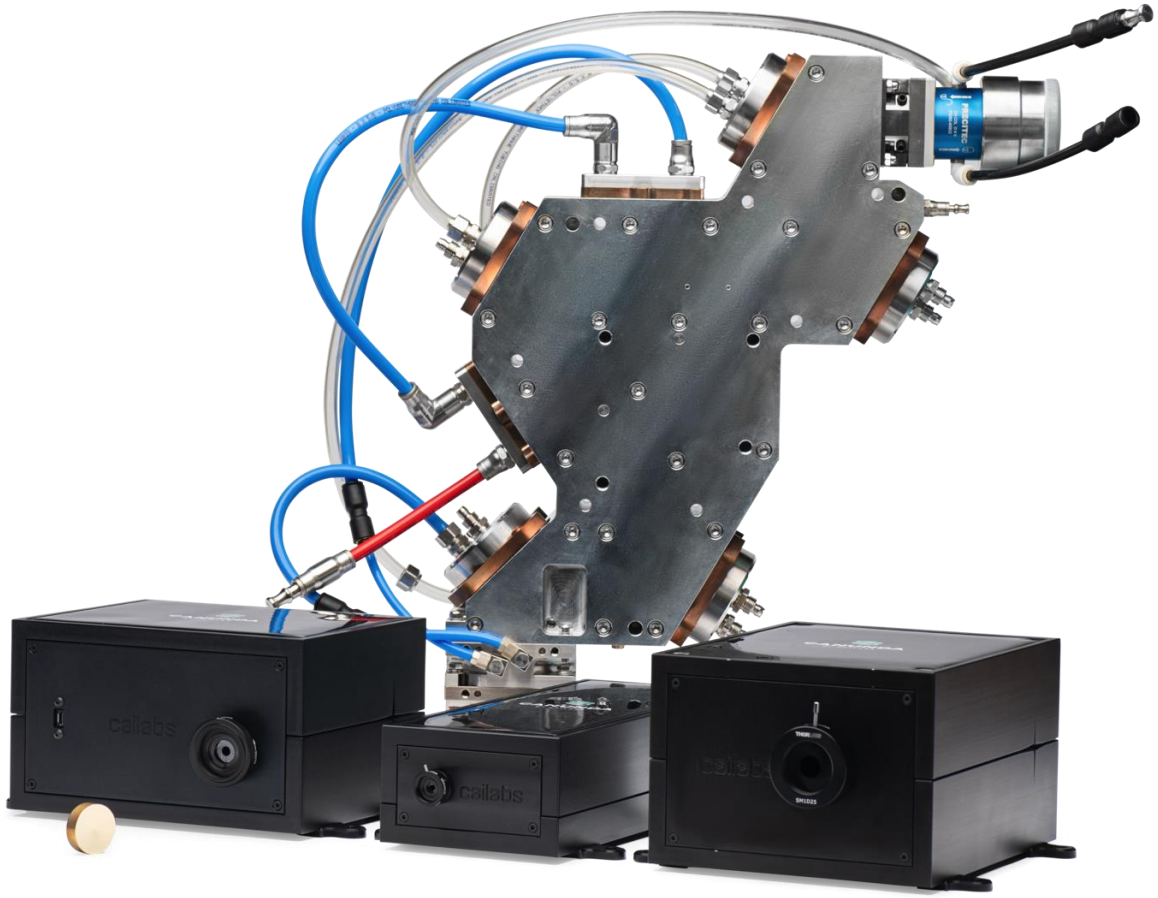
What are the next steps?



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What message to take home?
A tailored beam-shaping to improve micro and macro processes

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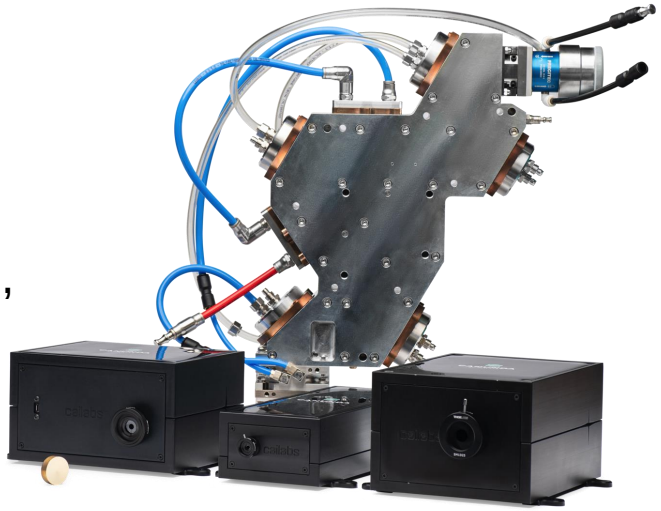
- MPLC technology has proven to be a breakthrought for mutiple applications :
  - Micro-welding using a **U shape**
  - Triangular gutters drilling using a **triangular shape**
  - Complex Automated Fiber Placement using a **rectangular top-hat**
  - HLAW thick plates welding with a **ring shape**
- Multiple development are on-going :
  - **Flexibility of the shaping** : splitting and shaping, shape switching, shape rotation, dynamic shaping…
  - **High energy/power handeling** (>kW fs / >24kW CW)
  - **And new wavelengths** : green and UV !

cailabs SHAPING THE LIGHT



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