Laser Cutting and Engraving

Safety, Fundamentals, and Troubleshooting





Spot the Hazard Before You Start



What do you notice?

1. What stands out?
2. What might be hazardous?
3. What could change the risk?

What could change the risk?

- Where the cord is routed
- Whether people walk through the area
- The condition of the cord
- Whether liquids or sharp objects are nearby
- Whether the workspace is cluttered

Keep cords clear, dry, and out of walkways. Clean up clutter and report hazards.

Spot the Hazard Before You Start



What do you notice?

1. What stands out?
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What could change the risk?

- What material is being cut or engraved?
- Are there flammable materials nearby?
- Is the exhaust working properly?
- Are people wearing the correct laser safety glasses?
- Is the laser being directly supervised?
- Is a fire extinguisher nearby and accessible?
- Is the workspace clean and free of clutter?

Lasers can ignite materials and produce harmful fumes. Always supervise the laser when in use.

When a Laser Fire Starts

STAY CALM.
ACT QUICKLY.
BE PREPARED.

1 BE PREPARED



- **A/B (Class A/B) fire extinguisher accessible.**
- **Monitor every job.**
- **Know the emergency stop.**



2 KNOW THE DIFFERENCE

A brief, momentary flare-up can be normal, especially when cutting wood. Watch closely. If the flame becomes sustained or grows, stop immediately.



Brief flare-up: monitor closely.



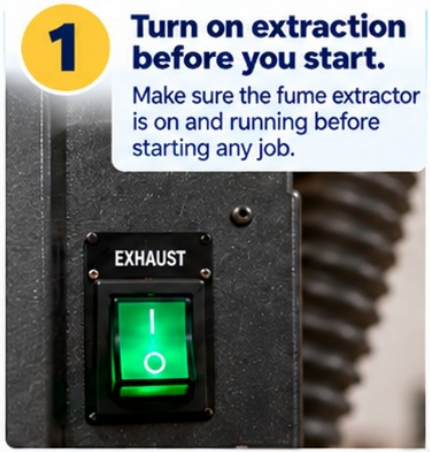
Sustained or growing flame: STOP immediately.

3 RESPOND

1. **Stop the laser using the emergency stop** when necessary.
2. **Keep the lid closed initially.** Do not open the lid reflexively, as this can introduce oxygen and make the fire worse.
3. **If fire persists,** follow the machine-specific emergency procedure.
4. **If not safely controllable,** evacuate the area and call for help.

Only trained staff should attempt extinguisher use on a small, contained fire.
Follow school policy.

Fume Extraction: Always On



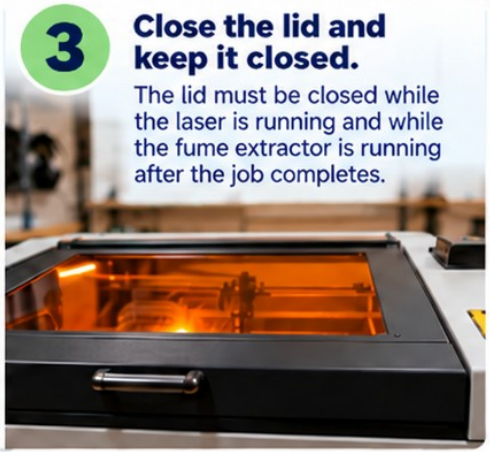
1 Turn on extraction before you start.

Make sure the fume extractor is on and running before starting any job.



2 Verify extraction is working.

Before starting, feel for strong airflow inside the laser (at the vents) and check that the machine is set to the correct extraction level.



3 Close the lid and keep it closed.

The lid must be closed while the laser is running and while the fume extractor is running after the job completes.

Keep Extraction Running After the Job

Continue running the fume extractor after the job completes to clear remaining smoke, fumes, and particles from the enclosure. Keep the lid closed until the air is clear.

Material	Recommended Minimum Extraction Time (After Job)
Birch plywood (wood)	**5 minutes**
Other wood (MDF, hardwood, etc.)	**5–10 minutes**
Acrylic (PMMA)	**15 minutes**
Delrin (POM)	**20 minutes**
Other plastics (PET, PETG, PP, PE, etc.)	**20–30 minutes**

Run longer if you notice lingering smoke or odor. Do not open the lid until the air is clear.

Material Compatibility for CO_2 Laser Cutting and Engraving

Use only approved materials. Some plastics and other materials release hazardous fumes, can damage the laser, or create a fire hazard.

Material	Recommendation for our Fab Lab	Key considerations
Birch plywood (wood)	**Preferred**	Excellent cutting, clean edges, good engraving.
Acrylic (PMMA)	**Preferred**	Excellent cutting, clean edges, good engraving.
Delrin / Acetal (POM)	**Conditional**	Cuts well, but releases formaldehyde during thermal decomposition; requires appropriate exhaust controls.
PET / Polyester	**Conditional**	Can sheets and films can cut; melting and fumes must be managed.
PETG	**Conditional**	Can melt, discolor, and produce less consistent edges than acrylic.
Polypropylene (PP)	**Conditional**	Thin sheets may work; melting and ignition are concerns.
Polyethylene (HDPE/LDPE)	**Conditional**	Tends to melt, warp, and create messy edges.
ABS	**Generally avoid**	Fumes, soot, odor, and inconsistent cutting.
Polycarbonate (Lexan)	**Generally avoid**	ULS supports processing, but discoloration, charring, and fumes make it a poor routine choice.
PVC / Vinyl	**Prohibited**	Corrosive hydrogen chloride and other hazardous decomposition products.
PTFE / Teflon and fluoropolymers	**Prohibited**	Potentially highly hazardous fluorinated decomposition products.
Polystyrene foam (EPS/XPS)	**Prohibited**	Particularly serious melting and fire hazard.
Metals	**Conditional**	Does not engrave bare metal. Can remove matte paint or anodized coatings if done with precision. Shiny metal surfaces can reflect the laser beam, potentially damaging the optics (lens/mirrors) — use extreme caution or avoid.

