POLITECNICO MILANO 1863

DIPARTIMENTO DI ECCELLENZA MIUR 2018-2022

Production 4.0 – Teaching Lab at DMecc

Advanced Manufacturing Processes

Lab 02 – Revision 2

Scheduling of laboratory activites

Lab 0 – Guidelines ---------- Today

- Introduction to lab Production 4.0
- Presentation of lab set up
- Presentation of case study

Lab 1 – Revision 1 ---------- 27th September

28th September -------- Deadline for group registration

- Moving heat source theory
- Implementation of thermal model in MATLAB
- Experimental data provided for efficiency calibration

Lab 2 – Revision 2 ---------- 26th October

- Revision of MATLAB code
- Definition of process parameters
- Gcode generation for testing optimised process parameters

Lab 3 – Revision 3 ---------- 3rd December

- Revision of manufactured workpieces
- Critical project considerations and comments

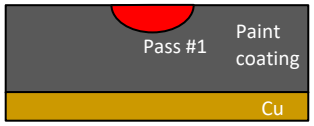
31st December -------- Forms hand-in for lab work evaluation

On-demand manufacturing of custom PCB boards

Aim of the project:

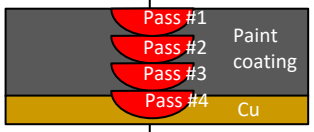
Design the manufacturing process for custom PCB board production

Single scan experiments

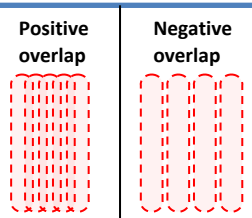


Understand the basics of laser material interaction

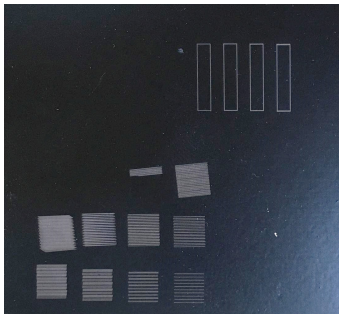
N° of passes?



Scan overlap?



Definition of technological parameters



Validation run

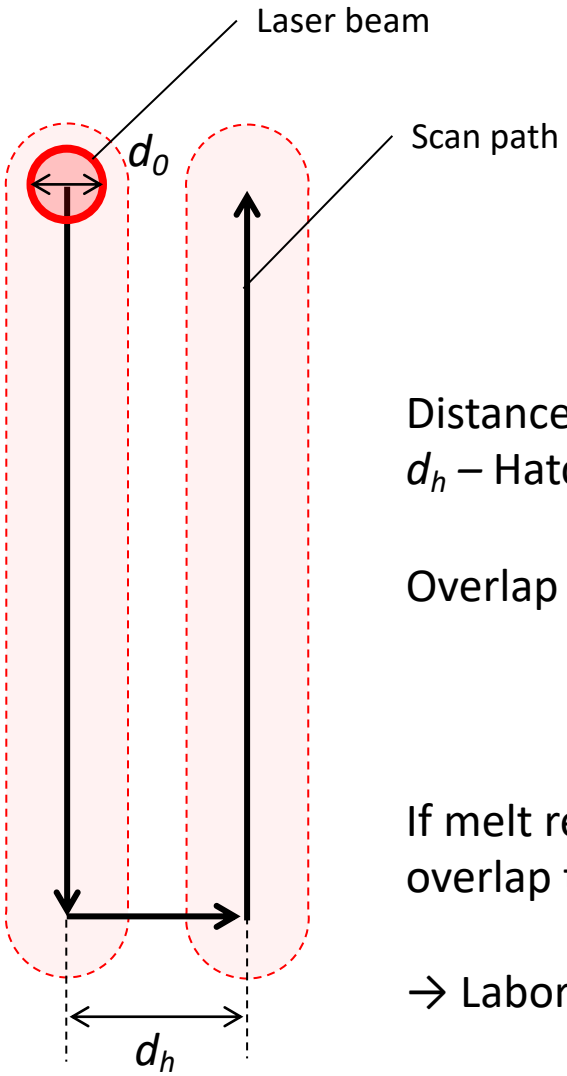
Proof of concept validation of initial test

PCB card prototyping

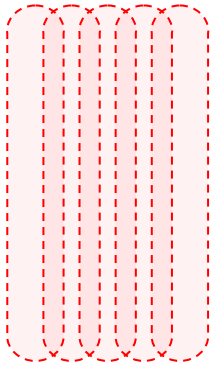
On-demand manufacturing

Large area processing

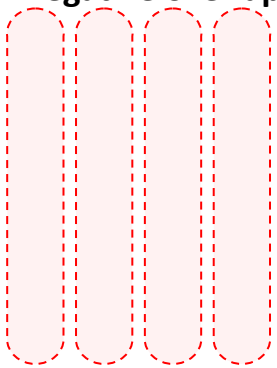
Theoretical concept



Positive overlap



Negative overlap



Distance between adjacent scan tracks:
d_h – Hatch distance

Overlap O_h

$$O_h(\%) = \frac{d_0 - d_h}{d_0}$$

If melt region > beam waist diameter d_0 we can have negative overlap to process large areas

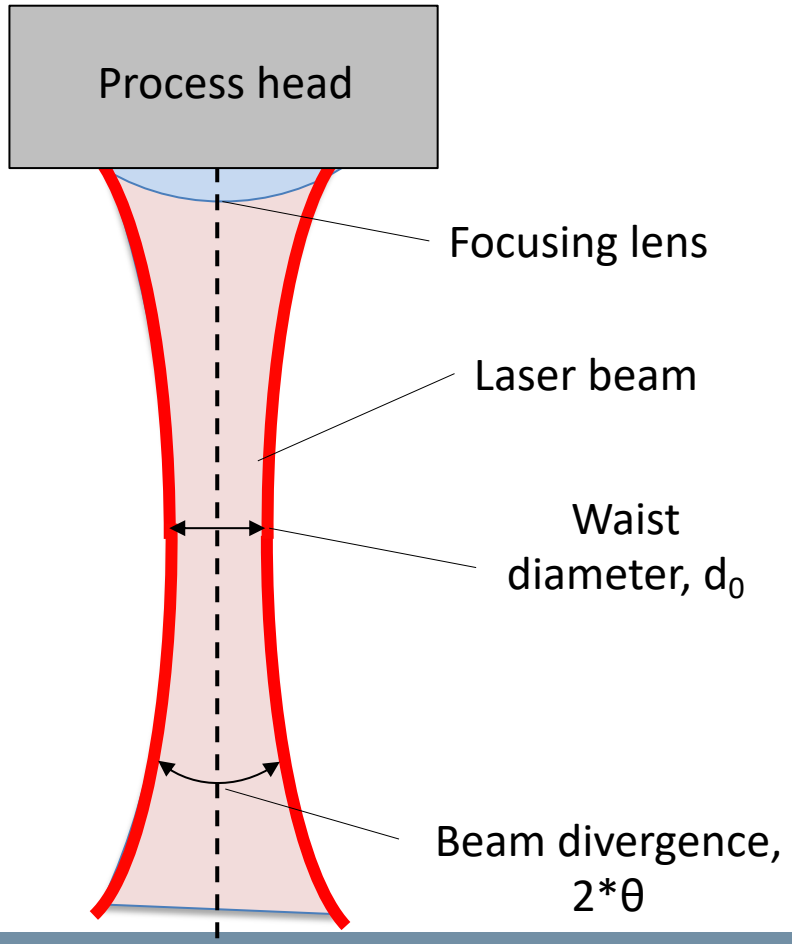
→ Laboratory experiments required to determine optimum overlap

Machine calibration

Theoretical method

Caustic equation:

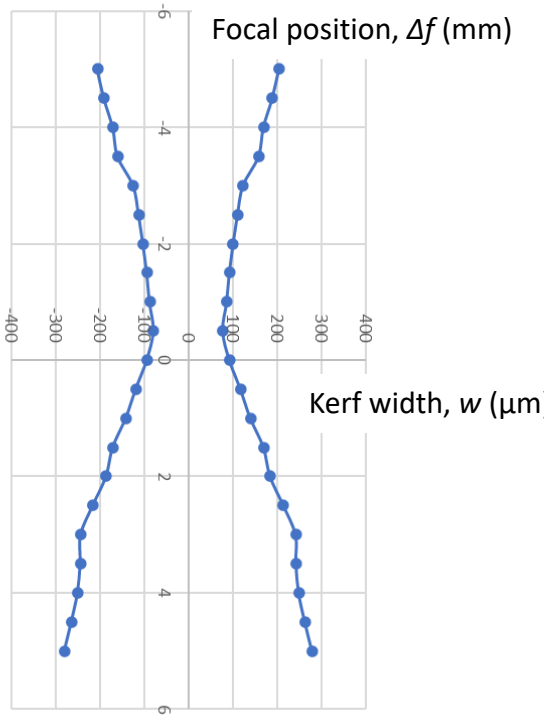
$$d_s^2 = d^2(z) = d_0^2 + \Delta z^2 (2\theta)^2$$

