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laser. marking cutting engraving

setting new standards

Laser Handbook

A comprehensive guide to industrial laser applications

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Overview

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Lasers are powerful tools with a wide range of capabilities that can help companies streamline processes, minimize downtime, and boost shop-floor efficiency. Created for those who cut and mark materials in industrial environments, the following handbook provides a technical overview of industrial laser types, features and capabilities, and an application guide to help operators use lasers to achieve optimum results.

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The many possible applications of the fiber laser

The following overview indicates which materials can be processed using a fiber laser.

	Material	Processability	Process
→ **Metals**	Aluminum	✓	Engraving
	Anodised Aluminum	✓✓✓	Engraving
	Polished / unpolished brass	✓✓✓	Engraving
	Carbides	✓✓	Polishing
	Chrome	✓✓	Engraving
	Polished / unpolished copper	✓✓	Engraving
	Gold	✓✓✓	Engraving
	Silver	✓✓✓	Engraving
	Platinum	✓✓	Engraving
	High-speed steel	✓✓✓	Annealing / Engraving
	Brushed / polished stainless steel	✓✓✓	Annealing / Engraving
	Titanium	✓✓✓	Annealing / Engraving
→ **Plastics**	ABS, PC, PA, PMMA, etc.	✓✓✓	Coloring
	Rubber	✓	Coloring
→ **Non-metals**	Ceramic	✓	Coloring
	Paper	×	
	Textiles	×	
	Glass	×	
	Wood	×	
	Stone	×	

✓✓✓ easy to process, even at high speeds

✓✓ easy to process

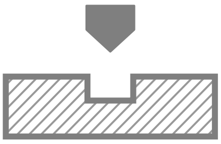
✓ difficult to process

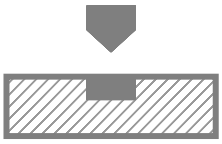
× unable to process

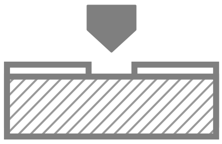
Processes

Unlike CO_2 laser machining, marking plastics and metal using a fiber laser (plotter or Galvosystem) can involve different processes. The following illustrates these processes in detail with examples.

Process overview: marking metals

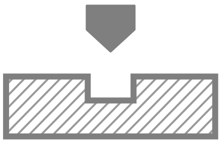
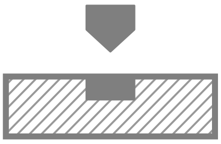
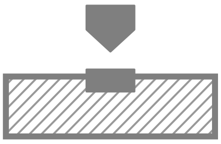
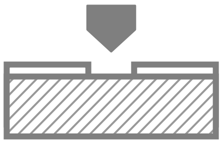






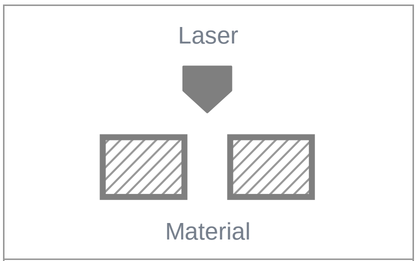
Engraving	Annealing	Coating removal
• Metal and ceramic • Metal partly evaporates during the process • This creates depressions • Very durable marking • High level of energy required	• Stainless steel, titanium, etc. • Local increase in temperature to just below the melting point of the material • Oxide layer created below the material surface • Surface not damaged • High contrast between the marking and the material	• Anodised Aluminum, coated metal, films • Coating layer removed • High contrast between the marking and the material • High marking speed

Process overview: marking plastics

Engraving	Coloring	Foaming	Coating removal
Laser  Material	Laser  Material	Laser  Material	Laser  Material
• Removal of material by melting and evaporating surface • Creates depressions • Very durable marking	• Result depends heavily on composition of plastic • Special compositions of plastic are available for good laser marking results • Surface not damaged during marking	• Air bubbles in the material cause the material to bulge • This creates dome-shaped marking	• Often used in the automotive industry or telecommunications (“day & night design” / marking keyboards) • Coating layer removed • High marking speed
			

Special process: cutting metals

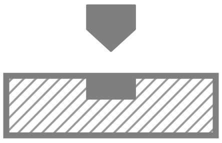
Cutting



As the engraving of metals removes the material, it can be assumed that by increasing the laser output, it is also theoretically possible to cut metals.