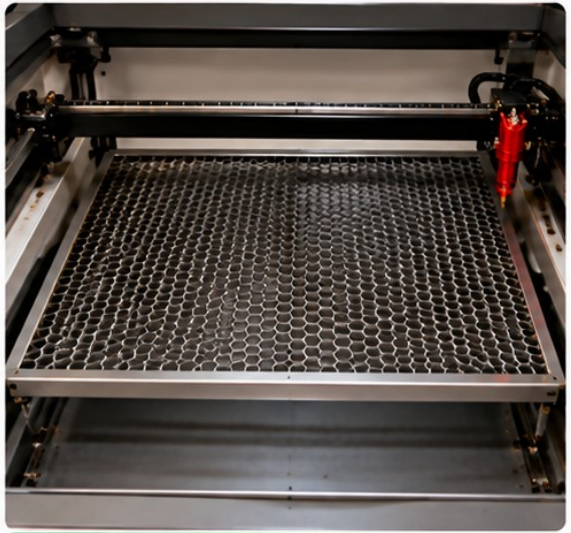
Keep the Laser Clean

1 Remove debris from the cutting tray

Before each job, remove all scrap pieces, dust, and small parts from the cutting tray and bottom pan. Keep the entire interior clear of debris.



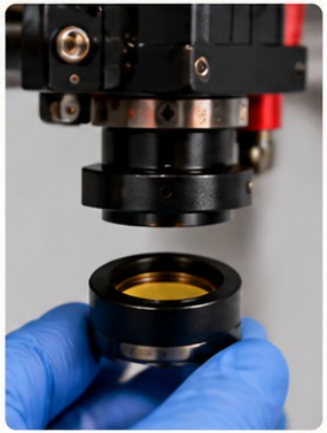
Before (Remove debris)

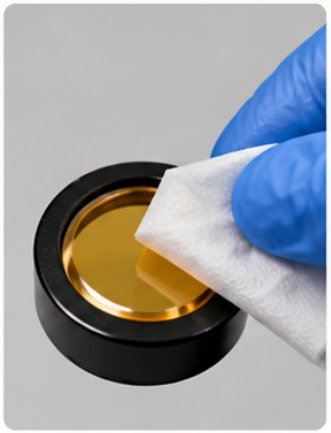


After (Clear tray and bottom pan)

2 Keep the lens clean

Remove the lens for cleaning. Use only the included materials and laser lens cleaning liquid. Do not clean the lens while it's installed.

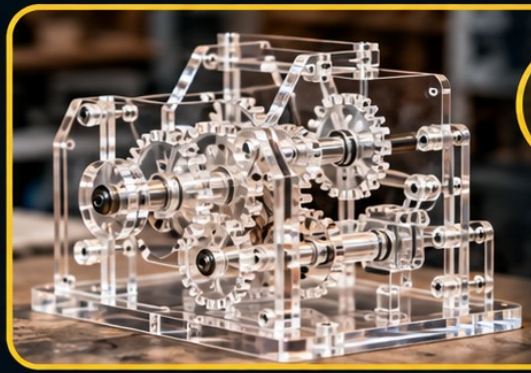




Pro tip:
Do not rub the lens when cleaning. Swipe once so carbon doesn't scratch the lens.

What Makes Laser Cutting So Powerful?

Because the laser gives us **speed, precision, and design freedom** that are hard to get any other way.



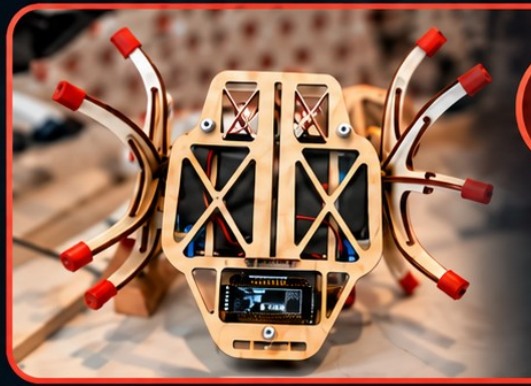
Fast Prototyping

Turn ideas into physical parts quickly and accurately.



Complex Geometries

Create precise, detailed designs that a 3D printer may not handle well, may struggle to scale, or may be too large to print efficiently.



Redefinition of Components

Cut and assemble custom parts that would be difficult or impossible to make otherwise.