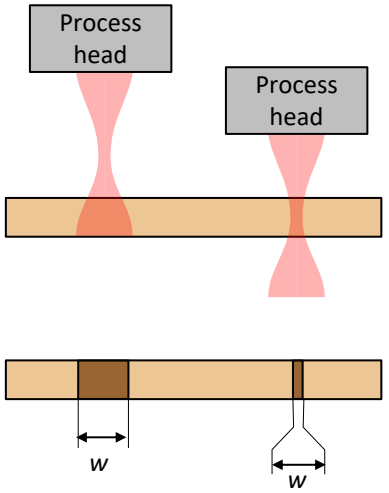


Technological method

Experiments:

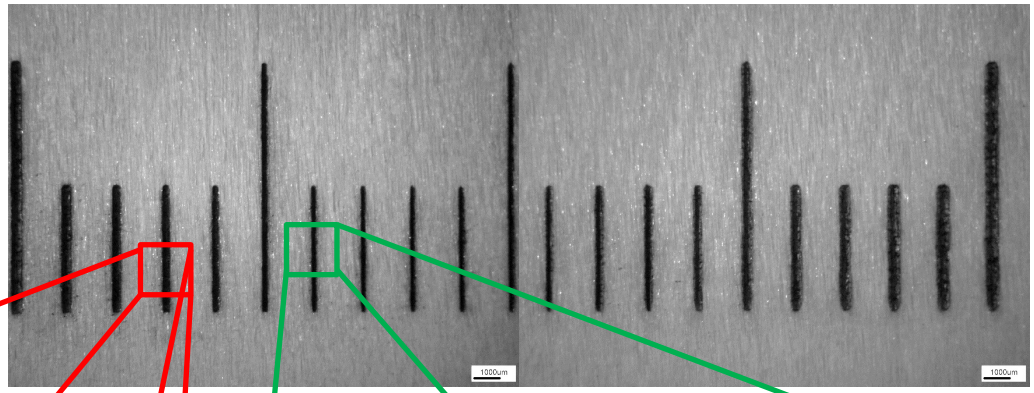
Single tracks in different working positions

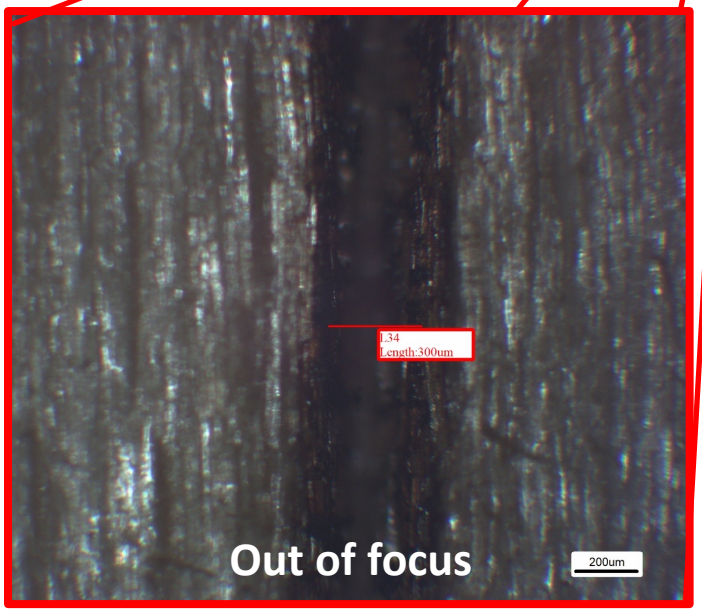


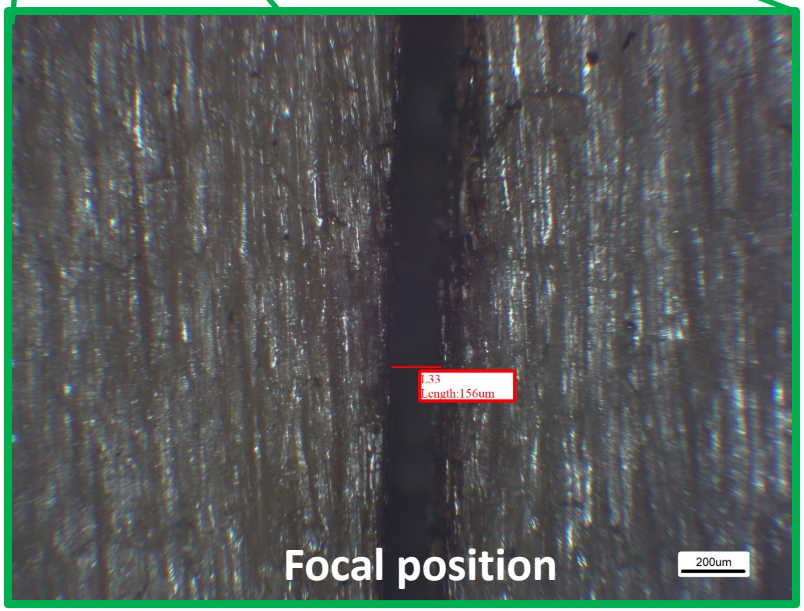


Machine calibration

Machine: Snapmaker A250
Process head: Laser
Material: Balsa wood
Experimental design:
Single tracks at different work positions
Characterization:
Optical microscope



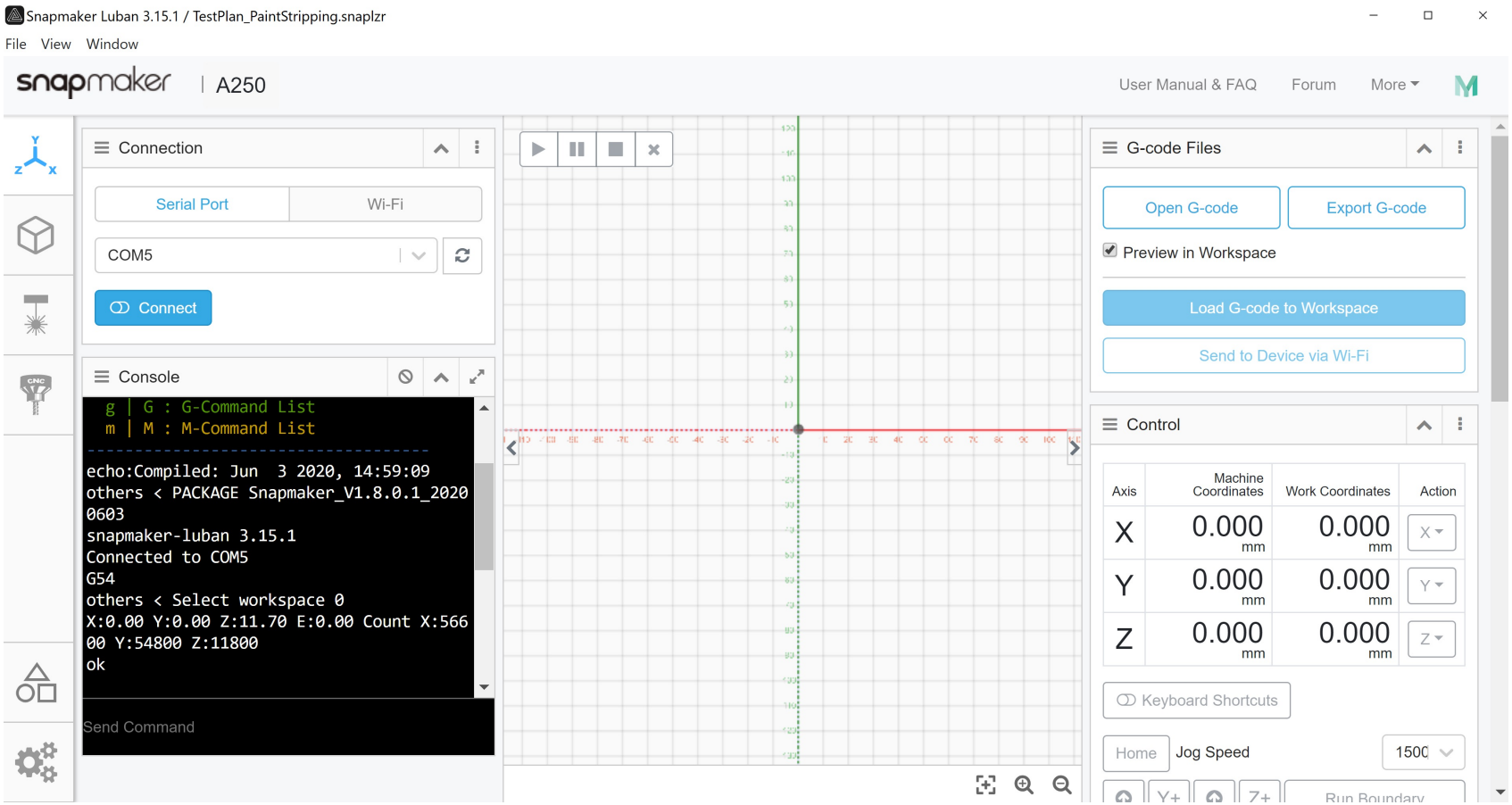




CAM software - Snapmaker Luban

CAM generation:

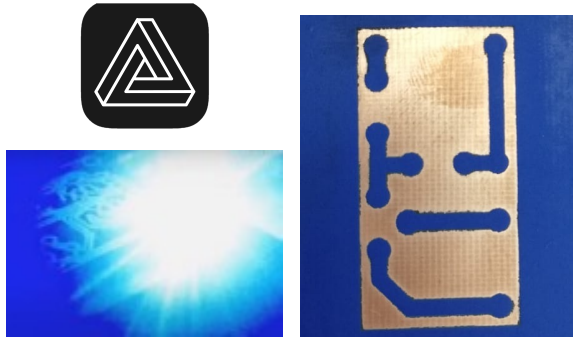
- Import .svg or .dxf files & assign toolpaths
- Design simple geometries & assign toolpaths
- Direct G-code coding



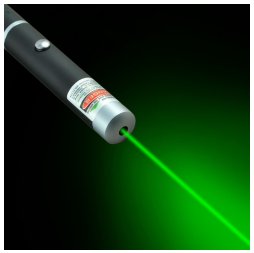
Aims

- Creation of a circuit drawing (.dxf) – voltage amplification of a photodiode signal

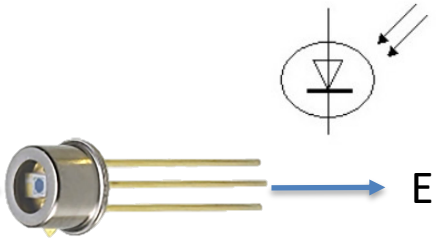
- Generation of the G code file (coordinates and process parameters) for laser stripping operation



Photodiodes – Working principle

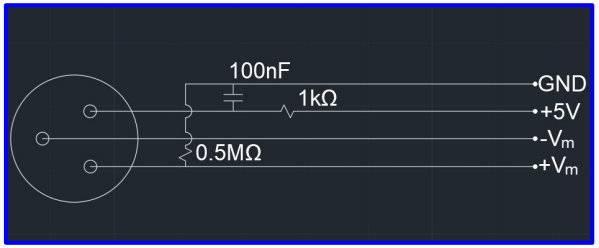


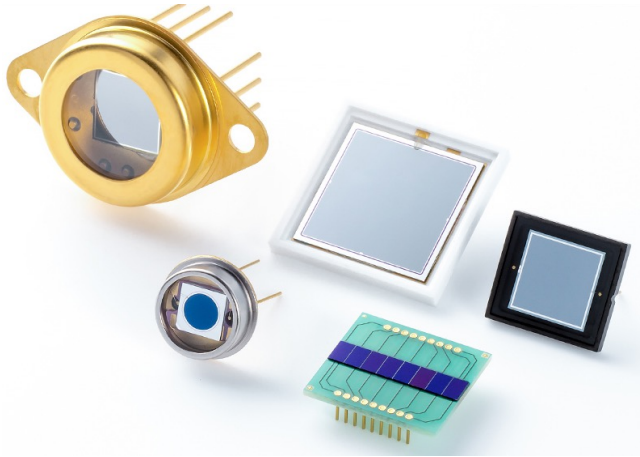
Light (photons)



Electric signal

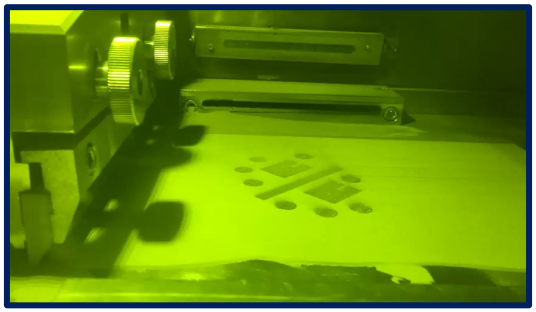
- Small, cheap and stackable
- Many applications:
  1. Laser pulse monitoring
  2. Spectrophotometry
  3. Sensors (proximity, motion)
  4. Telecomunication
  5. Optical disc drivers
- Laser source characterization. Laser pulse shapes

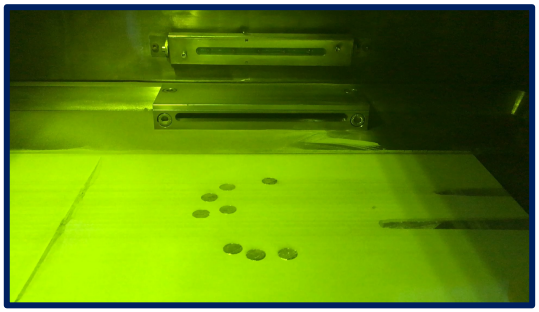


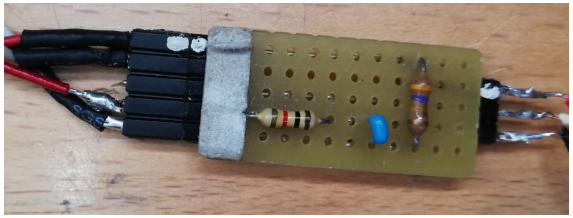


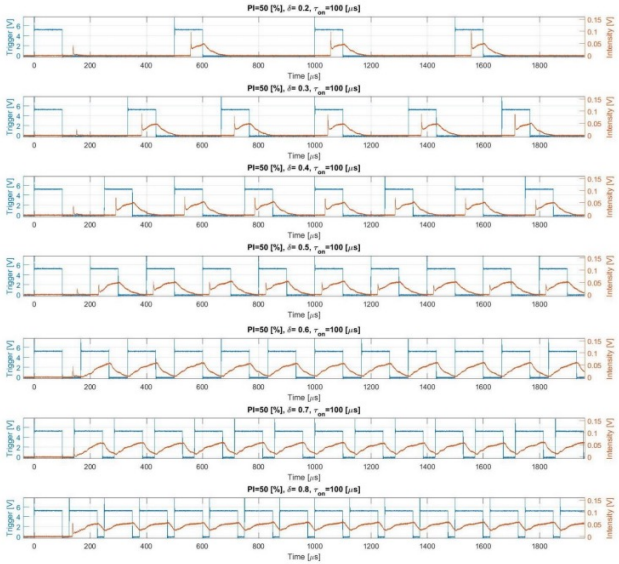
Photodiodes – Application example

Characterization of the PW emission of asingle mode fiber laser in an SLM machine









- Selective laser melting (SLM) is a metal additive manufacturing process
- SLM can be carried out both with CW and PW emission
- Free running in PW – µs-long pulses by power modulation
- The laser may not follow the desired square wave
- A fast photodiode can measure the emission