Under certain circumstances and a range of limitations, it is actually possible to cut metals such as Aluminum, stainless steel or even copper. A detailed description of the use of fiber lasers to cut metals is contained in Section 7 “Special process: cutting metals."

Marking metals by annealing

General information 	Marking by annealing involves heating the surface of metals in order to create an oxide layer. This oxide layer produces a visible result: the black marking which is easily legible due to the strong contrast. In order to mark rather than engrave the material, the laser beam must be defocused. This processing method therefore does not roughen the surface. This is of considerable advantage compared to engraving as a processing method, particularly with regard to the marking of surgical instruments.
Speed	Lower speeds are required to create the oxide layer when marking by annealing.
Resolution	A high resolution is essential to achieve a uniform image on the marking surface.
Materials	This process is suited to all metals on which it is possible to create a different colour oxide layer. It is particularly suited to steels and titanium. Aluminum and chrome are not suitable for marking by annealing (as in this case the oxide layer is transparent).
Points of note	By adjusting the pulse frequency, output and speed when processing steels it is possible to create different colours. The surface can be marked in tones of purple, green or yellow.

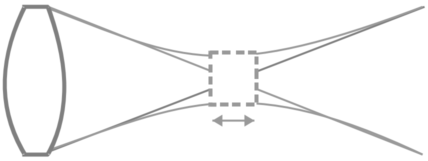
Examples of marking metals by annealing with a plotter

Material

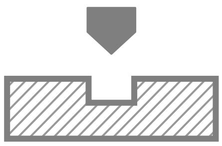
Stainless steel

Laser parameters

Output in watts	**10**	**20**	**30**
Output [%]	**100**	**100**	**100**
Speed [%]	**2.5**	**5**	**7**
Frequency [kHz]	**25**	**25**	**25**
Resolution [dpi]	**1000**	**1000**	**1000**
Defocus [mm]	**- 2**	**- 2**	**- 2**

FAQ: marking metals by annealing	
How do you know if the laser beam has been defocused correctly?	The laser beam must be defocused enough to create a light dot when marking. There should be no crackling noises as this means the focus is too sharp.
What can I so when the annealed inscription is not sharp at the edges?	If the edge of the inscription is not sharp, this indicates the speed is too low. Raise the speed and try again.
The annealed inscription is rough and brown in colour.	A slightly roughened surface or brown tone to the inscription indicates the focus is too sharp.
Is there anything I should look out for once the annealed inscription is complete?	Depending on the stress exerted on the marked surface, it may be necessary to passivate the material. This applies to many stressed materials, such as surgical instruments or marked knives, for example. This process is required for every fiber laser.
How does the focal tolerance affect the marking result?	The focal tolerance refers to the range within the laser focus in which there is a constant level of energy and consistent marking results are to be expected.  Lens Focal tolerance (arrow) In a Speedy 100 fiber or Speedy 300 fiber, the focal tolerance is approximately ±0.15 mm (0.006 in). If the difference between the highest and lowest levels of the workpiece is greater than 0.4 mm (0.016 in) the marking result will be uneven.  Difference of 0.5 mm (0.02 in)

Engraving metals

General information 	When engraving with a laser, the laser radiation causes the material to melt or evaporate. This requires a high level of energy. The intensity of the laser radiation must exceed a specific limit value - the so-called threshold intensity. The threshold intensity of materials with a high level of electrical conductivity is particularly high. The beam profile and where applicable the thermal conduction into the base material create a conical depression.
Speed	Increasing the level of output increases productivity. The deciding points are the desired depth of the engraving and the level of contrast to the material to be engraved.
Resolution	A high resolution is essential to achieve uniform marking.
Materials	This process is suited to all metals.
Points of note	Plotters can engrave to a limited depth. Several passes are required for deep engravings. As the material removed during the process falls back into the depression and is sealed back in, it is not possible to engrave to a depth greater than approx. 0.01 mm. By changing the alignment of the tool paths between the passes, Galvos are able to remove the material from the engraved depression more efficiently and thus produce deep engravings. The actual depth depends on the number of passes made. It is possible to create engravings several millimeters deep.

