Ultrashort Laser applications on Chem-Milling products

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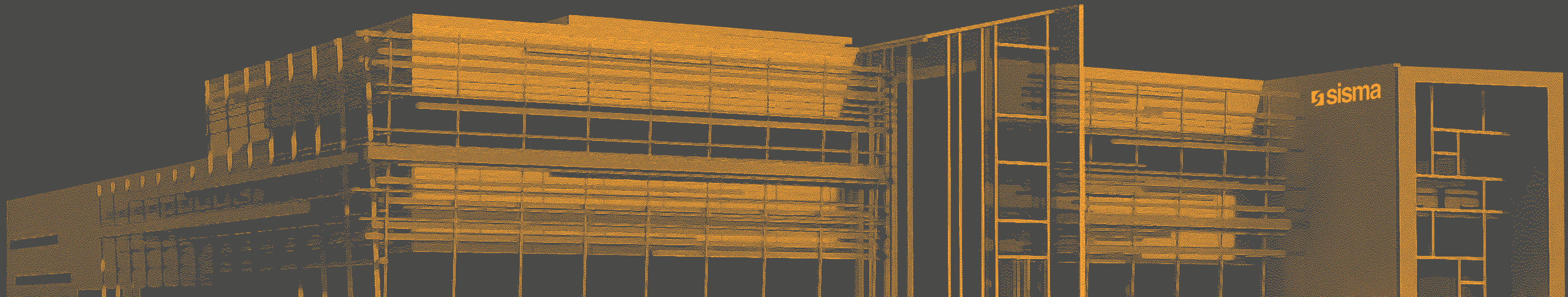
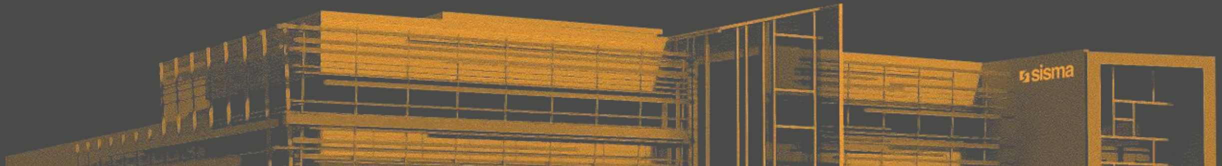


SISMA company

More than 60 years of experience

Branches, distributors and subsidiaries in more than 80 countries worldwide

More than 200 employees for over 100 models of machinery



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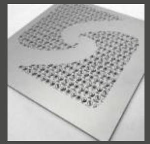
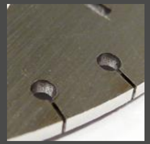
SISMA technological competences

Precision machining

Chain making machines

Laser technology

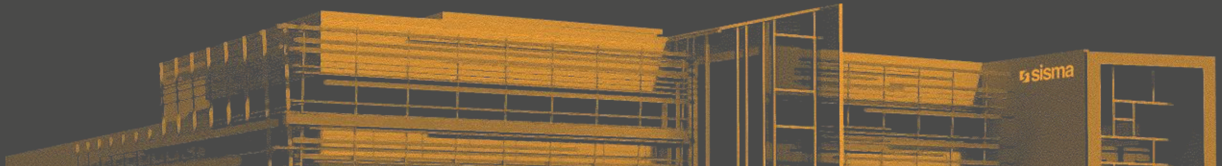




Laser marking, engraving, welding and cutting systems

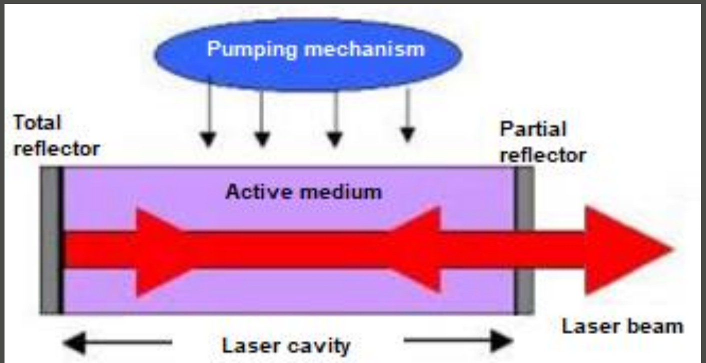
Additive manufacturing

3D powder metal printers



What is a laser?

A laser (Light Amplification by Stimulated Emission of Radiation) is a device able to supply coherent, low-divergence and monochromatic beam of light, with wavelength ranging from ultraviolet (UV) to infrared (IR); such unique properties are not feasible with other light sources.



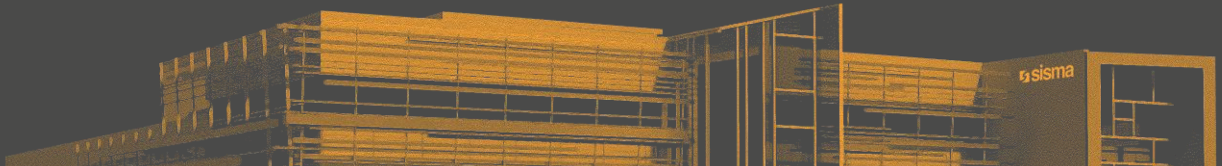
<u>Laser key parameters when buying a laser:</u>

Wavelength: colour of the laser, important for material absorption

Pulse duration: from CW to fs, important for laser-material interaction time

Average power, peak power and pulse energy: measure of the impact of the laser on the material

Intensity (irradiance): linked to the way laser power/energy is focused (concentrated) on the sample



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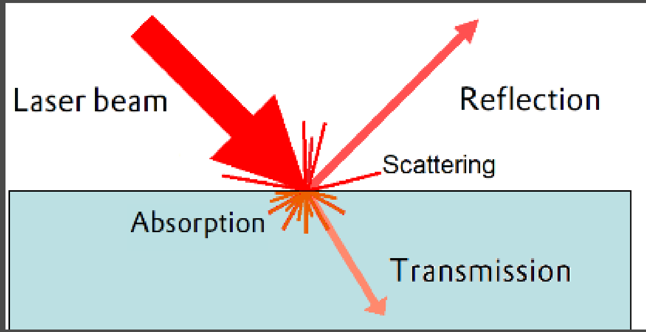
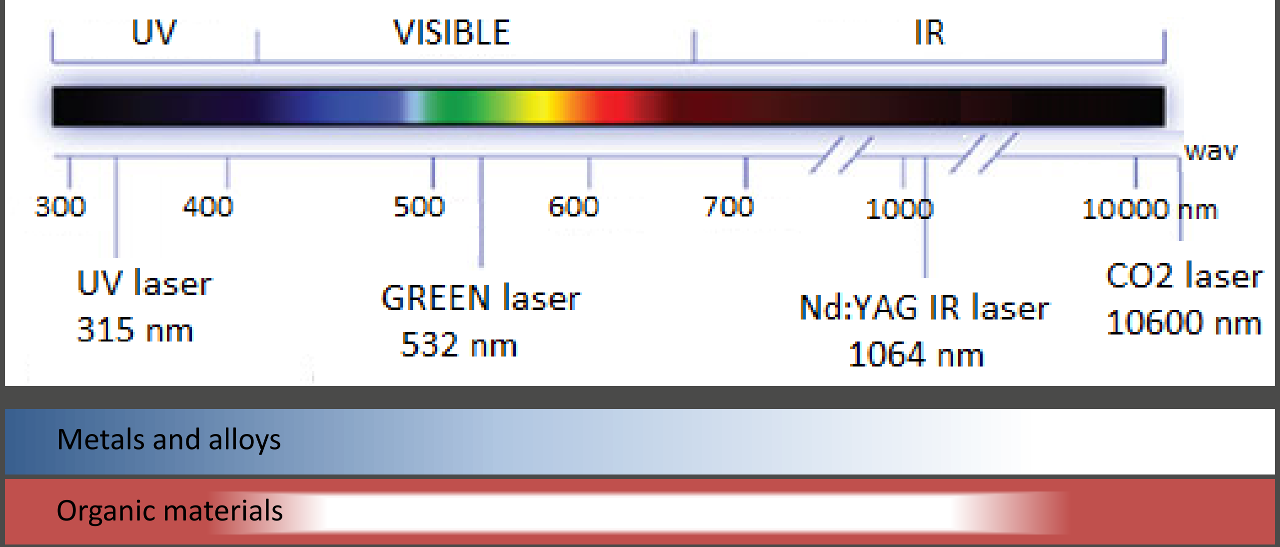
Laser beam and interaction with matter

Lasers cover most electromagnetic spectrum, allowing processing a big range of materials, according to their absorption spectrum.