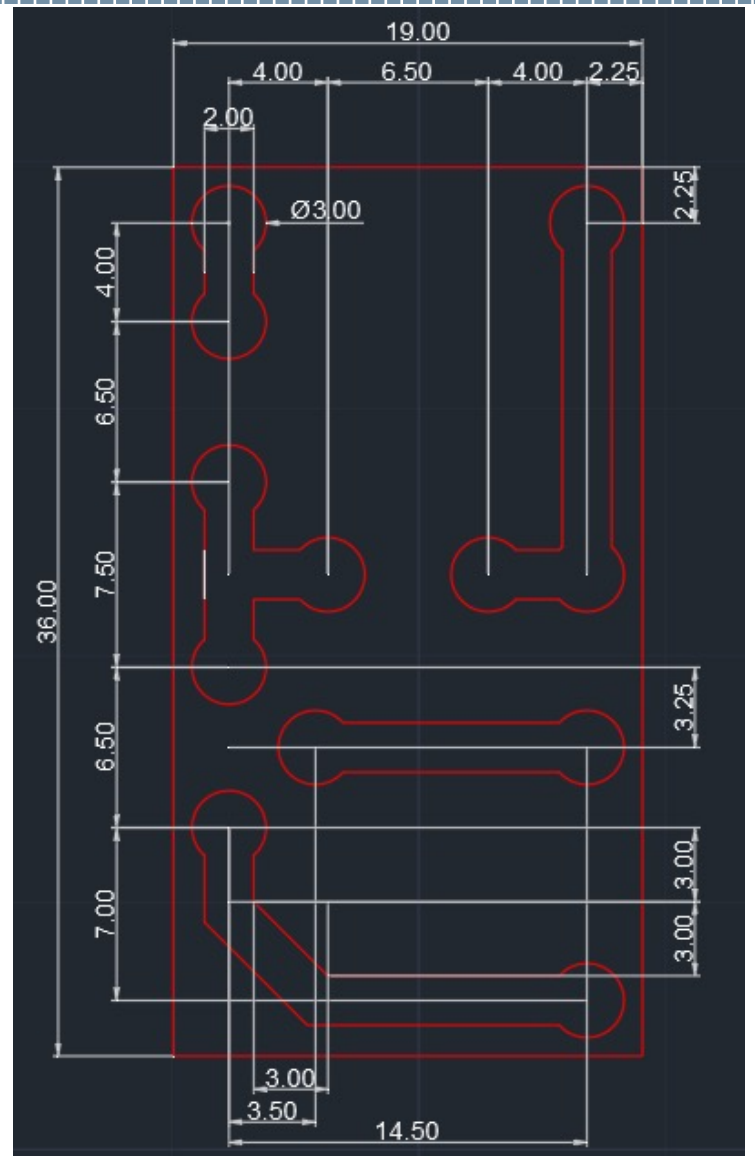
Caprio et al, J Mater Proc Tech 2019

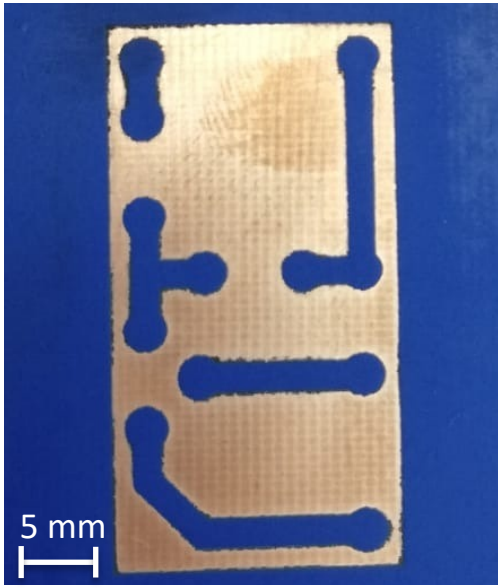
Photodiode circuit

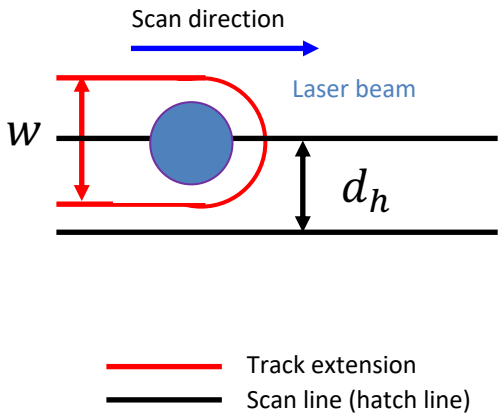
AUTOCAD

- The drawing shows the nominal dimensions
- The final dimensions will involve the track width and hathing
- All dimensions can be corrected by the following simplified expression

$$l = l_n + 2d_h - w$$

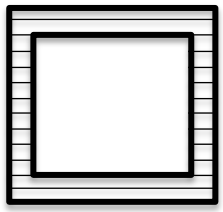




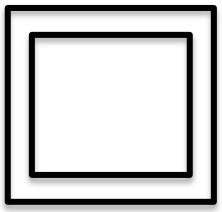


Snapmaker Luban - DXF generation

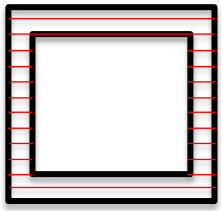
Target geometry



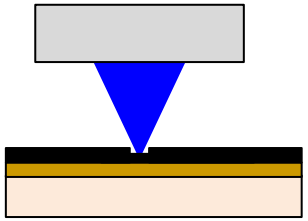
1) Contour creation



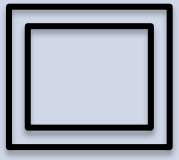
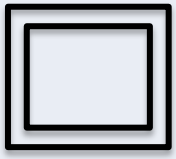
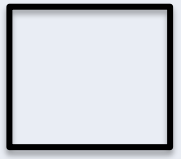
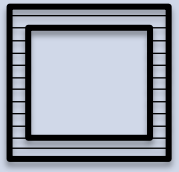
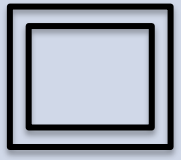
2) Import + Infill



3) G code/marking



- Recognition of closed geometry
- Recognition of inner geometries
- Hatch lines considered as area instead of lines

Autocad	Snapmaker
	
	
	

Summary:

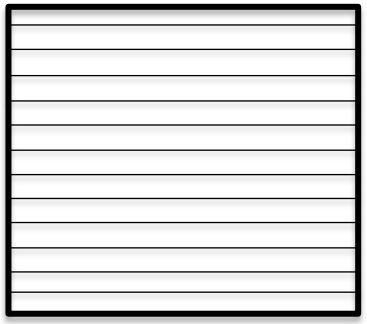
- Hatching is defined in AutoCAD
- Number of passes is defined in Luban Snapmaker