Examples of engraving metals with a plotter

Material

Polished stainless steel

Laser parameters

Output in watts	**10**	**20**	**30**
Output [%]	**15**	**10**	**5**
Speed [%]	**10**	**10**	**10**
Frequency [kHz]	**20**	**20**	**20**
Resolution [dpi]	**1000**	**1000**	**1000**
Defocus [mm]	**0**	**0**	**0**

Material

Stainless steel

Laser parameters

Output in watts	**10**	**20**	**30**
Output [%]	**100**	**100**	**100**
Speed [%]	**20**	**30**	**50**
Frequency [kHz]	**< 80**	**< 80**	**< 80**
Resolution [dpi]	**1000**	**1000**	**1000**
Defocus [mm]	**0**	**0**	**0**

* Exact frequency setting depends on the marking speed

Example of deep engraving metals with a Galvo system

Material

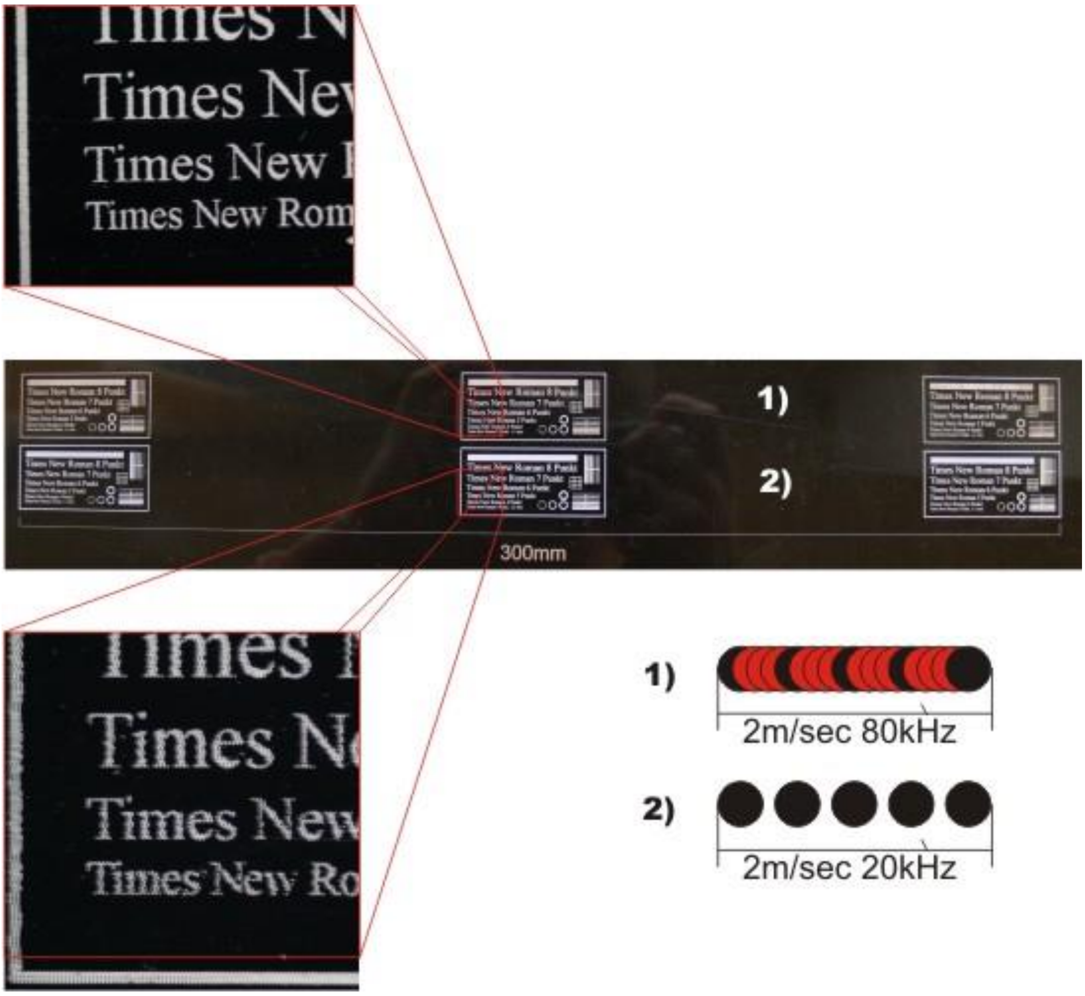
Silver

Laser parameters

Output in watts	**20**	**30**
Output [%]	**100**	**100**
Speed [mm/min]	**300**	**300**
Frequency [kHz]	**20**	**30**
Fill spacing	**0.01**	**0.01**
Angle*	**15°**	**15°**
Passes	**12**	**9**