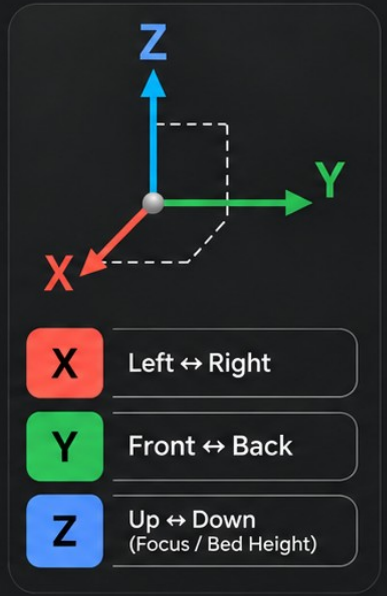


Precise Dimensions

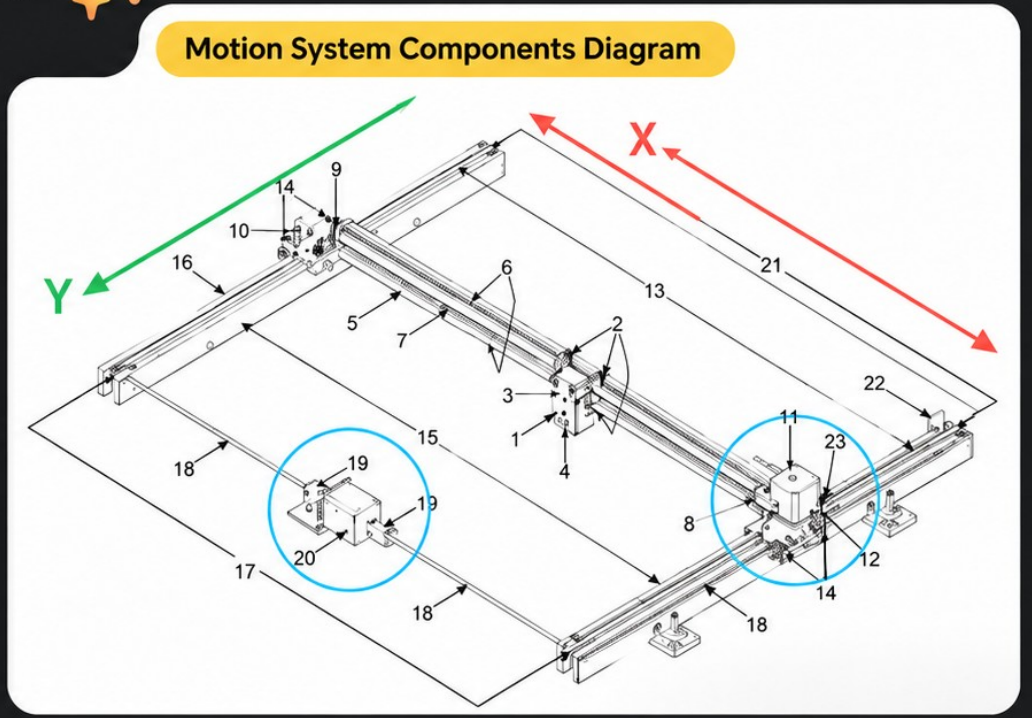
Achieve clean, consistent cuts and engravings for functional and aesthetic projects.

Cartesian Motion System
Coordinate Geometry





Motion System Components Diagram



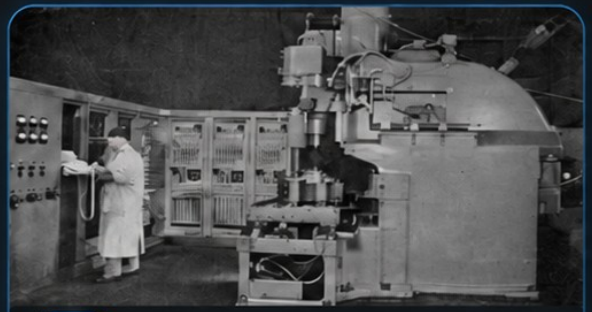
Precise Positioning

Straight-Line Motion

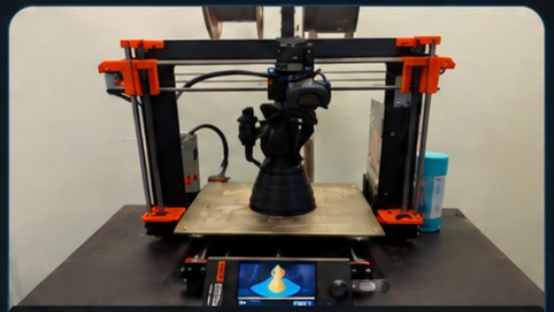
Rigid Structure

Wide Range of Applications

These Use Cartesian Motion, Too! ✨



First CNC at MIT (1950s)