Autocad – Hatching definition

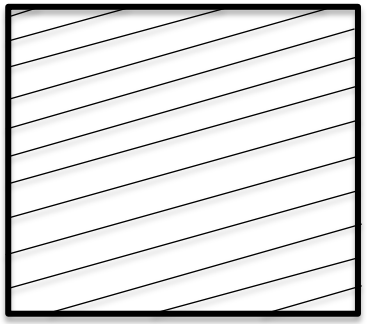
Hatching angle

Hatching angle must be 0° (horizontal lines) to have a single direction

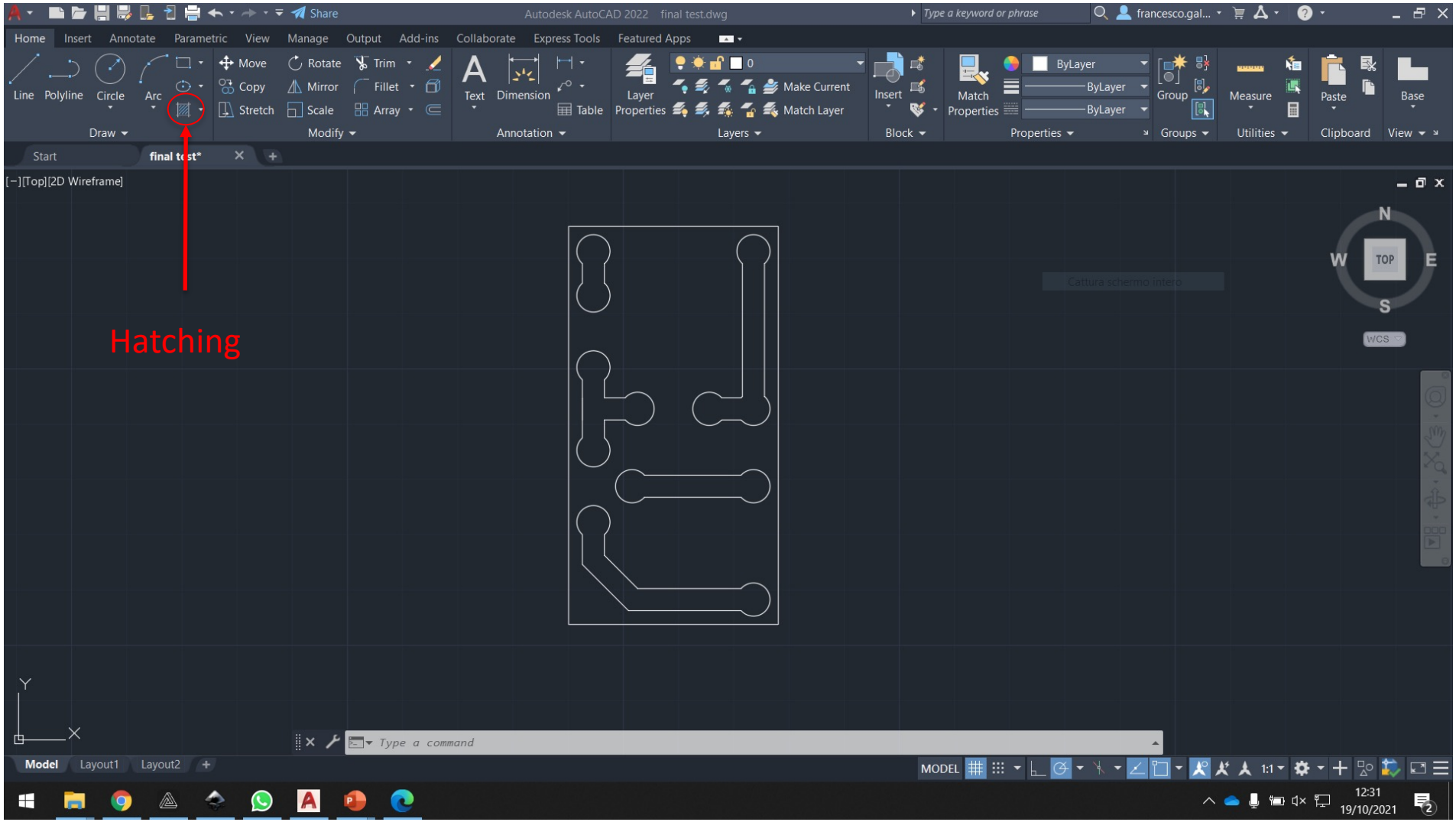
Yes



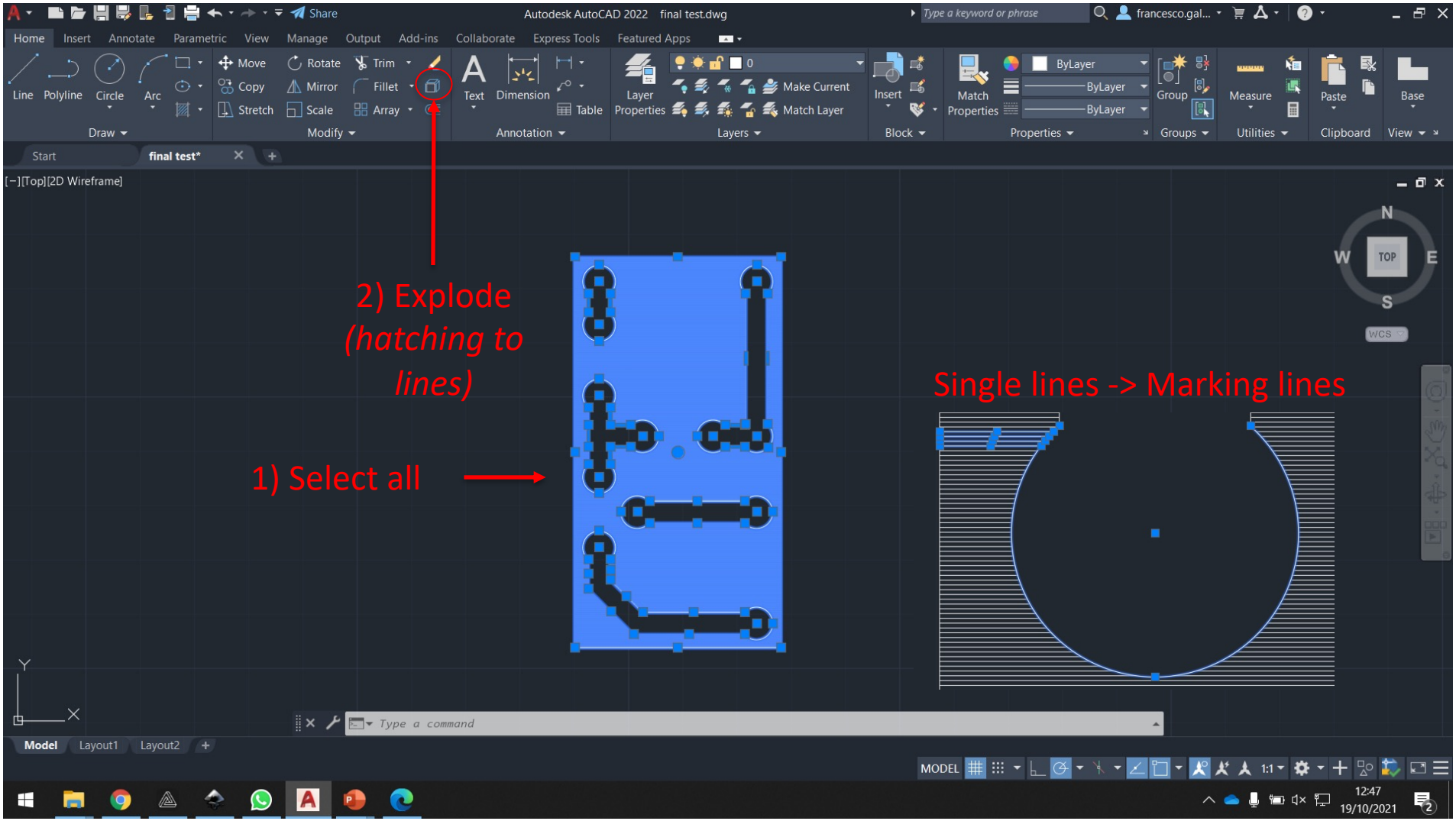
No



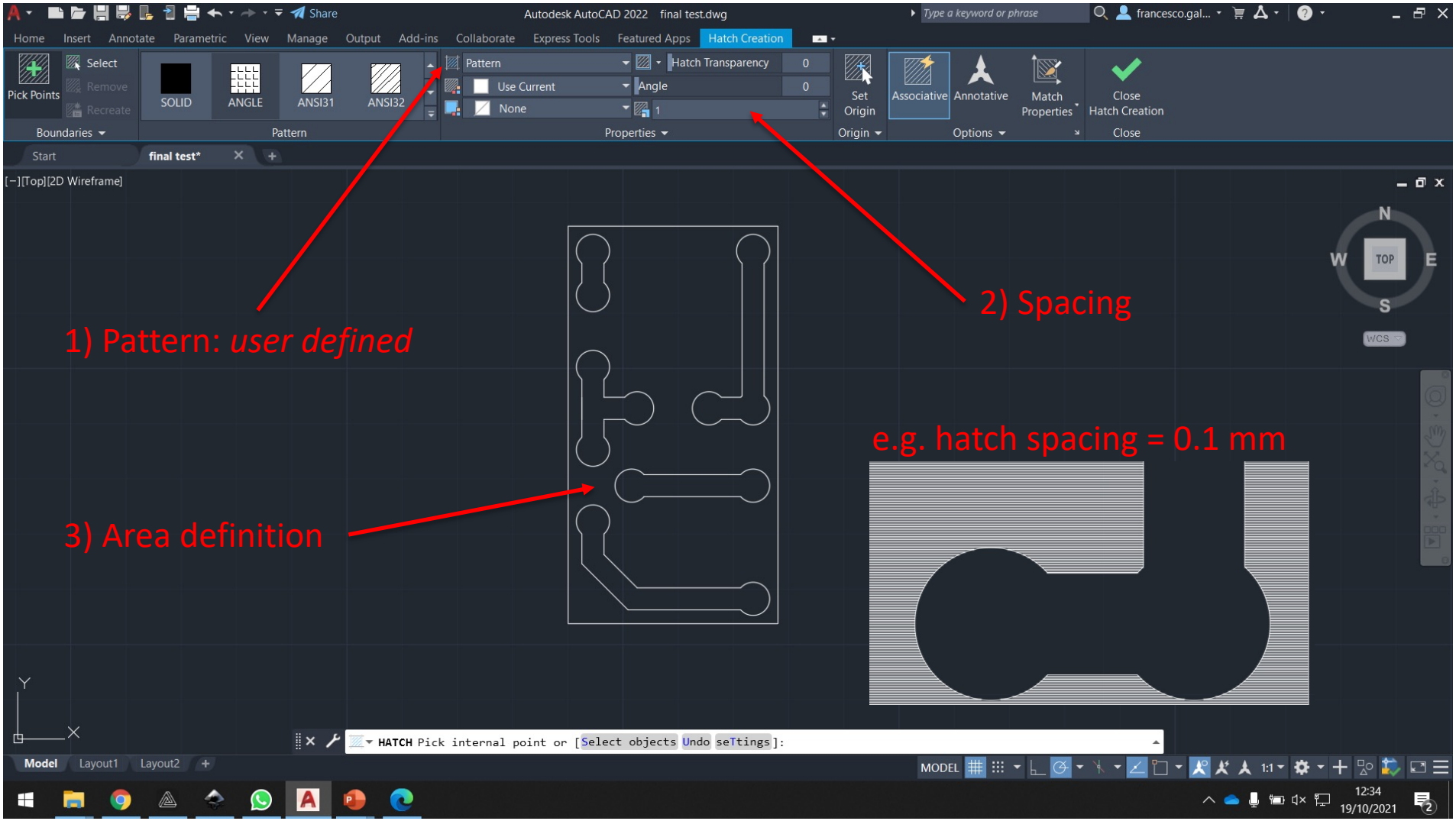
Autocad – Hatching definition



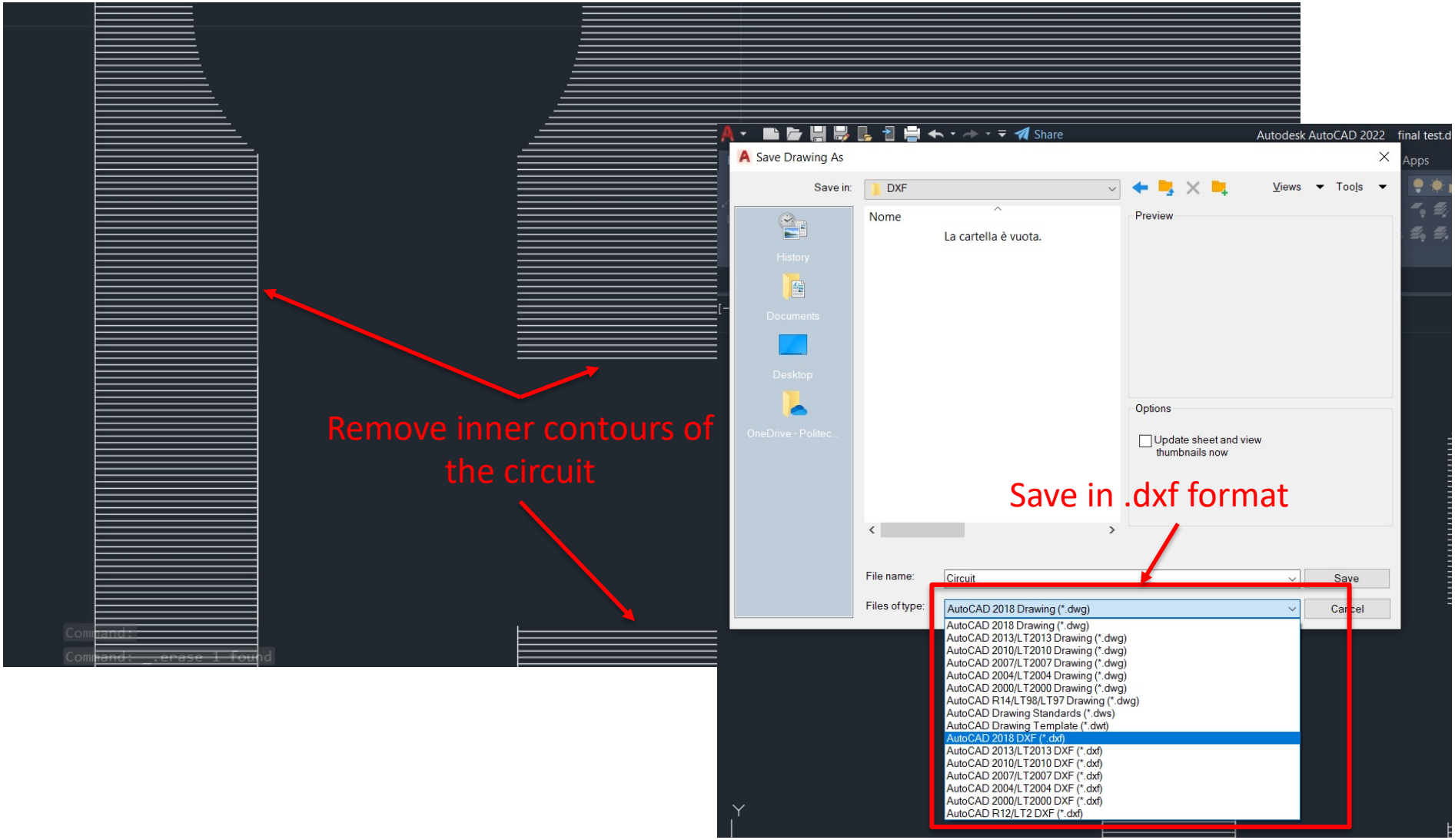
Autocad – Hatching definition



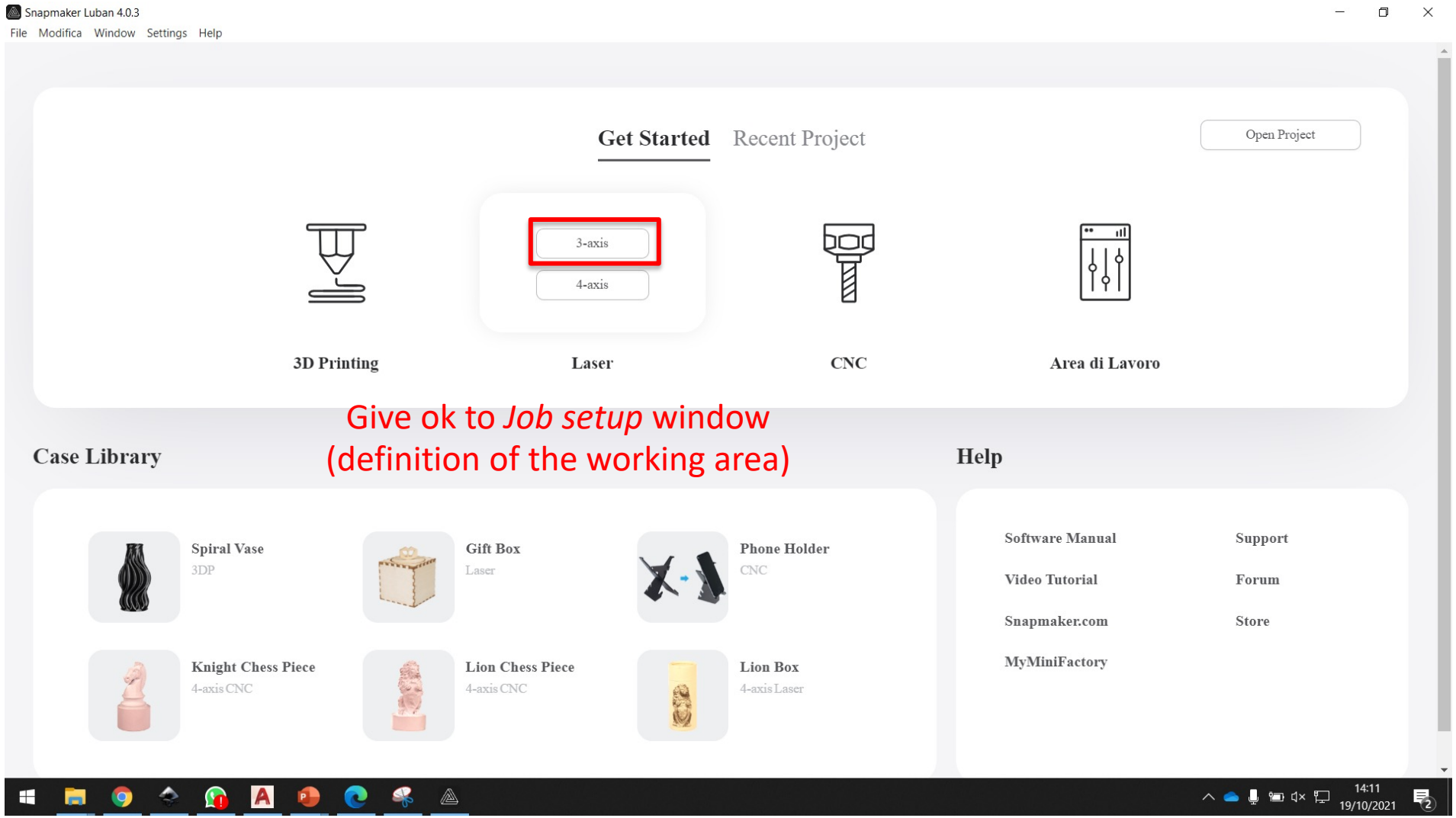
Autocad – Hatching definition



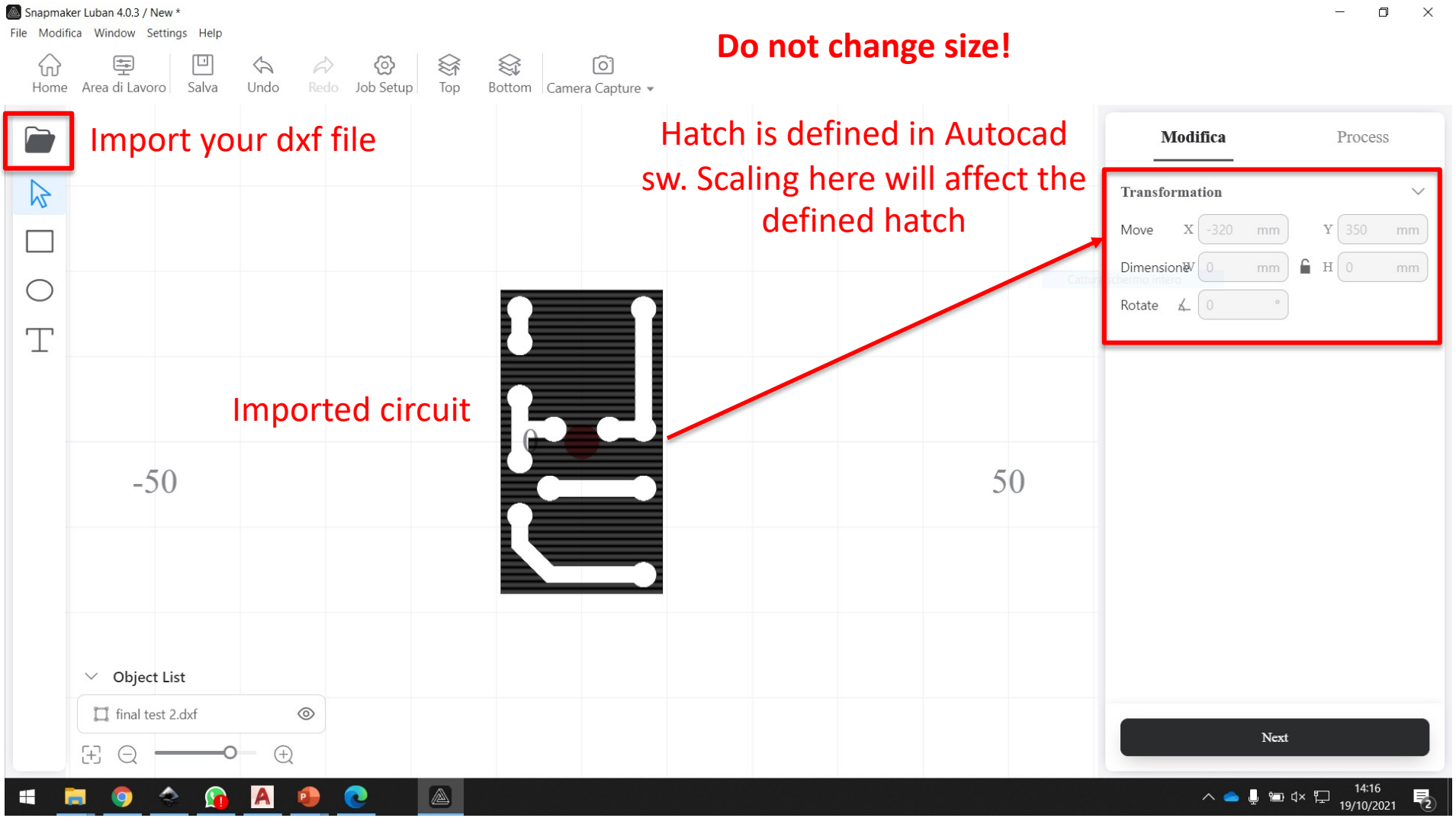
Autocad – Final steps



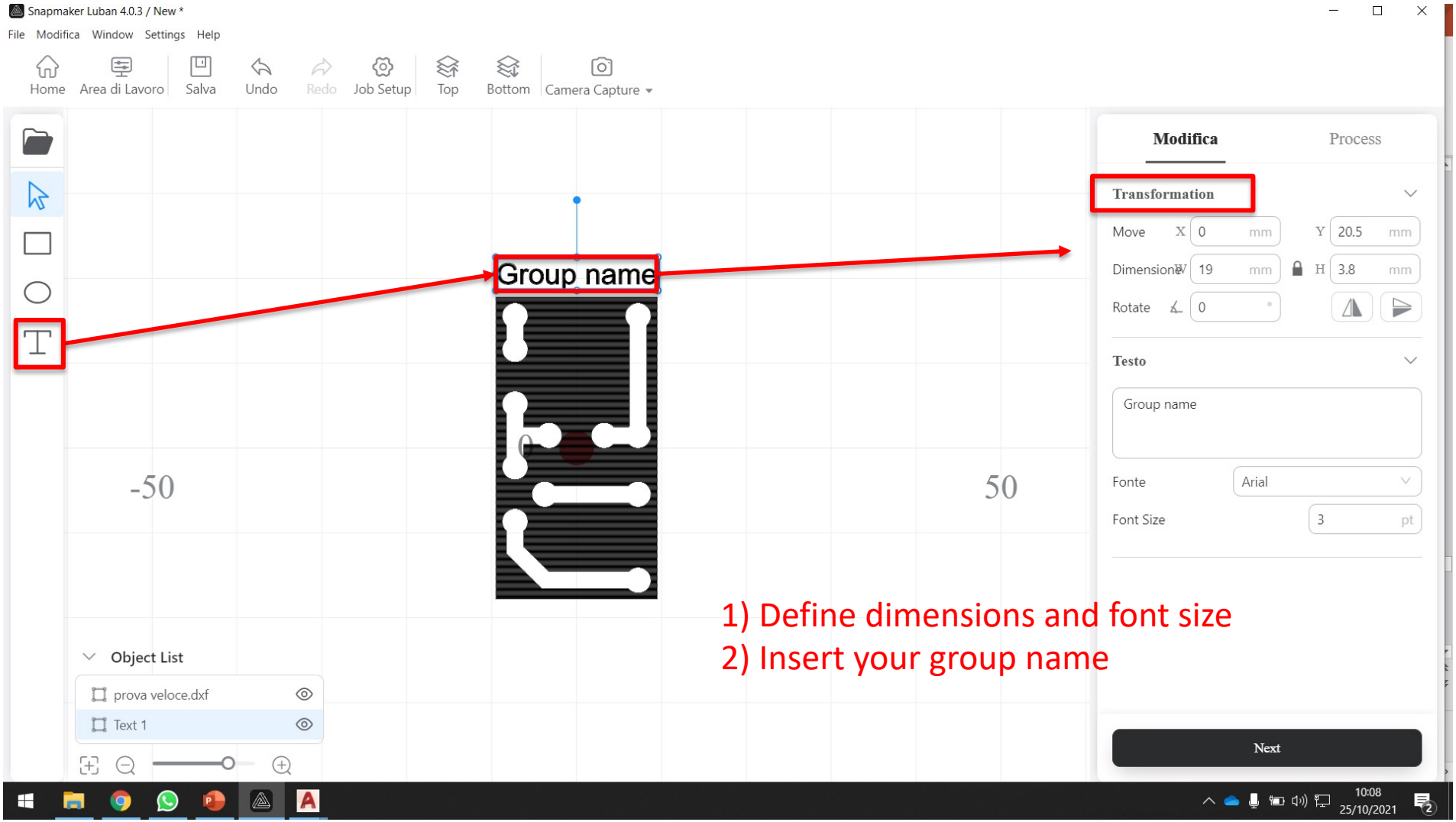
Snapmaker Luban – G code creation



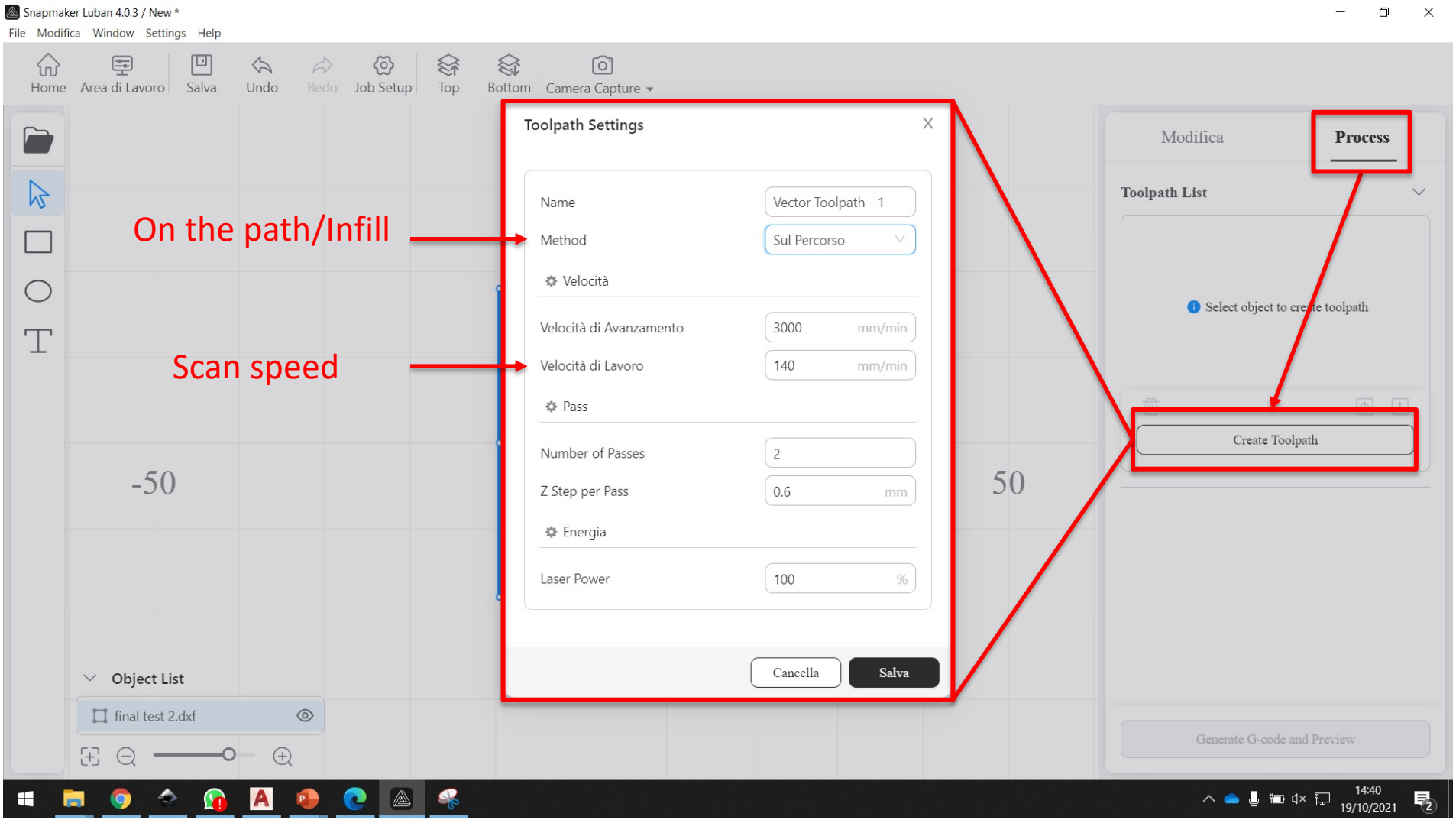