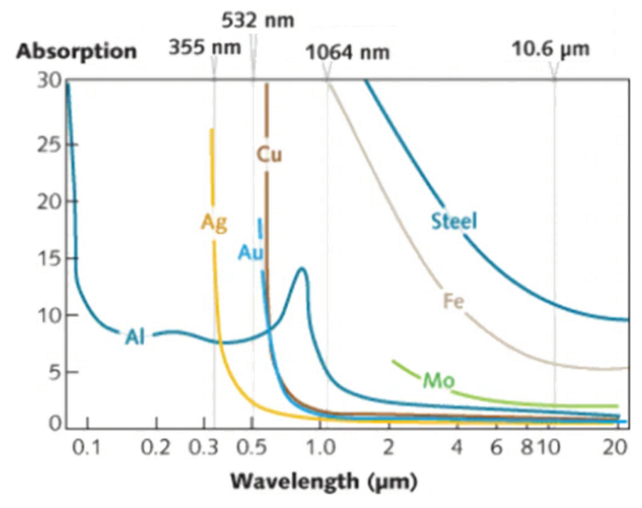
Metal absorbance is high in the UV, and it decreases with wavelength, being very low towards mid-IR. For organic materials, laser absorbance is high in UV and mid-IR, and very low in the visible and near-IR.

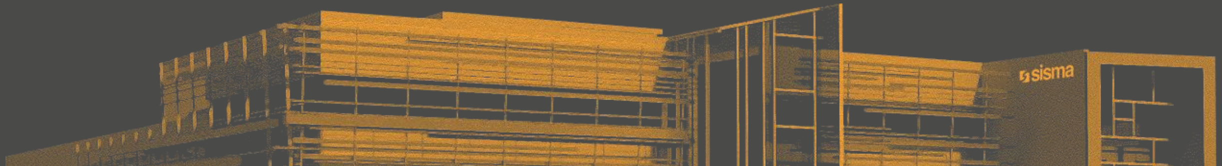
Best yield is when laser wavelength matches material peak absorption.





Material absorption rate



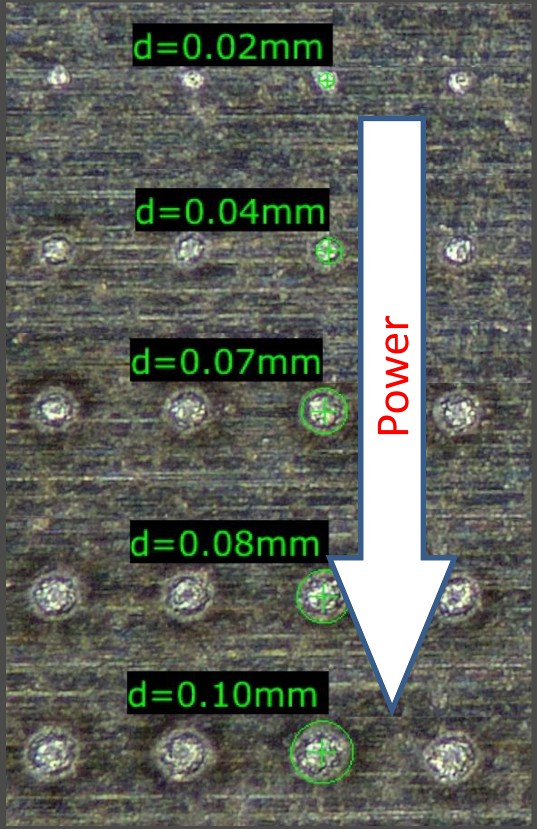


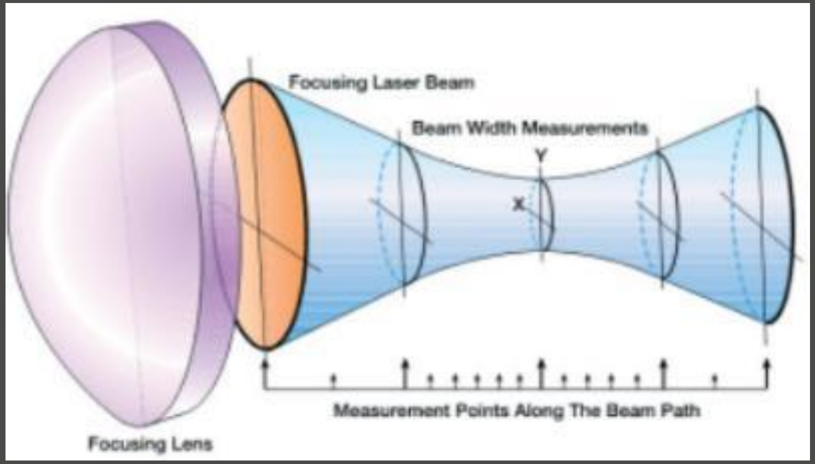
Laser spot size

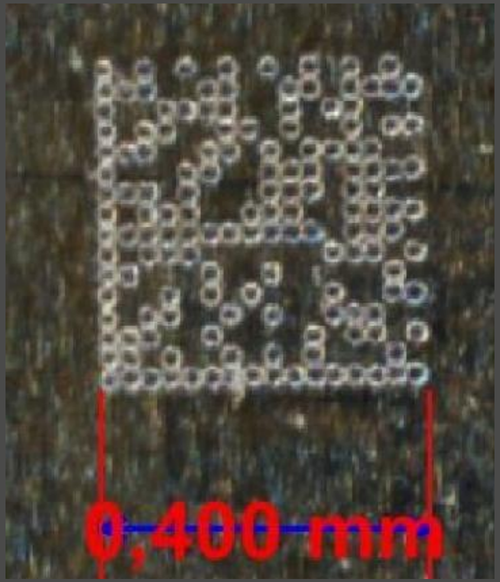
When a laser beam passes through a focusing optical lens, light is concentrated on a tiny spot. Its minimum diameter is found at the optical system focal distance, and its value mainly depends upon:

- lens focal length
- laser wavelength
- laser power
- pulse duration
- material properties

$$d_{spot} = \left(\frac{4\lambda}{\pi}\right)\left(\frac{f}{D}\right)M^2$$







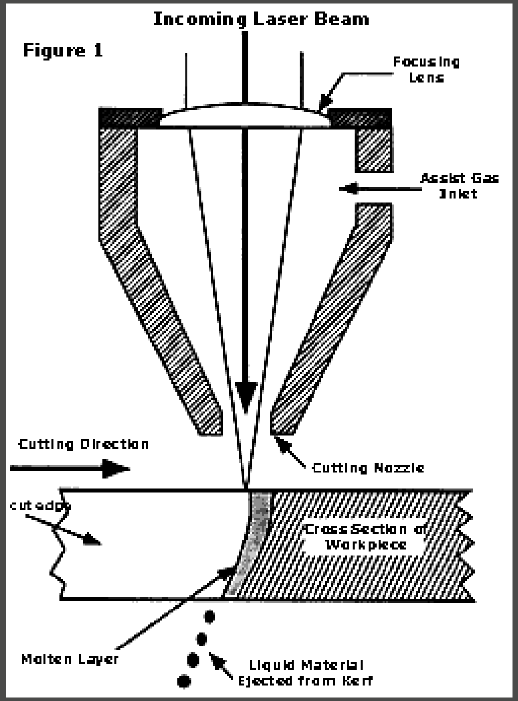
Instrumentation:
- 3 W UV ns laser
- 30 W fiber laser

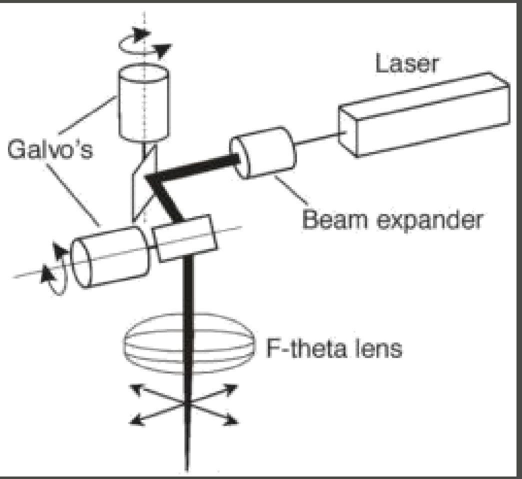
Laser delivering and focusing system

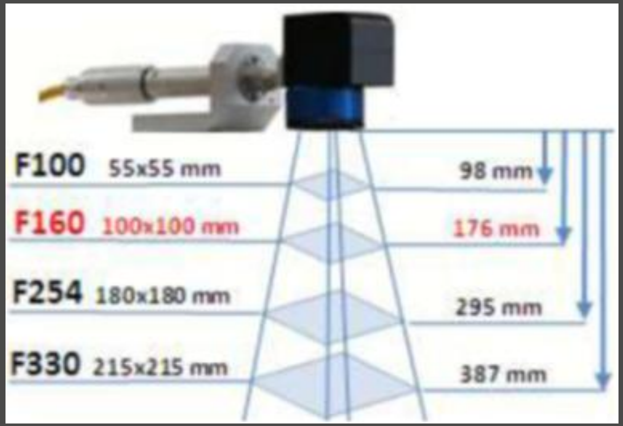
There are two methods to guide and focus a **laser beam** to the desired position of the material surface:

1. with a focusing optical head mounted on a mechanical handling system (used in Cartesian cutting machines). The laser beam is collimated and focused with a **lens** placed very close to the surface.