3D Printer



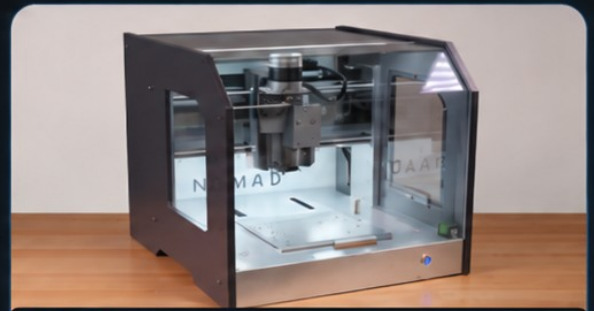
Construction Printer



Cartesian Gantry



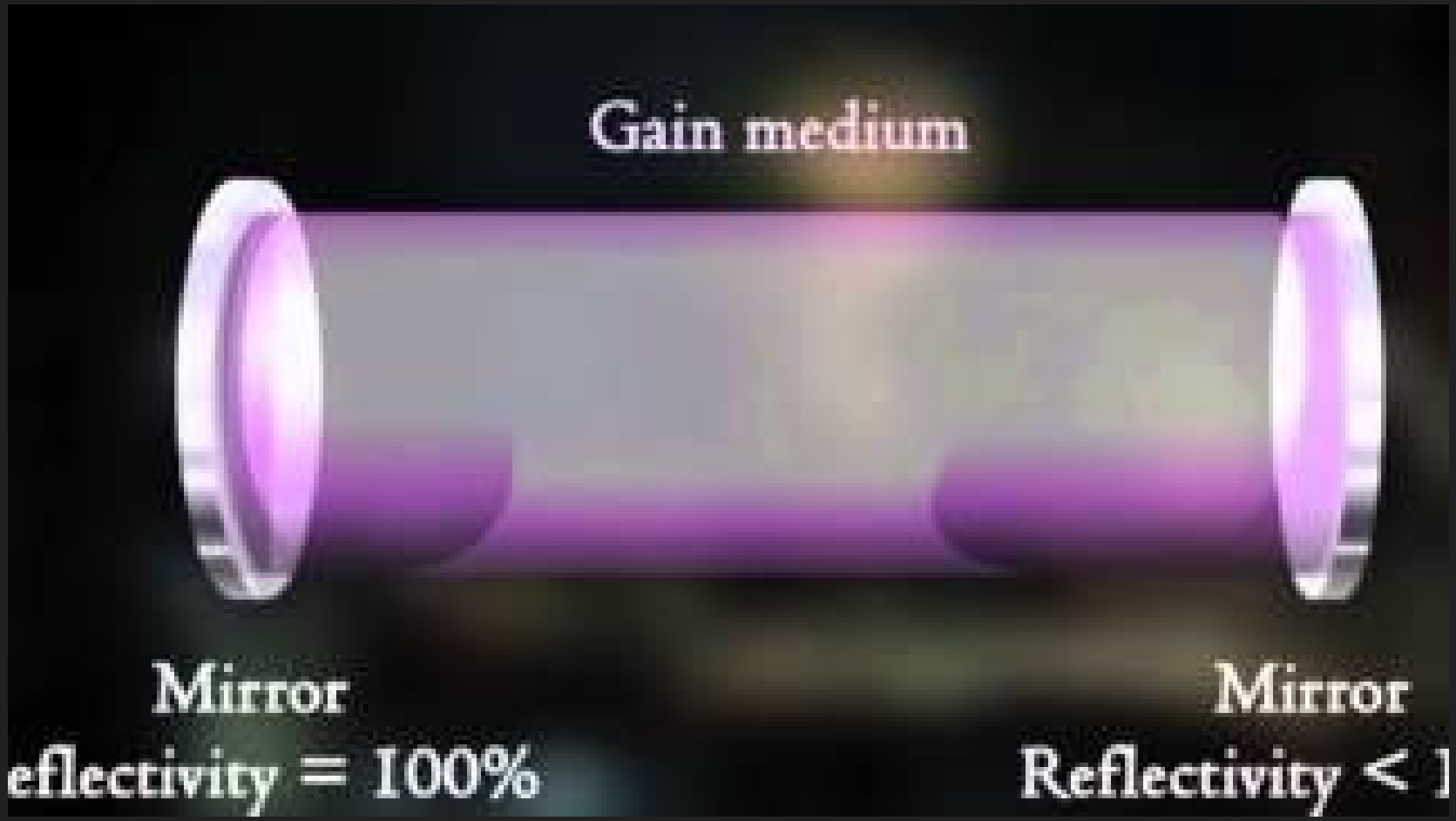
CNC Machines



Desktop CNC

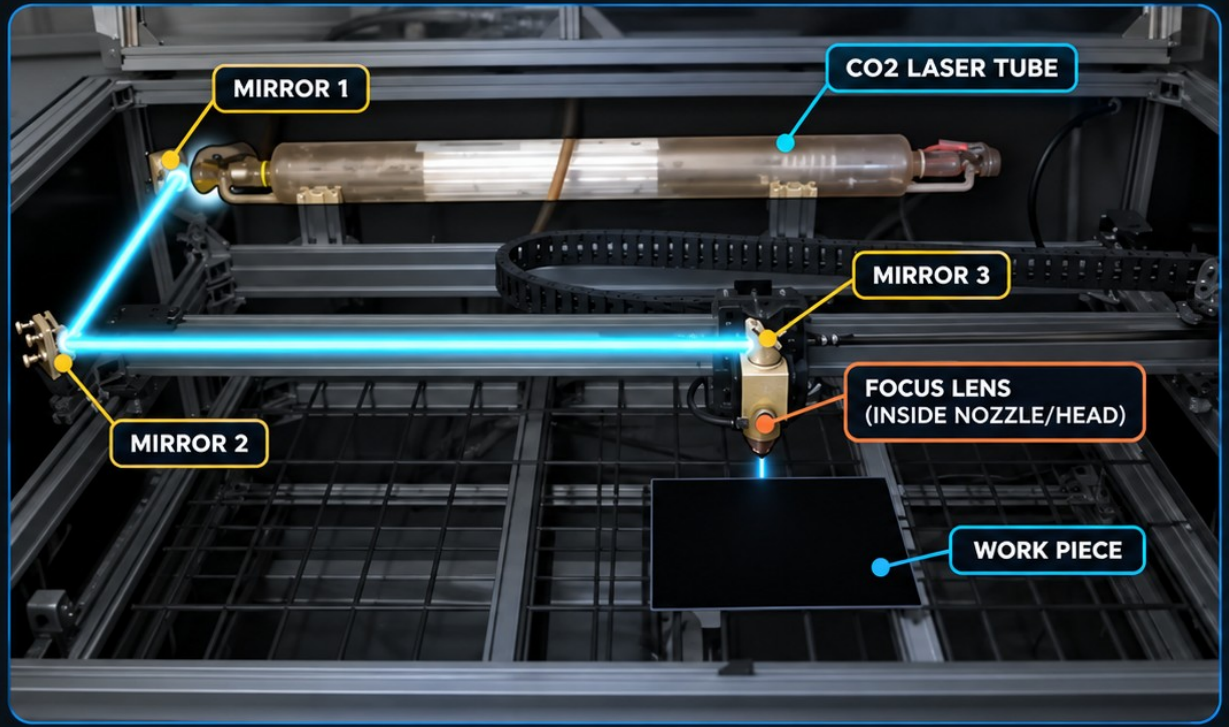
Different tools, same **X-Y-Z motion logic.**

Mirrors



How the CO2 Laser Works

Inside the laser cutter

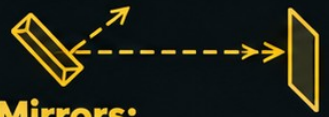


1



CO2 Laser Tube: generates the infrared laser beam.

2



Mirrors: redirect the beam through the machine.