Snapmaker Luban – G code creation



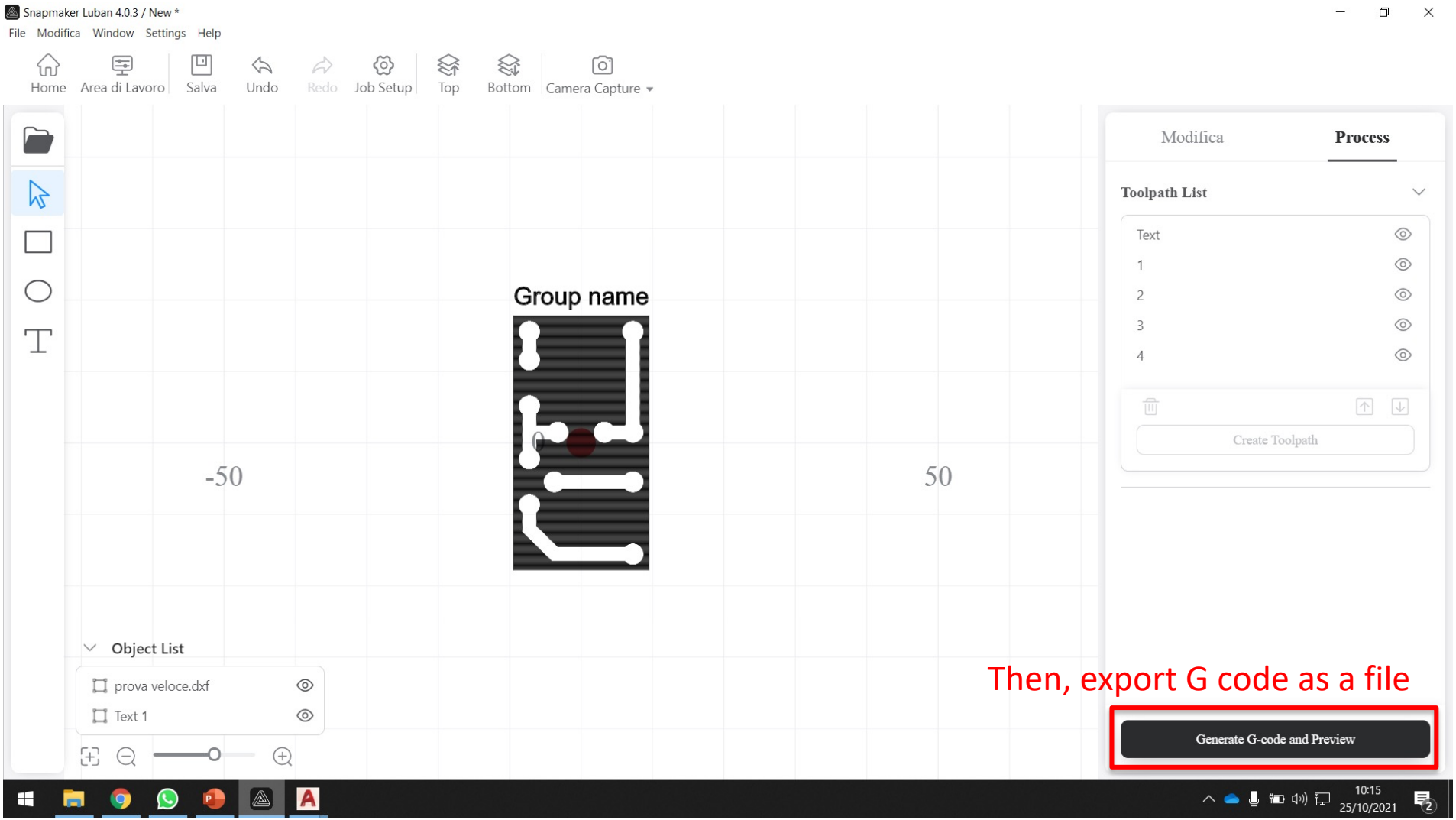
Snapmaker Luban – G code creation



Snapmaker Luban – G code creation



Snapmaker Luban – G code creation



Deadline

- Lab 2 – Revision 2 – 26/10/2021

Deadline: 09/11/2021

- Upload zip folder on WeBeep (***Consegne -> Lab 02 Assignment***) containing:
  - **G code file** called "Group name"Deadline: upload G code file on the beep folder
  - **A text file (.txt)** called "ProcessParameters_Group name", containing the list of process parameters you have set in (hatching, scan speed and number of passes)

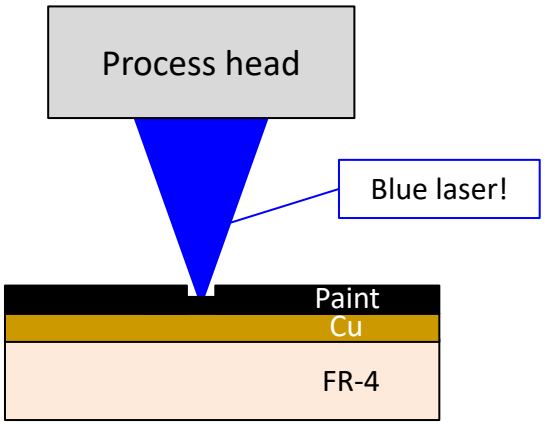
TBN! Zip folder must be titled "Groupname" too