2. with **galvanometer scanning optical head** and f-theta lens. Optical head is fixed as **extremely precise and fast** galvanometric mirrors steer the laser beam to follow a user-defined path. Lens is far from the sample, reducing laser energy density compared to case 1.







Metal cutting with fixed cutting head

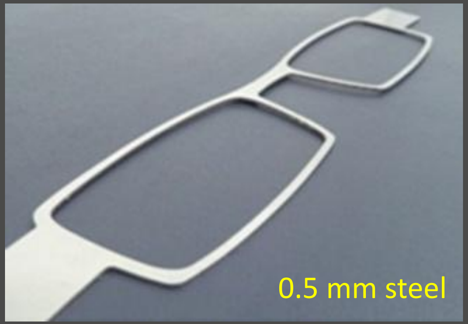
With lens very close to sample, metal cutting is done by gas-assisted laser pressure-induced **fusion** process. Handling of the optical head is mechanical, not particularly fast, and subject to the **loss of focus and efficiency** when moving away, even slightly, from the focus position

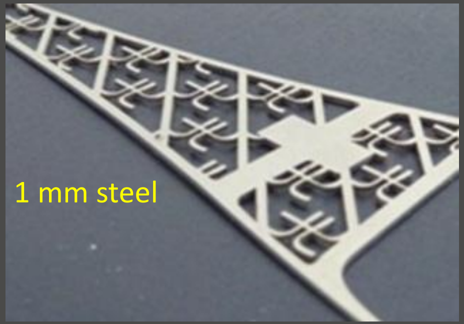
→ need of capacitor sensor to keep nozzle-to-metal constant (around 0.5 to 1 mm).

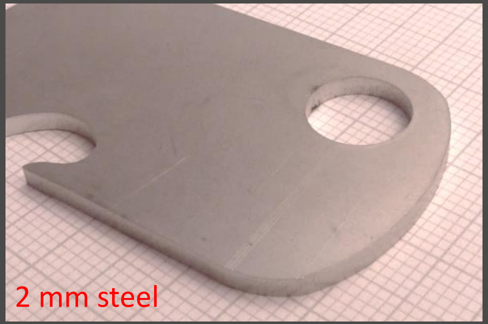
→ usable only for metals

Laser cutting is clean and made by one pass even for thick metal samples.

Fiber lasers working in dual-mode (CW and QCW) can cutting all metals, even those with highly-reflecting (e.g. bronze, copper, silver…).



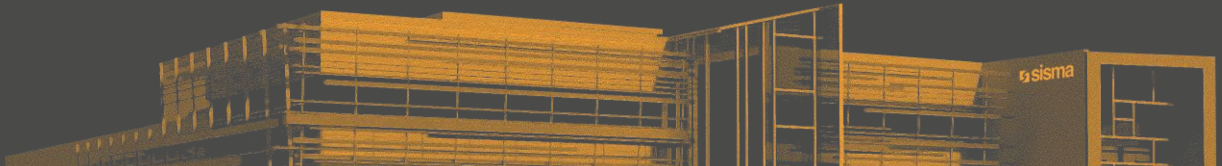




Instrumentation:

- 450/4500 W fiber laser

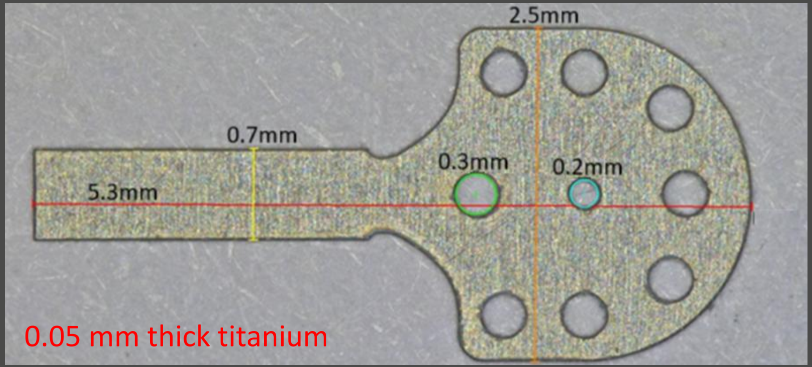
Better performance if machine supplies Nitrogen and Oxygen gases.



Metal cutting with galvo head (remote cutting)

With a scanning head, distance lens-to-sample is higher, and metal cutting occurs on **ablation** (phase transformation from solid to gas). This solution requires longer processing times and it is not suitable for thick samples, but it is cheaper and structurally simpler. Moreover, it offer several other advantages:

- No mechanical movement
- Tolerance on the focal distance
- Beam wobbling available
- Around 30 µm spot size
- Combination with other laser processes (e.g. marking, engraving)



0.05 mm thick titanium


0.5 mm brass

1 mm aluminum

<u>Instrumentation:</u>
- 50 to 100 W fiber laser

Multiple laser processes with just one machine

0.5 mm brass marking and cutting

1 mm aluminum engraving and cutting

Instrumentation:

- 100 W MOPA fiber laser

Laser processing with fiber lasers (ns pulses)

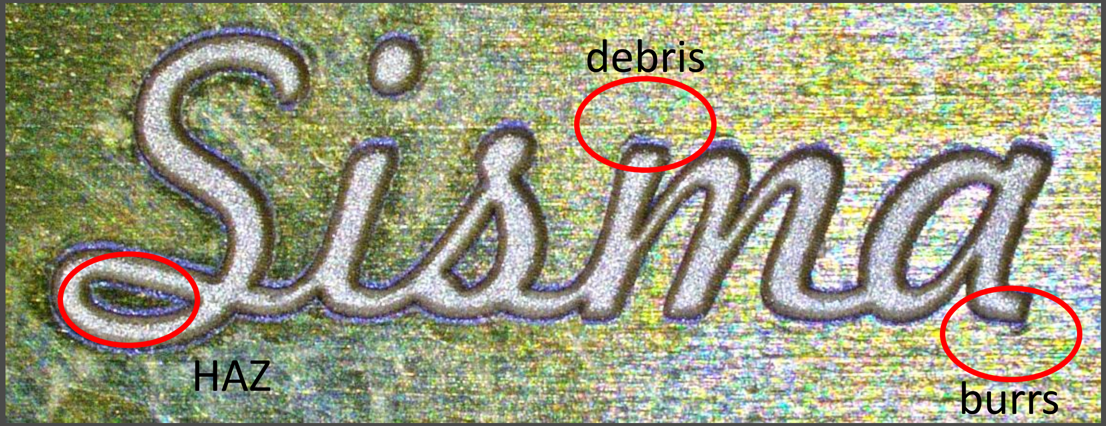
Standard commercial fiber lasers operate in fixed-duration ns pulse mode (~100 ns FWHM), while more advanced MOPA version allows adjusting pulse duration from hundreds down to few ns.

The result of a ns laser processing (cutting, engraving, marking) can be aesthetically and functionally unacceptable by high-end customers, where only minor or no post-processing is permitted

Outcome can show heat affected zone (HAZ), debris and burrs → **post-processing** required.

Brass engraving with standard ns laser

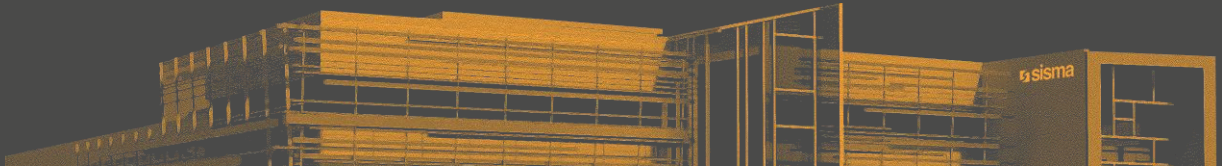
Brass engraving with MOPA ns laser



	Speed	Quality	Price
Standard ns	High	Low	$
MOPA ns	High	Medium	$$
Ultrashort	Medium	Very high	$$$$

Ultrashort pulse lasers (ps/fs) solve these problems.