3

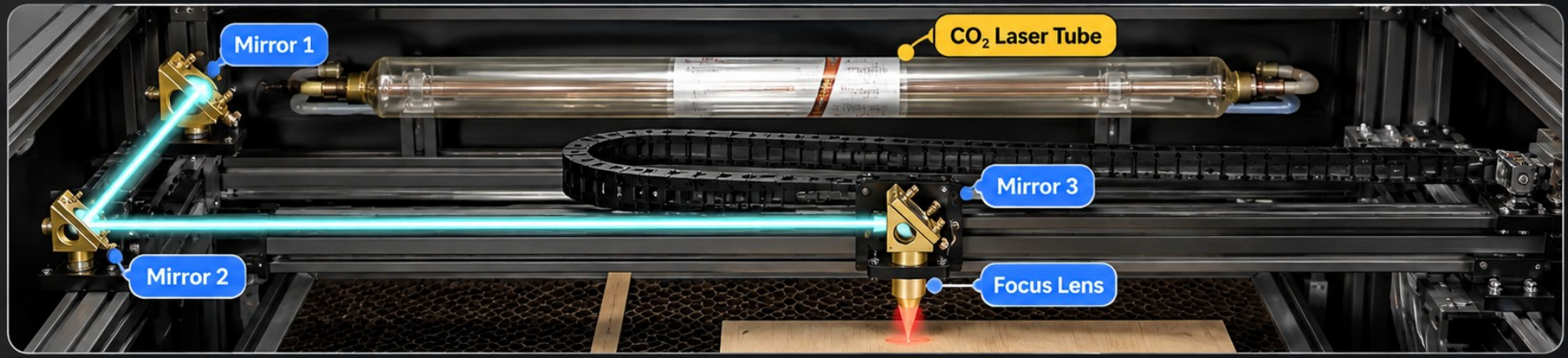


Focus Lens: concentrates the beam onto the material.

A focused beam + precise motion = cutting, engraving, and marking.

Inside the Laser: From Tube to Material

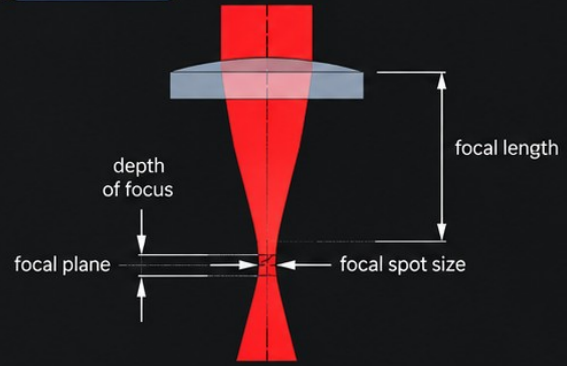
Our machine uses a CO_2 laser. The beam is created in a glass tube, reflected by mirrors, then focused through a lens onto the material.



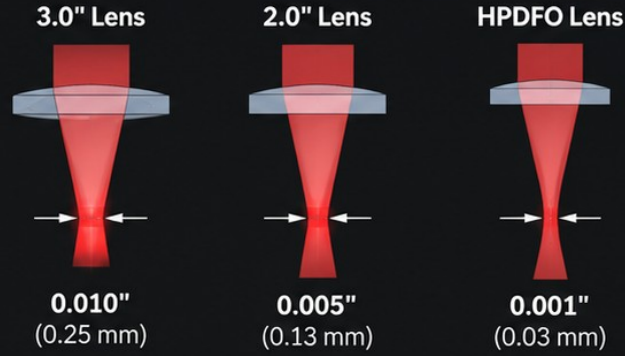
Mirror (45°)



Focus Lens

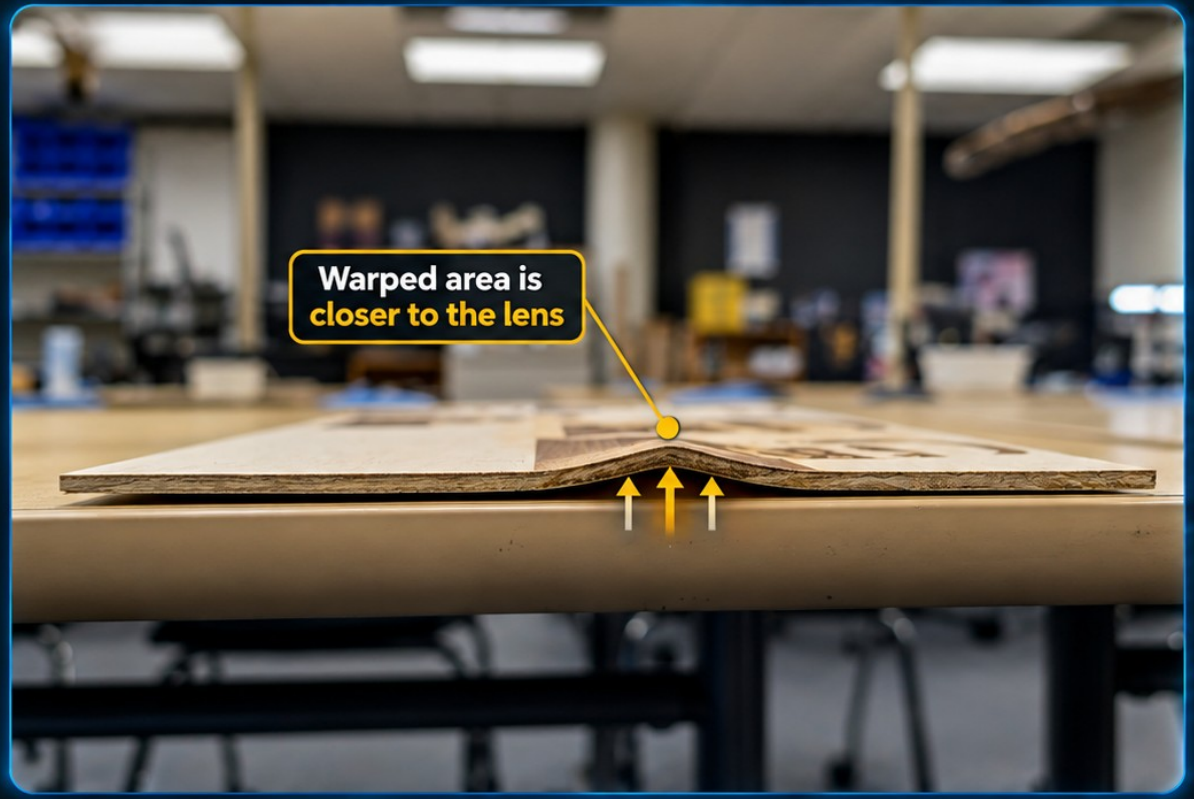


Different Lenses = Different Focus

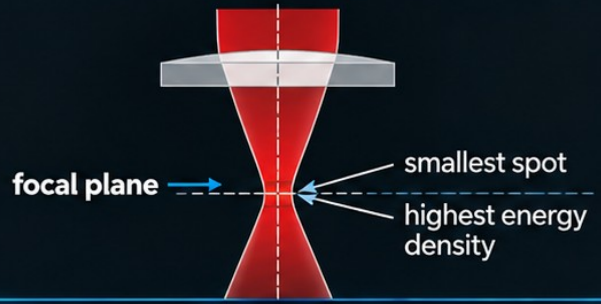


Focal Plane vs. Warped Material

When the surface moves out of focus, cut quality drops.