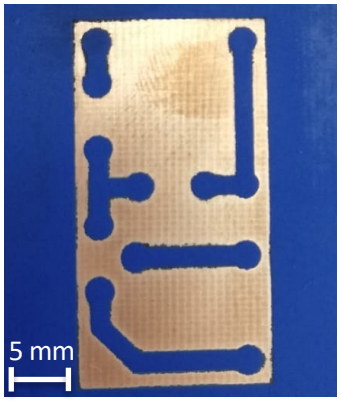
- Laser stripping of the circuits 09/11 – 21/11

- Lab 3 – Revision 3 – 03/12/2021

Effect of scan speed

Process

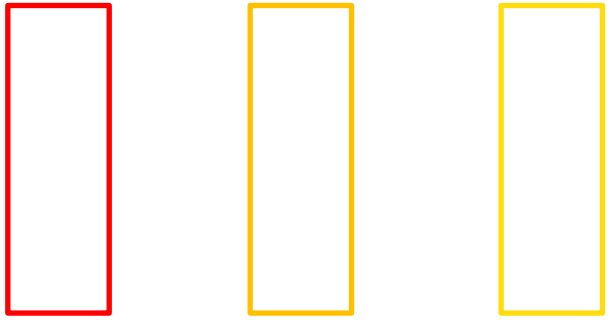




Experimental design:

Fixed factors	
Power, *P* (mW)	1600
Emission wavelength, λ (nm)	445
Focus position, *f* (mm)	0
N° of passes	1
Variable factors	
Feed rate, *v* (mm/min)	400 – 800 – 1600

Single tracks cannot be drawn on Snapmaker Luban
→ Rectangles with only outer outline



Characterization:

Measure track width

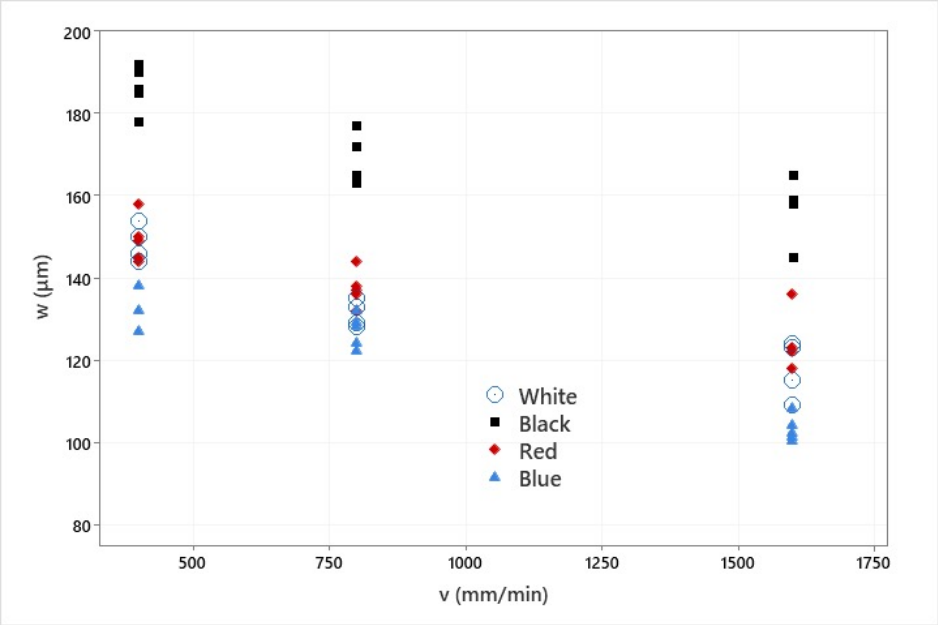
Define track overlap % to ensure etching of large areas

Calibrate efficiency using thermal model

Estimate penetration depth
→ n° of passes required?

Track width vs scan speed

v [mm/s]	N°	Black	White	Red	Blue
400	1	192	150	145	138
400	2	178	154	144	132
400	3	190	146	150	132
400	4	185	144	149	127
400	5	186	146	158	132
800	1	172	133	136	129
800	2	163	129	144	132
800	3	177	135	138	124
800	4	177	135	132	128
800	5	165	128	137	122
1600	1	159	123	122	104
1600	2	165	124	118	108
1600	3	158	115	123	102
1600	4	145	115	136	101
1600	5	158	109	122	100



- Stripping will be performed with P_{max} and v= 800 mm/min
- What about setting different scan speed? What happens to productivity?

Contact details

DIPARTIMENTO DI ECCELLENZA
MIUR 2018-2022

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