Instrumentation:
- 20 W MOPA fiber laser
- 20 W fiber laser



Advantages of ultrashort laser pulses (ps and fs)

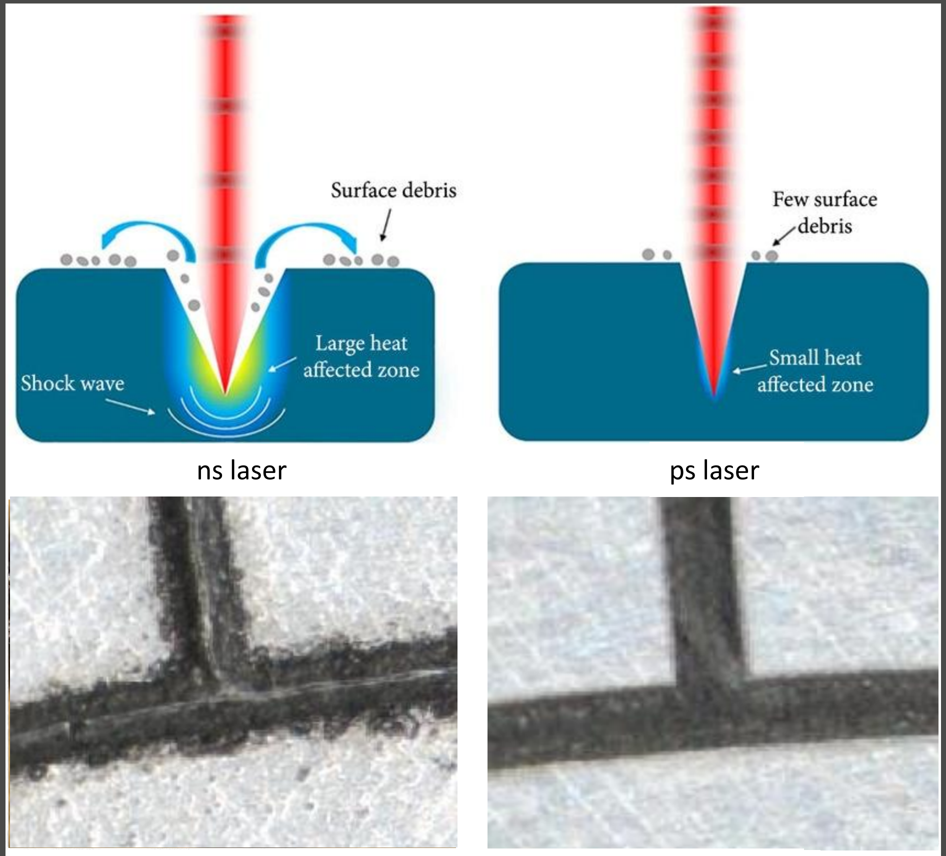
When laser pulses are shorter than few ps, you can have the following advantages:

- ✓ "Cold" ablation process
  - → HAZ-free
  - → no burr
  - → sharper side walls
  - → lower roughness

  } *accuracy*
- ✓ Processing of (semi-)transparent materials } *flexibility*
- ✓ Usable on end-products!
  - → no post-processing needed
  - → higher-quality outcomes

  } *time & money savings*

Main disadvantages are higher cost and lower laser power



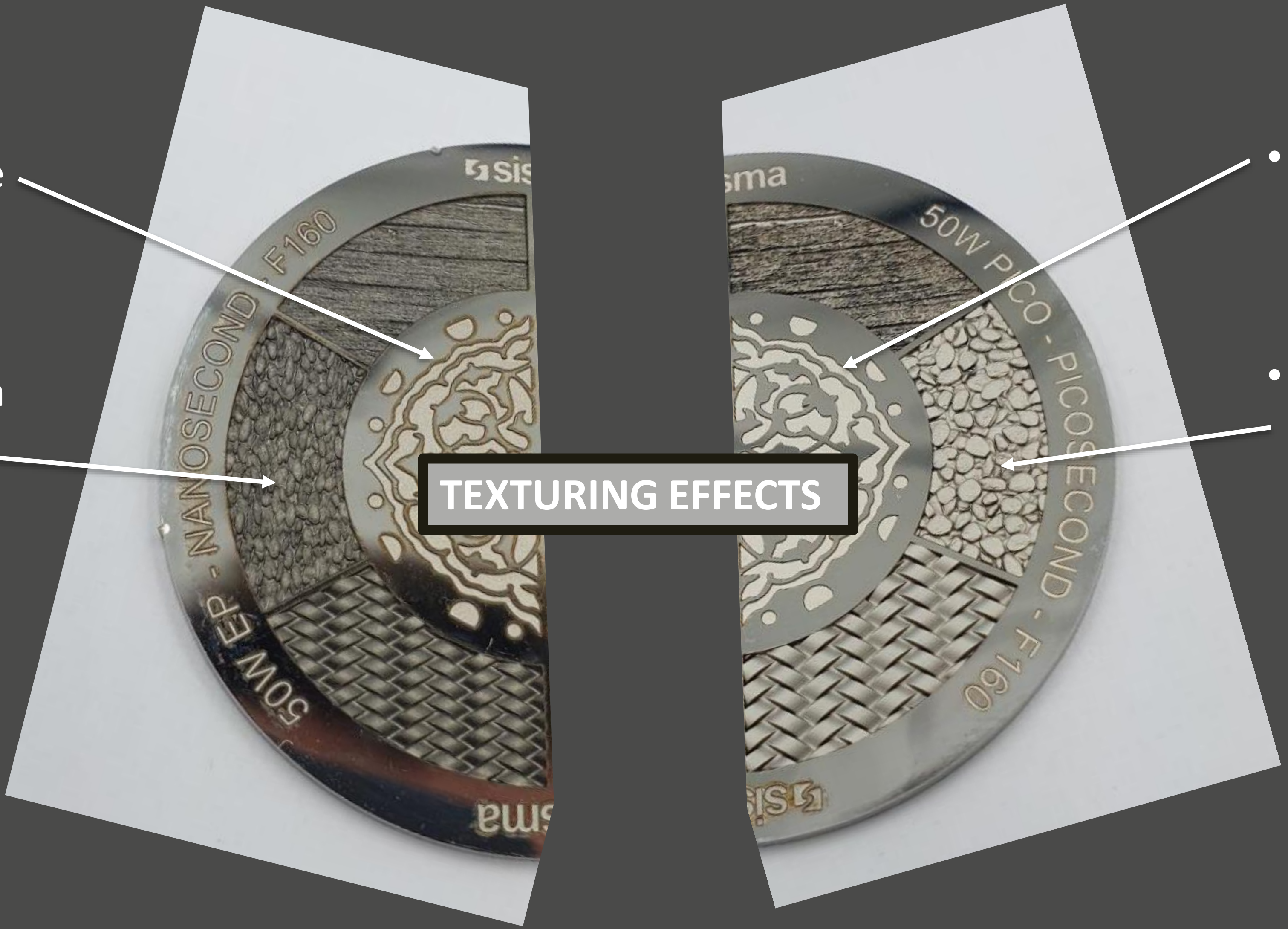
Laser engraving aluminum plate

Instrumentation:
- 20 W MOPA fiber laser
- 50 W IR ps laser

ns versus ps pulses on stainless steel

NANO

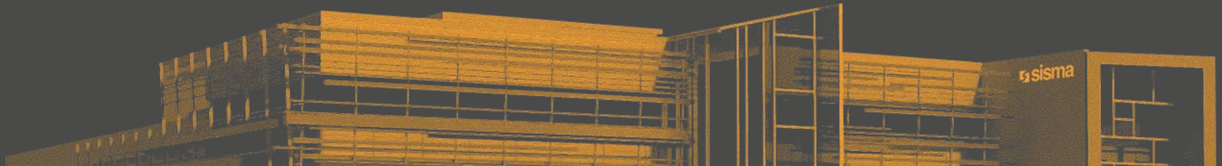
- **browning** on the marking edges (burr)
- **less precision** on small shapes



PICO

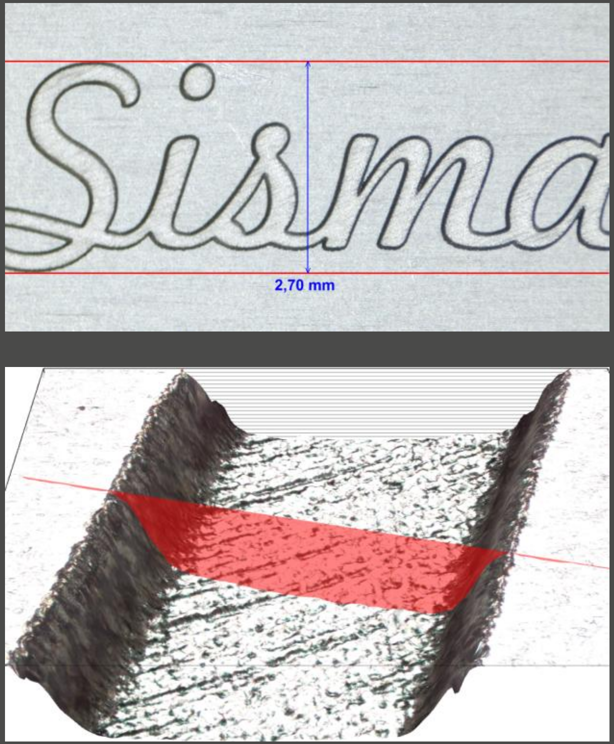
- **clean** and **sharp edges**
- **high precision** on small shapes

Instrumentation:
- 50 W MOPA fiber laser
- 50 W IR ps laser
- SLC³ SISMA software



Examples of engraving with ps lasers

Huge improvements in terms of surface finishing and ablation rate on several materials, even on transparent ones.