The Focal Plane



1. **Best focus =** smallest beam spot.

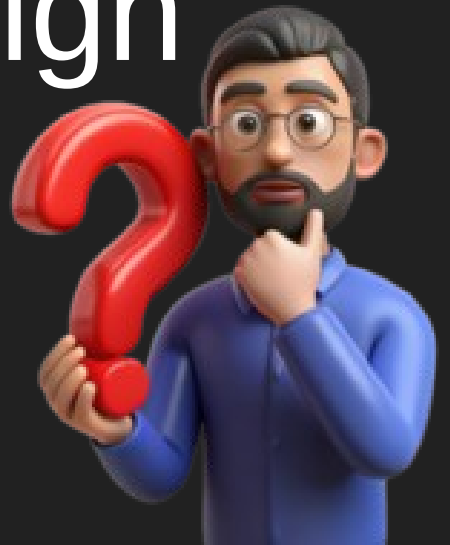
2. **Warped material** shifts the surface above or below the focal plane.

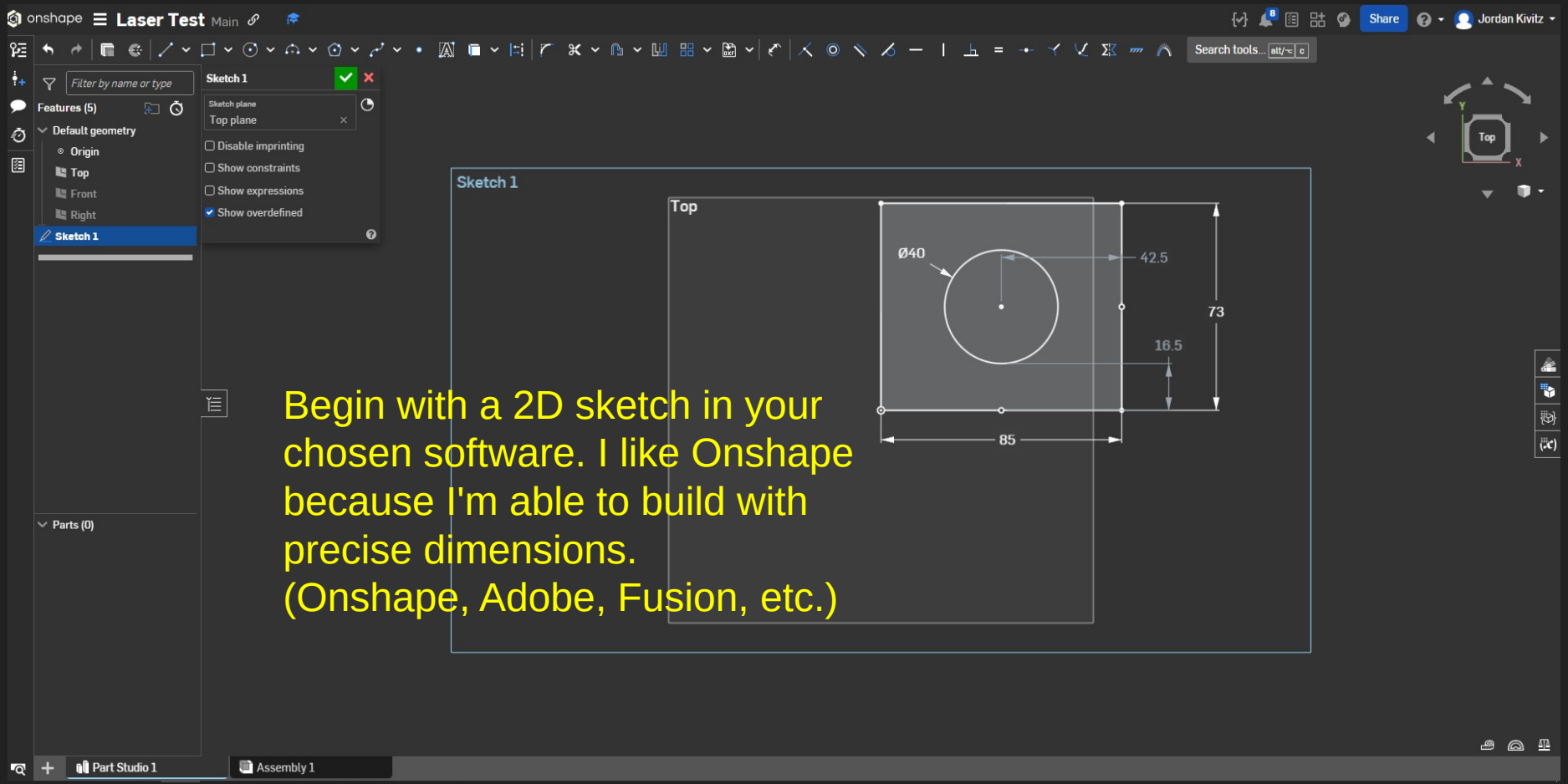
3. **Out of focus =** wider beam, less energy, poorer cutting/engraving.