* Change in angle between passes

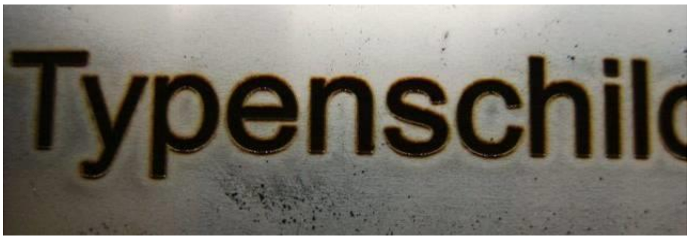
FAQ: engraving metals	
The relationship between frequency and speed	The greater the marking speed, the higher the required frequency setting. A higher chosen speed (e.g. 100%) and lower frequency (e.g. 20 kHz) cause a “perforation." This means that the laser source is not pulsing quickly enough to mark a continuous line. The example below explains the relationship between frequency and speed.



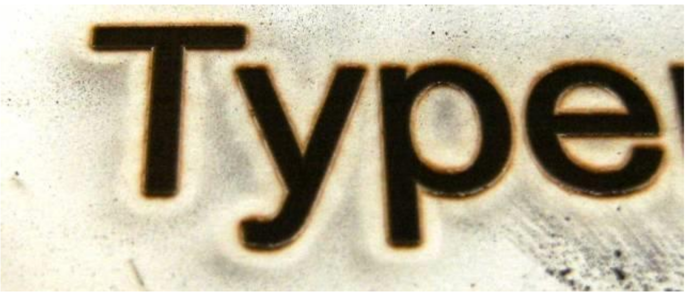
FAQ: engraving metals

How should you clean engraved surfaces?

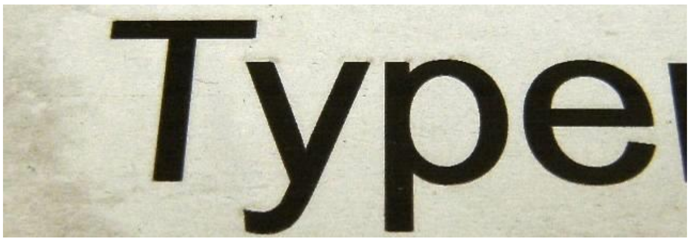
The rapid increase in temperature during the engraving process and the explosive evaporation create smoke marks on the surface of the material. This creates a fuzzy engraving. The edges of the engraving appear uneven and the quality of the engraving appears inferior.



An uncleaned result directly after engraving.

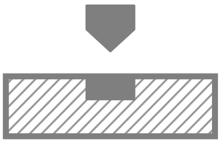


For perfect results the engraved workpiece must be cleaned with a sponge and water, then left to dry naturally.



You should not use any cloths (cotton) when cleaning as the fibers catch on the engraving.

Marking plastics

General information 	Operators may mark plastics in various ways. The processes include those already mentioned: changing the colour of the surface; engraving; foaming by changing the surface; and the removal of coatings. The most suitable type of marking depends on the marking specifications and the material used. Most thermoplastics are usually processed by means of changing the colour by carbonising or by foaming.
Speed	High speeds are therefore required.
Resolution	A high resolution is essential to achieve a uniform image on the marking surface.
Materials	The laser markability depends heavily on the type and composition of the plastic. The FAQs (6.2) contain a list of the established types of plastic, rated according to their laser markability.
Points of note	Some proprietary types of “laser plastics” are available which are used for the production of ID cards, for example.