Titanium

Stainless steel

Sapphire

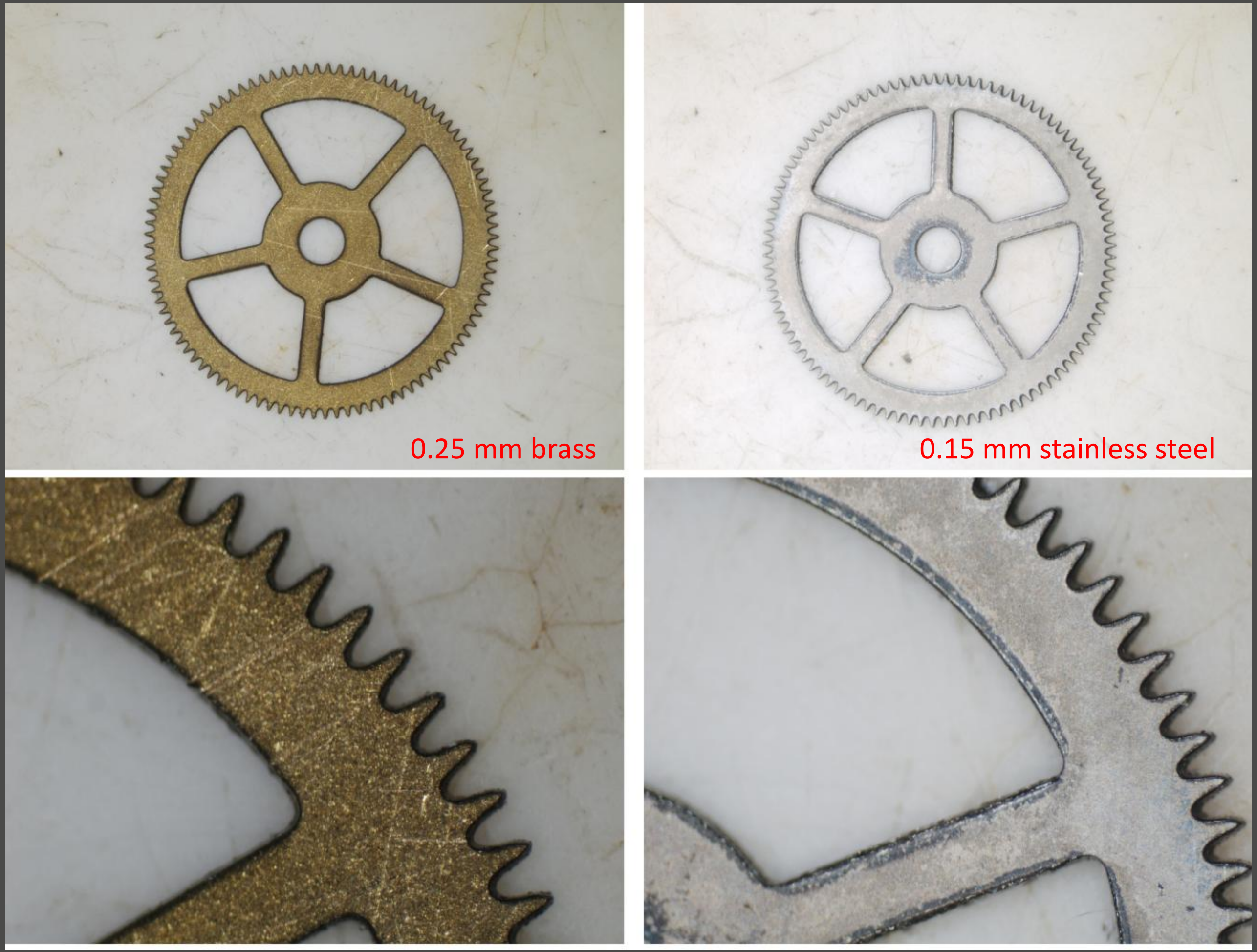
Instrumentation:

- 50 W IR ps laser

Ultrashort lasers for microcutting application

Complex and small geometries can be cut on thin metallic plates, with minimal burr and HAZ, removing the need of additional post-processes.

0.1 mm thick stainless steel



0.25 mm brass

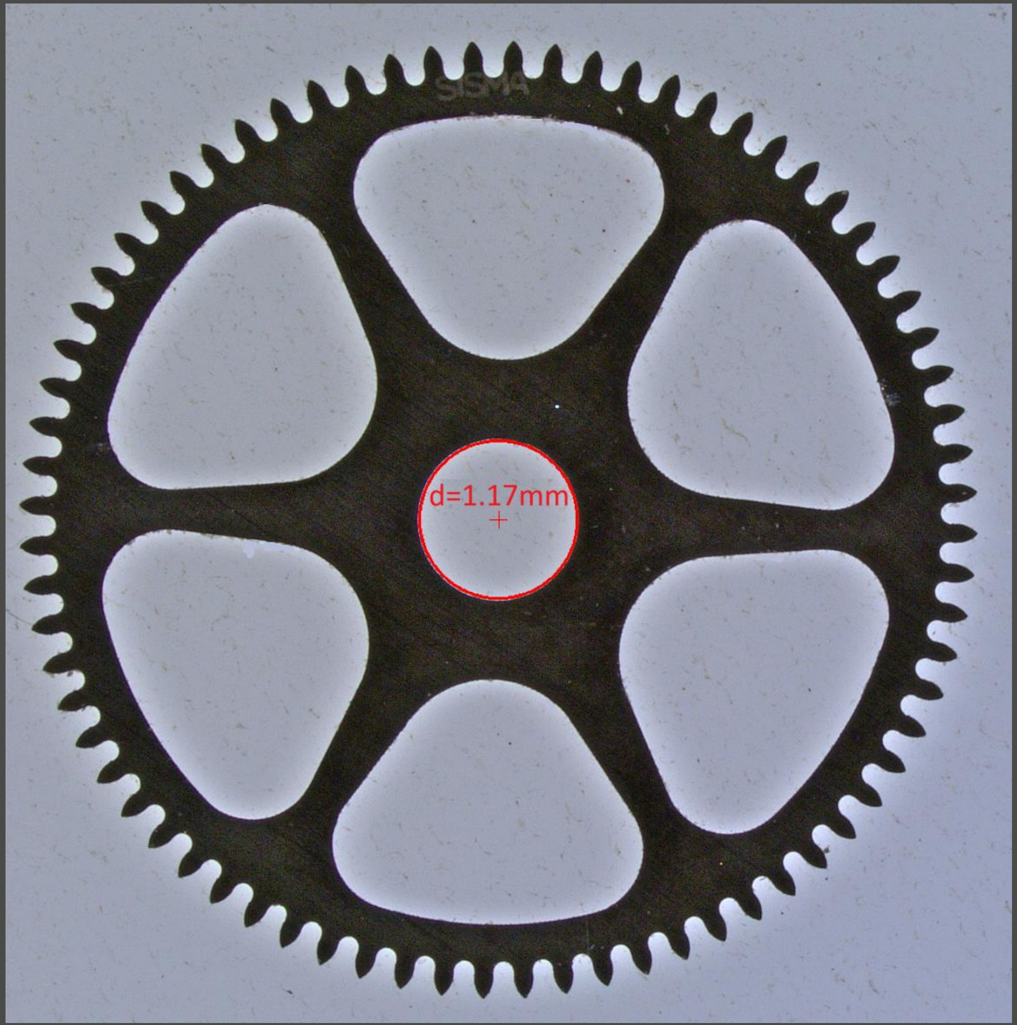
0.15 mm stainless steel

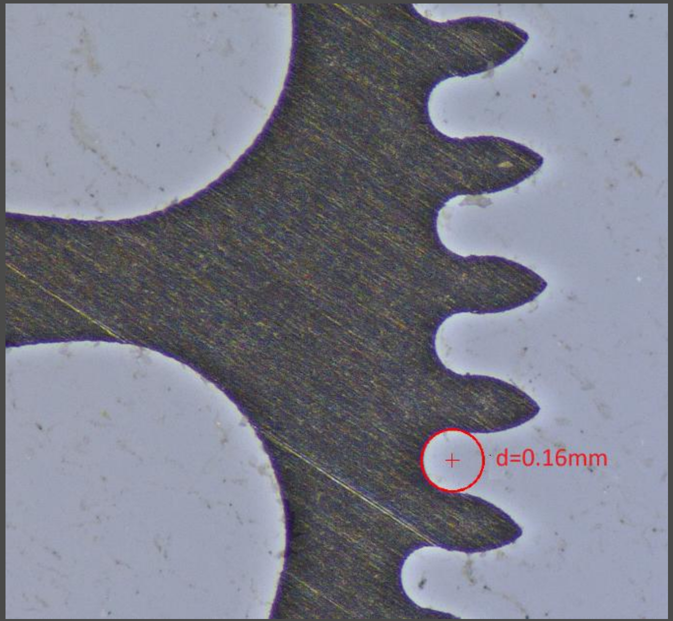
Instrumentation:

- 50 W IR ps laser

Ultrashort lasers for microcutting application

Cutting a 0.1 mm thick stainless steel minigear





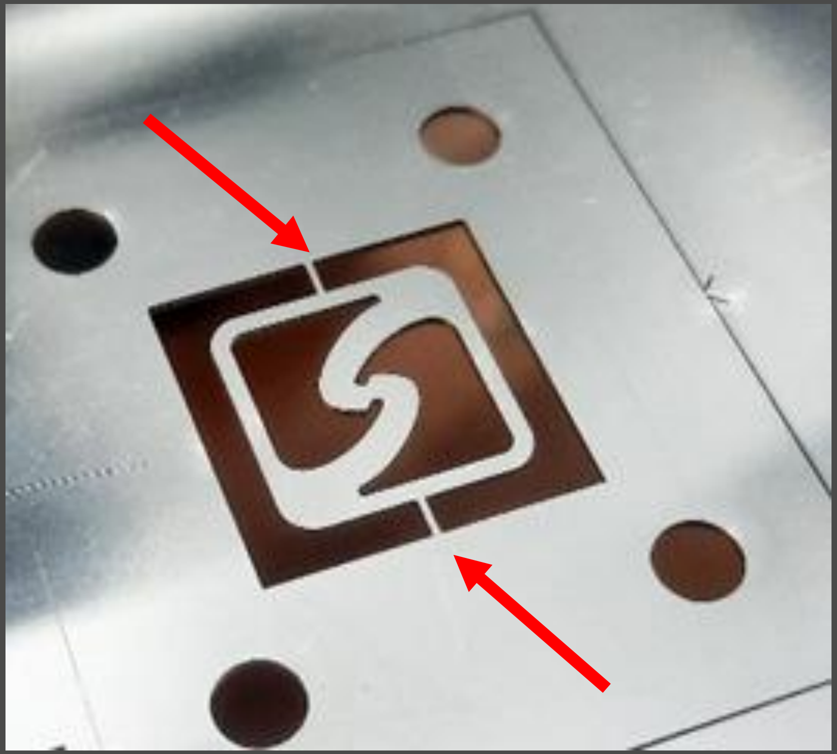
Instrumentation:

- 50 W IR ps laser

What about laser processing on a precise position of the sample?

Example: cutting supporting tabs. It could be relatively easy with big samples, but what about dealing with tiny parts, very thin samples, or with high-precision requirements?

Coaxial vision system solves the problem



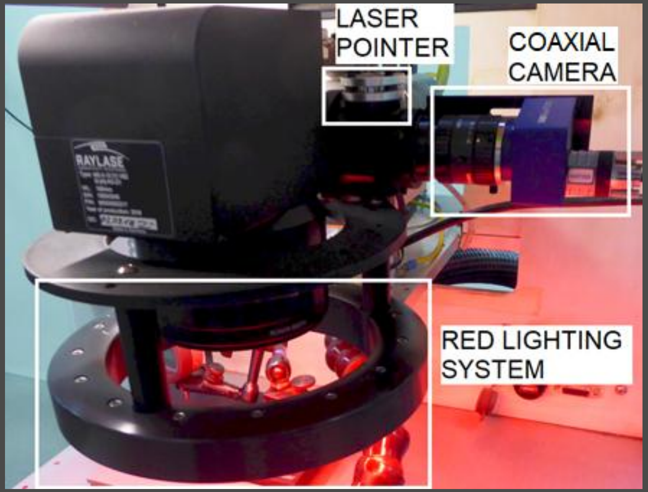
Instrumentation:
- SLC³ SISMA software

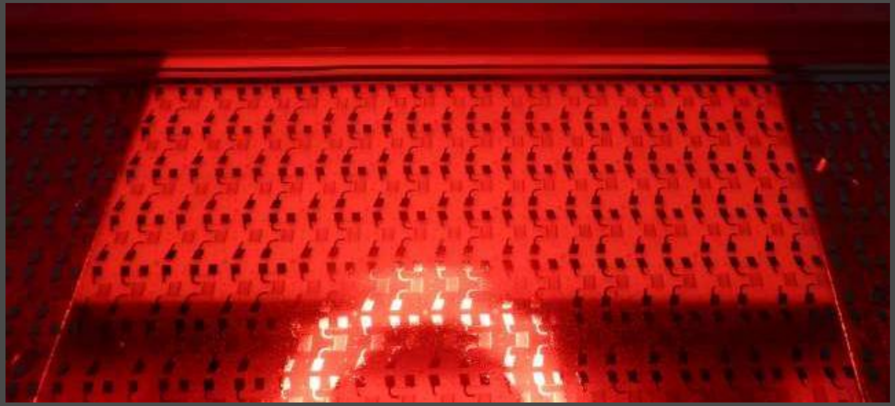
Coaxial camera vision and pattern matching with scanning head

Coaxial camera vision (with optional pattern matching) takes a photo of the sample, following the same path of the laser. What the camera sees, there the laser can mark.

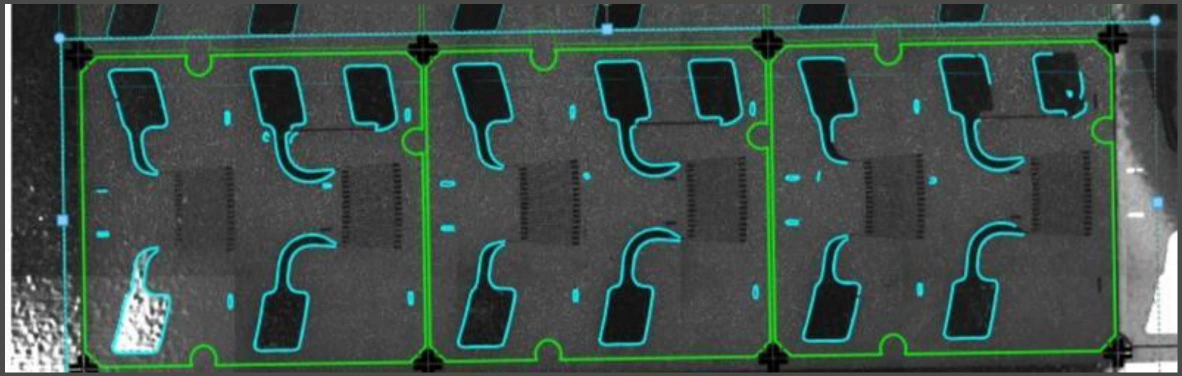
Main advantages:

- fast and precise positioning, with the help of deep learning algorithms
- removal of the requirement for fixtures
- result monitoring and validation
- parallax problem free
- high signal-to-noise ratio thanks to monochromatic lightning





Kapton circuits



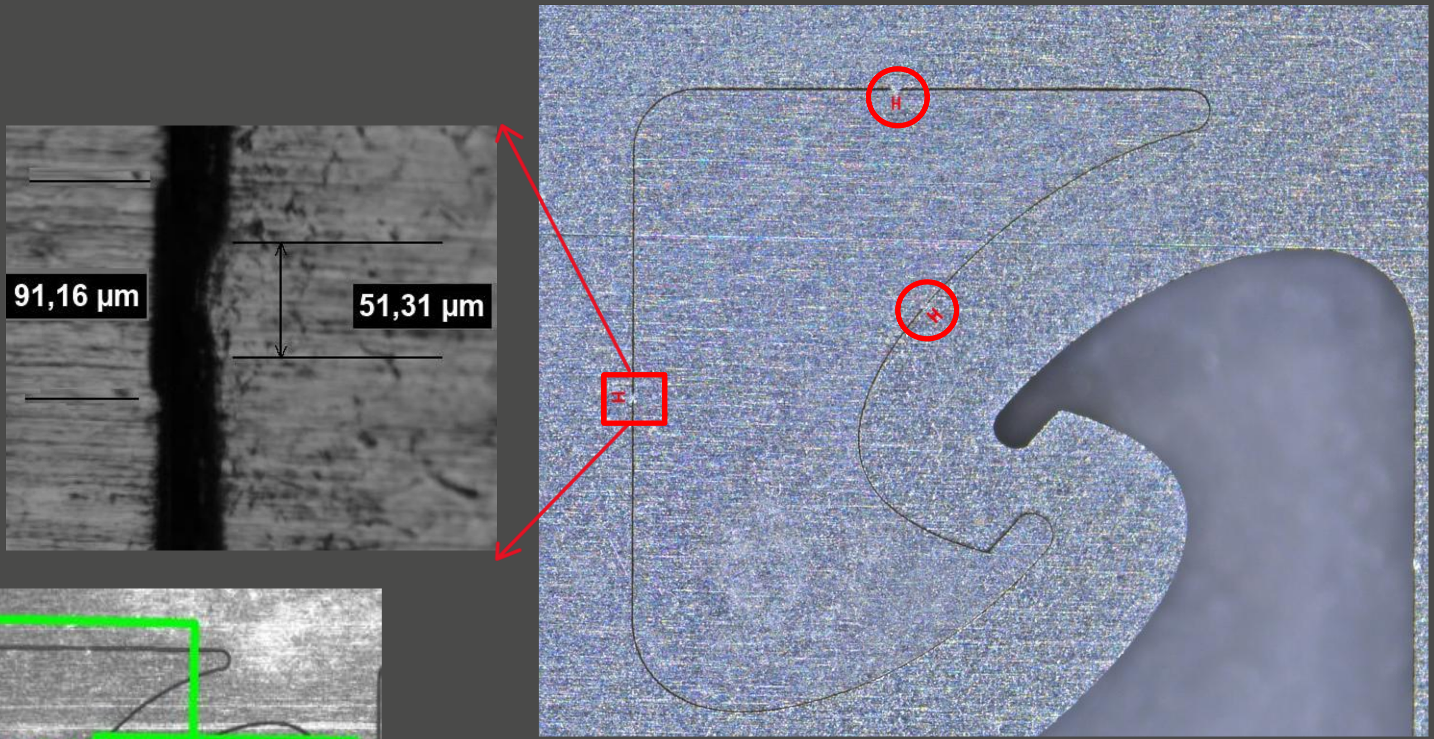
Instrumentation:

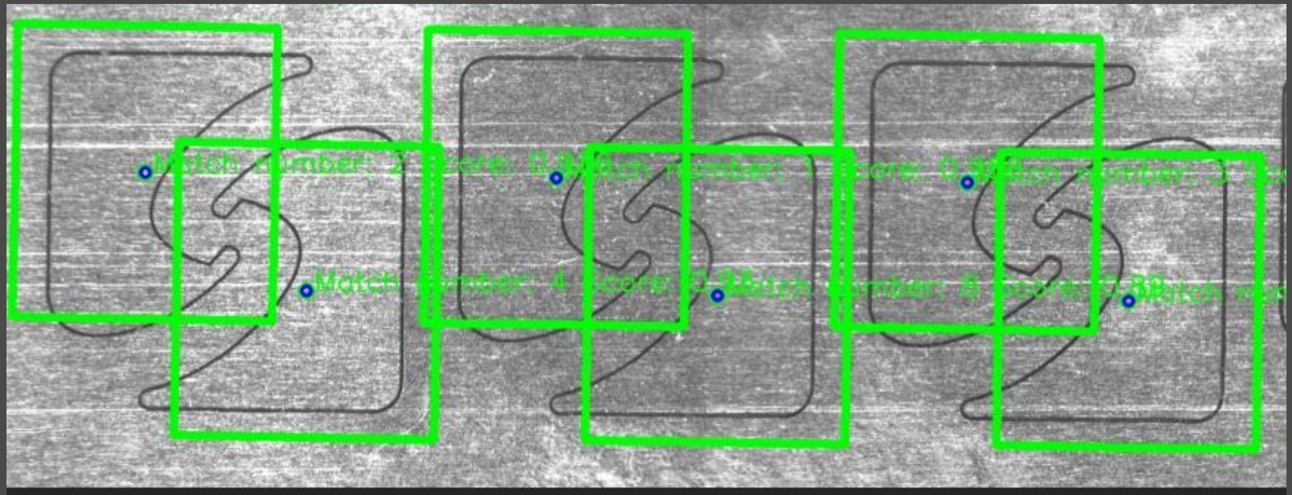
- SLC^3 SISMA software

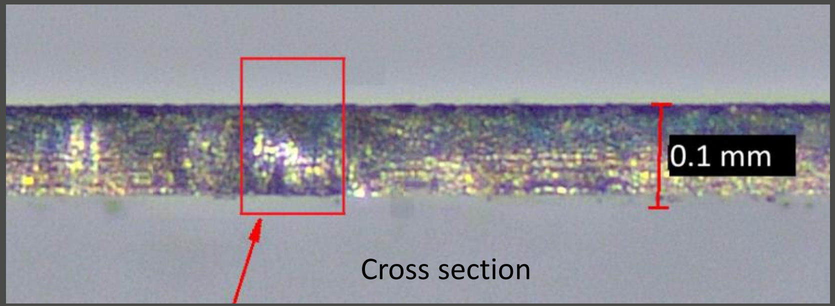
Automatic laser cutting of supporting tabs

A classical example of laser cutting the supporting tabs of pre-cut shapes on a 0.1 mm thick stainless steel slab.

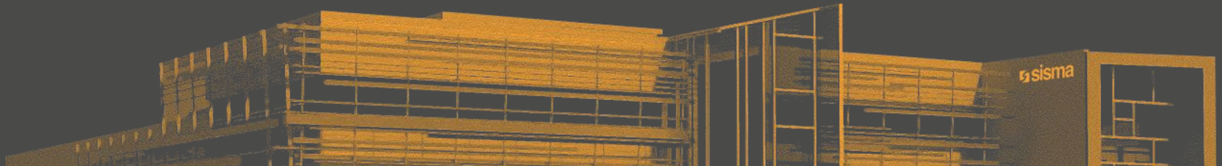
Coaxial vision and pattern matching guarantee down to 0.02 mm precision in automatic positioning.





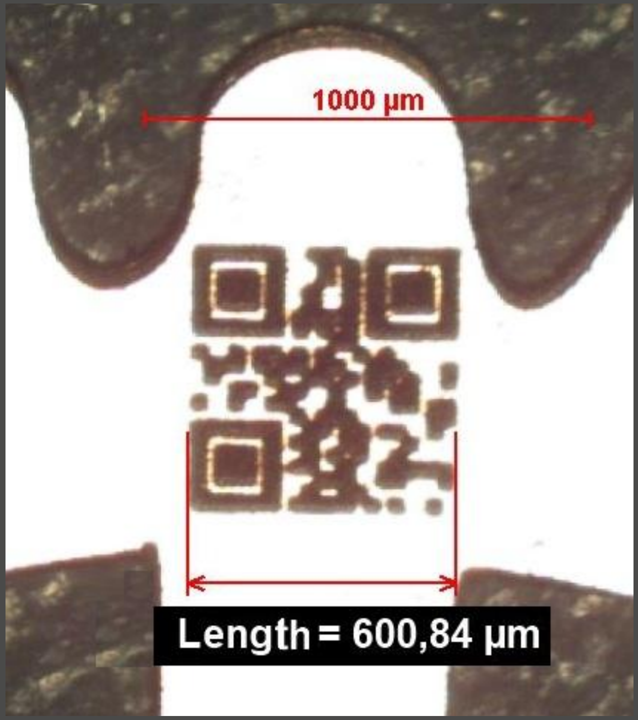


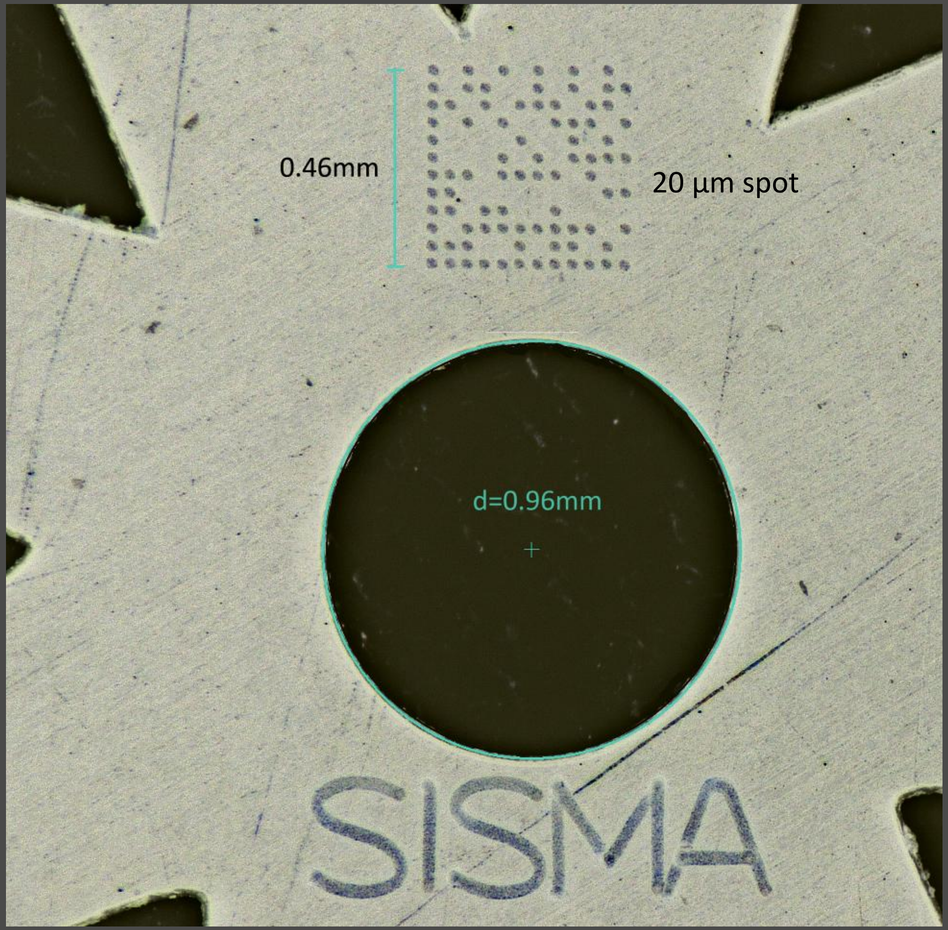
Instrumentation:
- 50 W IR ps laser



Marking and micromarking

Using the same optical setup of cutting, with the laser it is possible to mark microfeatures such as microtexts and 2D microcodes.