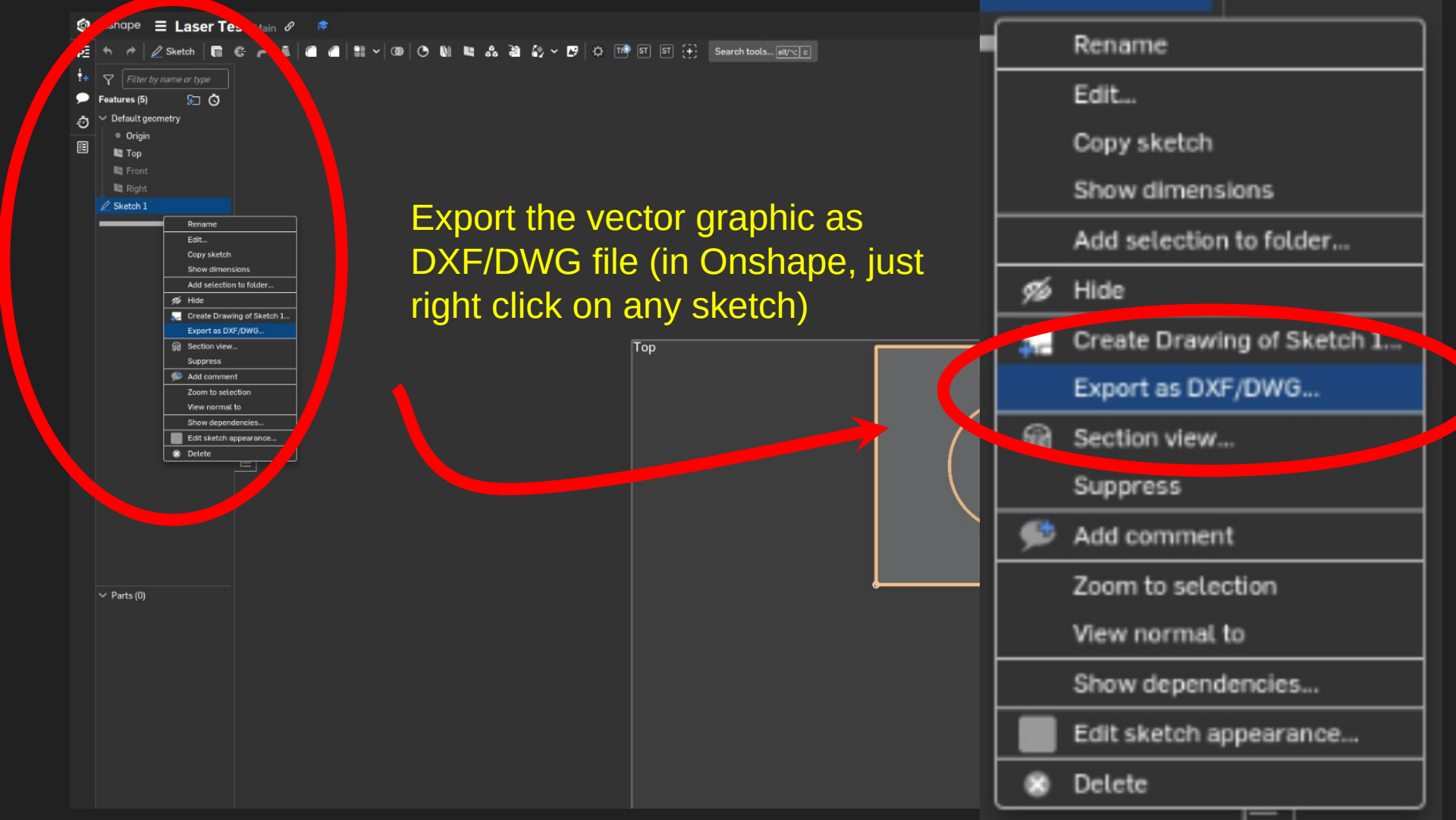
Flat material keeps more of the surface at the focal plane.