Examples of marking plastics with a plotter

Material

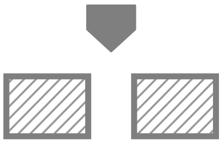
Plastics

Laser parameters

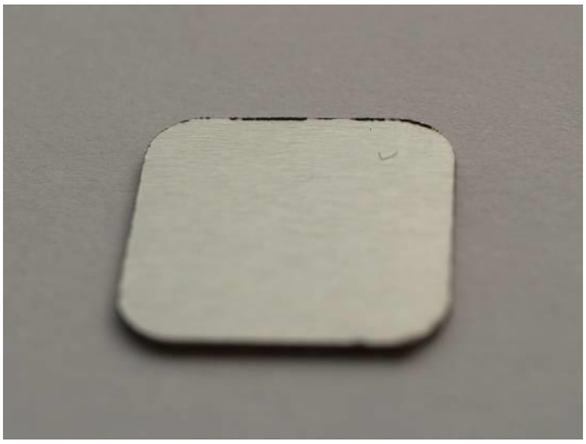
Output in watts	**10**	**20**	**30**
Output [%]	**30**	**20**	**10**
Speed [%]	**100**	**100**	**100**
Frequency [kHz]	**< 80**	**< 80**	**< 80**
Resolution [dpi]	**1000**	**1000**	**1000**
Defocus [mm]	**0**	**0**	**0**

* exact frequency setting depends on the marking speed

	FAQ: marking plastics
Which plastics are suitable for laser marking?	**Easy** ABS (dark marking) PA (light and dark marking) PBT (dark marking) PC (dark marking) PPS (dark marking) Polysulfone (dark marking) Makrolon (PC) PET (CO_2) **Difficult** as colour dependent, etc. PU (polyurethane) PP (polypropylene) transparent PE (polyethylene) transparent PS (polystyrene) PVC (polyvinylchloride) POM (polyoxymethylene) NAS (transparent) SPS (transparent) **Poor** ASA (dark on light)

Special application: cutting metals	
General information 	When cutting with a laser, a sheet of material is separated using a focused laser beam. Cutting metals with fiber lasers of up to 50 watts and without auxiliary process gases is a multi-stage process. Several passes are required. The number of passes can range from a few to several dozen. The metal is thus “engraved through” by repeatedly passing along the cutting lines. It is therefore possible to cut materials such as Aluminum, brass, steel or gold up to max. 0.5 mm thick. The separation process itself does not depend on the hardness of the respective material. The decisive factors are the optical qualities of the material and the thermal conductivity. Aluminum is therefore easier to cut than steel. Aluminum dissipates the heat more easily, which can be seen by the positive fact that the material warps less. The removed material sits along the cut edge as swarf forming a pitched surface. It is therefore not possible to cut filigree geometries of less than 5 mm. On the one hand the kerf is resealed by the swarf and on the other hand the warping of the material affects the shape of the cut geometry. It is theoretically possible to cut metal cleanly with a fiber laser. However, this requires greater laser output and the use of pressurised process gases such as oxygen. Neither of these are available on plotter and Galvosystems.
Speed	Several passes are required. The number of passes required depends on the desired strength of material.
Resolution	Irrelevant
Materials	Aluminum, steel, brass, gold, silver
Points of note	This is a special application subject to limitations and may only be carried out under specific circumstances. Carrying out thorough cutting tests on material before purchasing a system is highly recommended.

Examples of cutting metals with a plotter



Material

Aluminum, 0.5 mm

Laser parameters

Output in watts	30	50
Output [%]	100	100
Speed [mm/min]*	3000	5000
Frequency [kHz]	30	50
Resolution [dpi]	-	-
Defocus [mm]	0	0
Passes	30	15

* troCAM

Material

Stainless steel, 0.5 mm

Laser parameters

Output in watts	50
Output [%]	100
Speed [mm/min]	2500
Frequency [kHz]	50
Resolution [dpi]	-
Defocus [mm]	0
Passes	35

Examples of cutting metals with a Galvo

Material

Brass, 1.5 mm

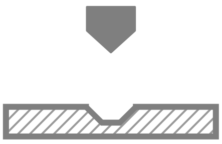
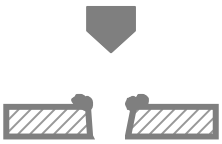
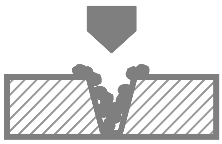
Laser parameters