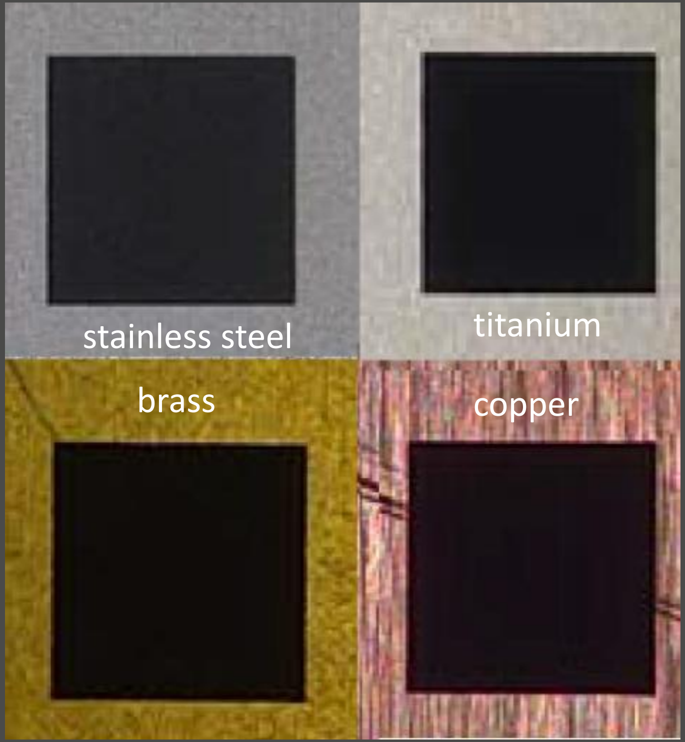
Instrumentation:
- 20 W MOPA fiber laser
- 50 W IR ps laser

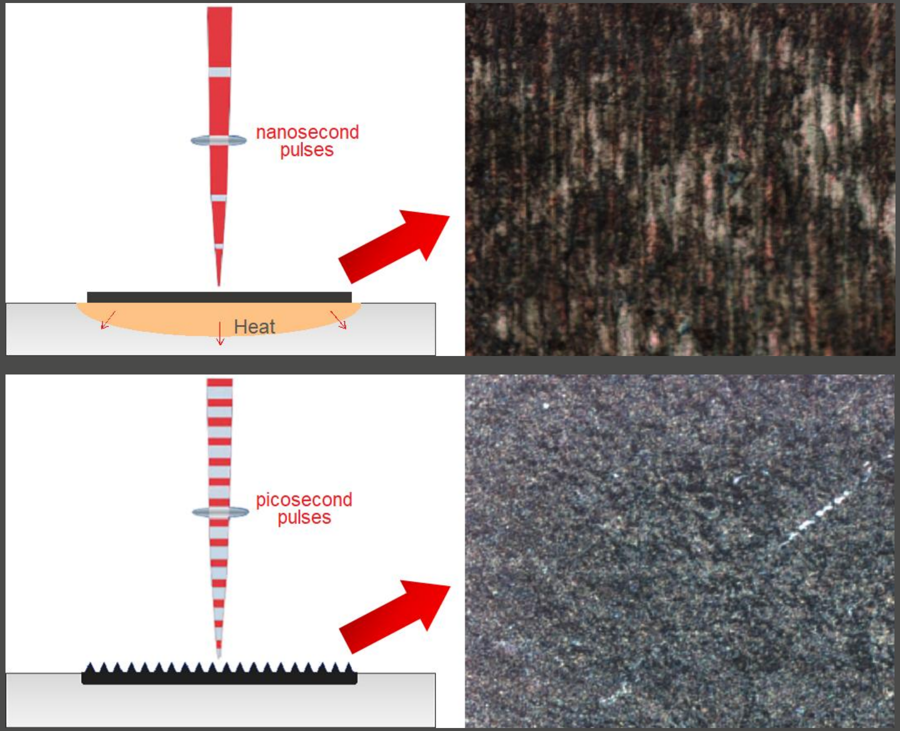
Metal blackening

Ultrashort pulses create impalpable deep black on most metal surfaces, as they develop light-trapping surface textures, while not affecting the underlying material. This surface alteration withstands the repeated passivations and normal manual handling. With ns lasers, superficial blackening can be done only on few metals (e.g. stainless steel), affecting however the underlying material.

Black marking on medical instrument

ps blackening





Instrumentation:
- 50 W IR ps laser

N. Maguolo, S. Mazzucato, Ultrashort Laser Pulses Mark Lasting Codes on Devices, Europhotonics, E20, 2021

Aesthetic effects

Appropriate laser parameters, in combination with dedicated in-house software allow creating and marking colourful, iridescent and/or Guilloché-like decorative effects on a wide range of materials.

Nickel-Silver

Brass

Stainless steel

Stainless steel

<u>Instrumentation:</u>

- 20 W MOPA fiber laser

- 50 W IR ps laser

- SLC^3 SISMA software

Conclusions: advantages of laser processing

Laser-based techniques have the following decisive advantages over conventional processing methods:

- Non-contact, zero-force processing, therefore no tool wear
- Better tolerance level especially for thick samples compared to standard etching technique
- Low thermal input on the workpiece, due to the very high energy density in a tiny spot
- Processing of very hard, brittle, or soft materials, without sample preparation
- Realization of a variety of different machining geometries without changing tools
- No masks needed
- No chemicals involved, hence environment friendly
- Economical friendly

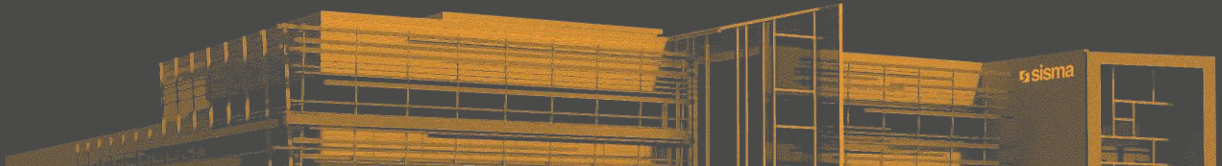
Use of galvo-head combined with camera system and pattern matching leads to:

- Automatic positioning with high precision
- Cutting, marking, engraving with only one laser machine

Ultra-short laser processing adds the following advantages:

- Minimum or absence of HAZ, burrs, and debris
- Usable on end-products as no post processes are needed

With all these advantages, can this solution replace conventional chemical etching process?

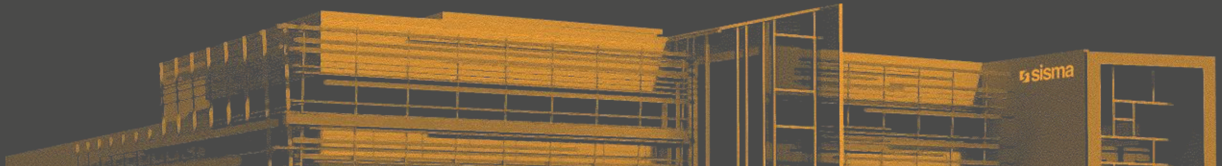


Laser as complementary solution

Laser-based machine is a powerful solution, capable of performing processes which chemical etching cannot do, or does with difficulties.

However, in several cases, chemical etching can be superior in terms of speed, precision and quality, especially in cutting thin metals for mass production.

Therefore, with the advantages and limitations explained in the previous slides, we can finally conclude that an ultrashort laser system, equipped with galvo scanner, camera vision (with optional pattern matching) is a perfect complementary solution for chemical etching applications.



Thank you for your attention

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ISO 14001
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Special acknowledgements

to **CHIMIMETAL**

for invitation