Output in watts	**20**
Output [%]	**100**
Speed [mm/sec]*	**300**
Frequency [kHz]	**20**
Resolution [dpi]	**-**
Defocus [mm]	**0**
Passes	**300**

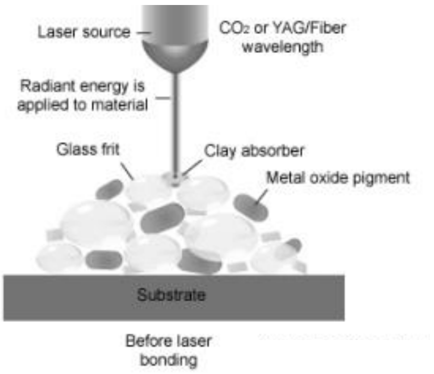
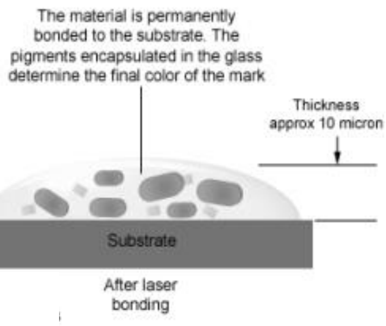
* Speedmark

FAQ: cutting metals

How thick a piece of material can you cut and what are the limitations?

Stainless steel 0.5 mm	Stainless steel 0.5 mm	Stainless steel 1.0 mm
		
Cut after a few passes	Cut after many passes	Cut after many passes
• Ablation without swarf (pitch)	• Removed swarf creates a pitch on the cut edge • Filigree geometries of less than 5 mm are not possible as the swarf reseals the kerf and the warping of the material affects the shape.	• There is no suitably efficient way of removing the generated swarf. • The swarf falls back into the kerf and seals it. It is therefore not possible to cut through the material.
		

Alternative method for laser marking metals

Laser marking with a CO_2 laser and paste or spray	
General information   	CO_2 operators often use ceramic powders to mark metals. This powder is applied to the workpiece by means of a paste or spray and washed off following the laser process. During the laser machining process, the powder is burned into the material. If this process is used to laser mark metals, it is even possible to achieve a high contrast on absorption-weak metals with a CO_2 laser. Oxidation occurs on the metal's surface. Sprays and pastes are available from manufacturers such as TherMark™ or CerMark™. A 50 g spray can cost approx. $56. The costs of wear items and the time-intensive production process make this process economical only for individual pieces and small production runs as an additional application on an existing CO_2 system.
Speed	It requires a considerable amount of energy. It must proceed at a correspondingly slow speed.
Resolution	Depending on the desired marking result, it is possible to work at values between 125 and 1000 dpi.
Materials	stainless steel, only suitable for metals
Points of note	The paste or spray can also be burned on using a fiber laser.

Examples of laser marking with a CO2 plotter and paste or spray

Material

Stainless steel

Laser parameters

Laser output in watts	10	20	30
Output [%]	30	20	10
Speed [%]	100	100	100
Frequency [kHz]	< 80	< 80	< 80
Resolution [dpi]	1000	1000	1000
Defocus [mm]	0	0	0

* Exact frequency setting depends on the marking speed

FAQ: laser marking with a CO2 laser and paste or spray

Process flow for CO_2 marking with paste or spray

					
Workpiece	Apply paste	Dry	Laser	Wash clean	Finished workpiece

Process flow for fiber laser marking

		
Workpiece	Laser	Finished workpiece

Advantages and disadvantages of CO_2 marking with paste or spray

Advantages	• You have the option of marking metal using an existing CO_2 laser plotter • It's very economical for individual pieces or small production runs • There's a high contrast on many metals (stainless steel, aluminum) • Process is chemically resistant to solvents, acids and bases; UV and moisture resistant; (Caution: customers may have other "abrasion resistance" requirements - tests recommended)

Disadvantages	• Spray and paste are expensive (50 g paste costs approx. $56)
	  • Process is not economical for short production runs
	• It is a time-intensive process
	• It is not scratch resistant or mechanically resistant to abrasion
	• Not all metals are suited to paste/spray marking
	• Marking often damages the surface and removes the material
	  • This is undesirable in many applications (medical, some engineering)
	• Annealing marking, engraving or coating removal is not possible
	• Fine details such as those achieved by fiber laser marking are not possible