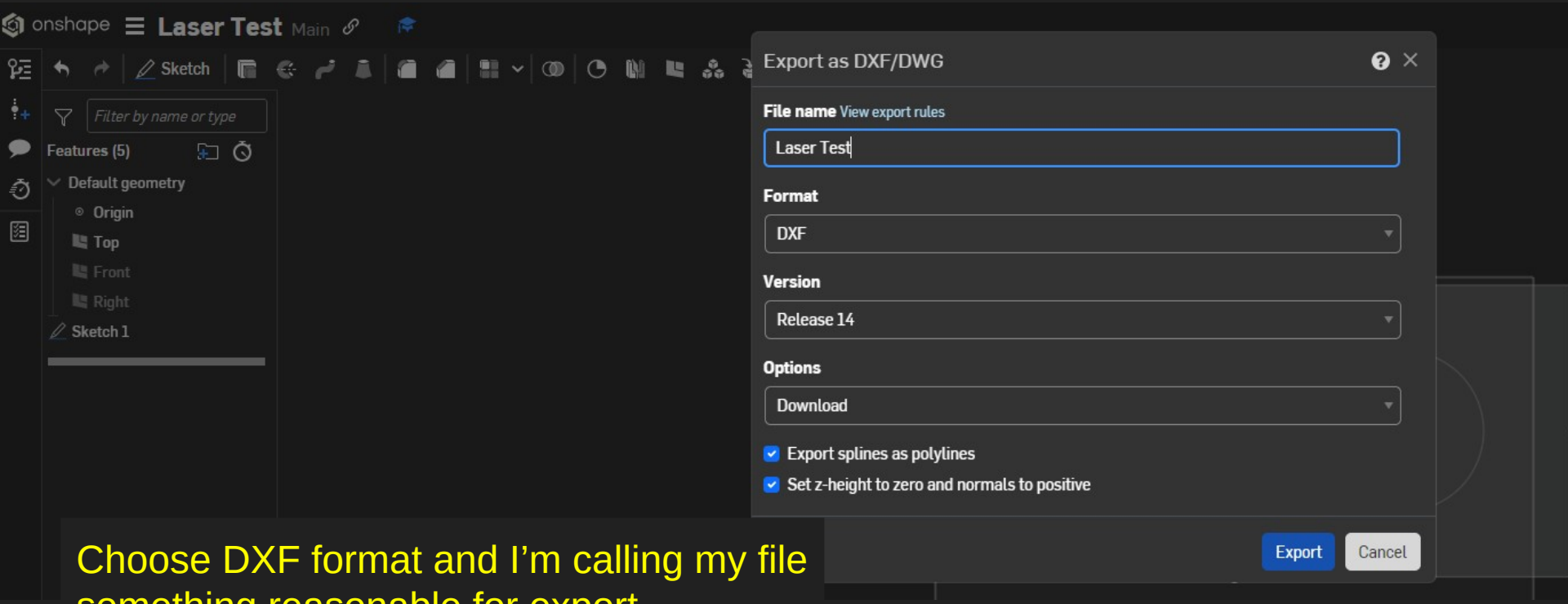


How to Model a Design




onshape
Laser Test
Main
Share
Jordan Kivitz
Search tools...
Filter by name or type
Features (5)
Default geometry
Origin
Top
Front
Right
Sketch 1
Parts (0)
Sketch 1
Sketch plane
Top plane
Disable imprinting
Show constraints
Show expressions
Show overdefined
Sketch 1
Top
Ø40
42.5
73
16.5
85
Begin with a 2D sketch in your chosen software. I like Onshape because I'm able to build with precise dimensions.
(Onshape, Adobe, Fusion, etc.)
Part Studio 1
Assembly 1


Export the vector graphic as DXF/DWG file (in Onshape, just right click on any sketch)
Top
Rename
Edit...
Copy sketch
Show dimensions
Add selection to folder...
Hide
Create Drawing of Sketch 1...
Export as DXF/DWG...
Section view...
Suppress
Add comment
Zoom to selection
View normal to
Show dependencies...
Edit sketch appearance...
Delete



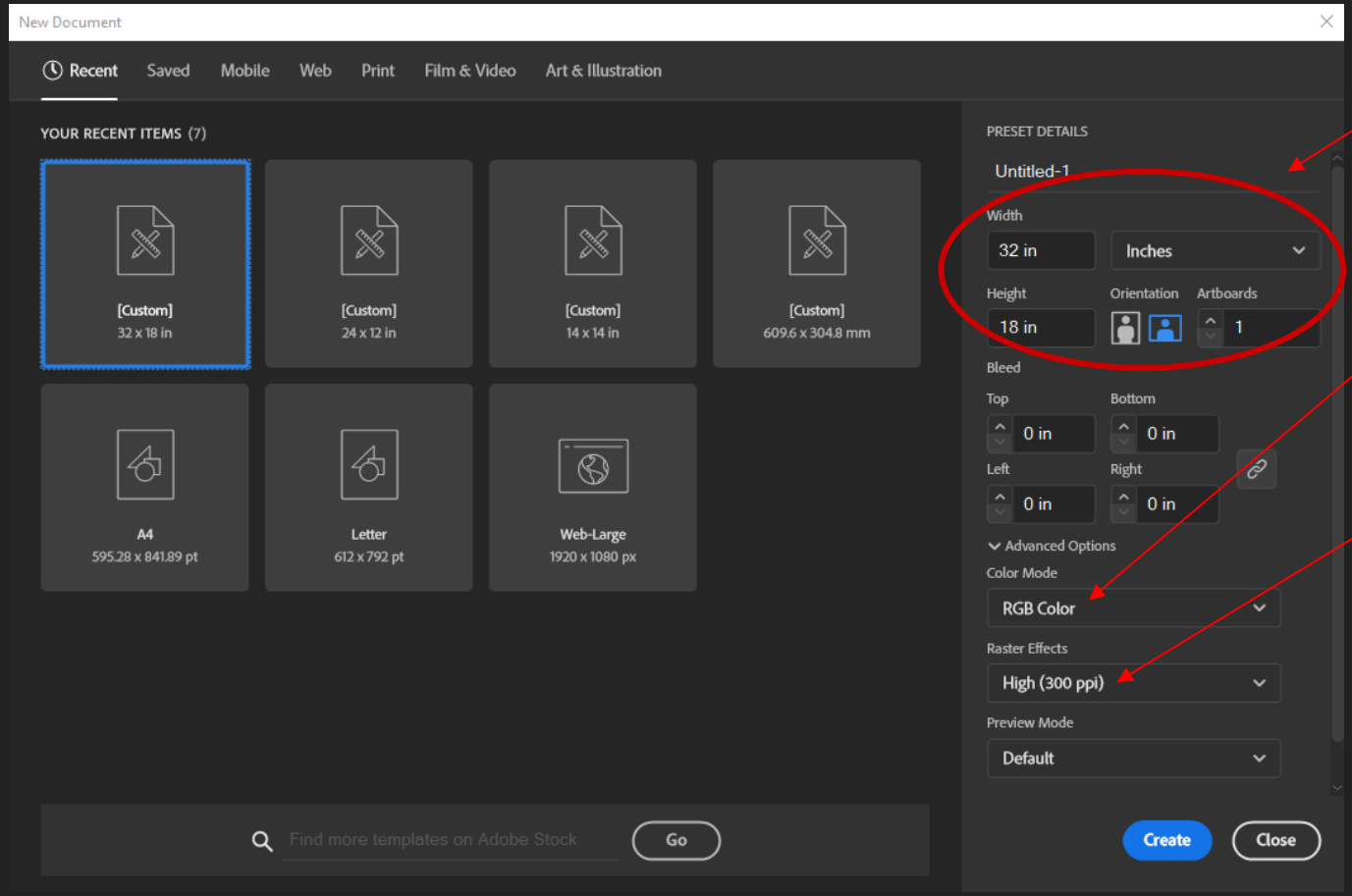
Choose DXF format and I'm calling my file something reasonable for export.



How to Illustrator



To begin, open Adobe Illustrator and create a new document.
Then follow the practices to the right.



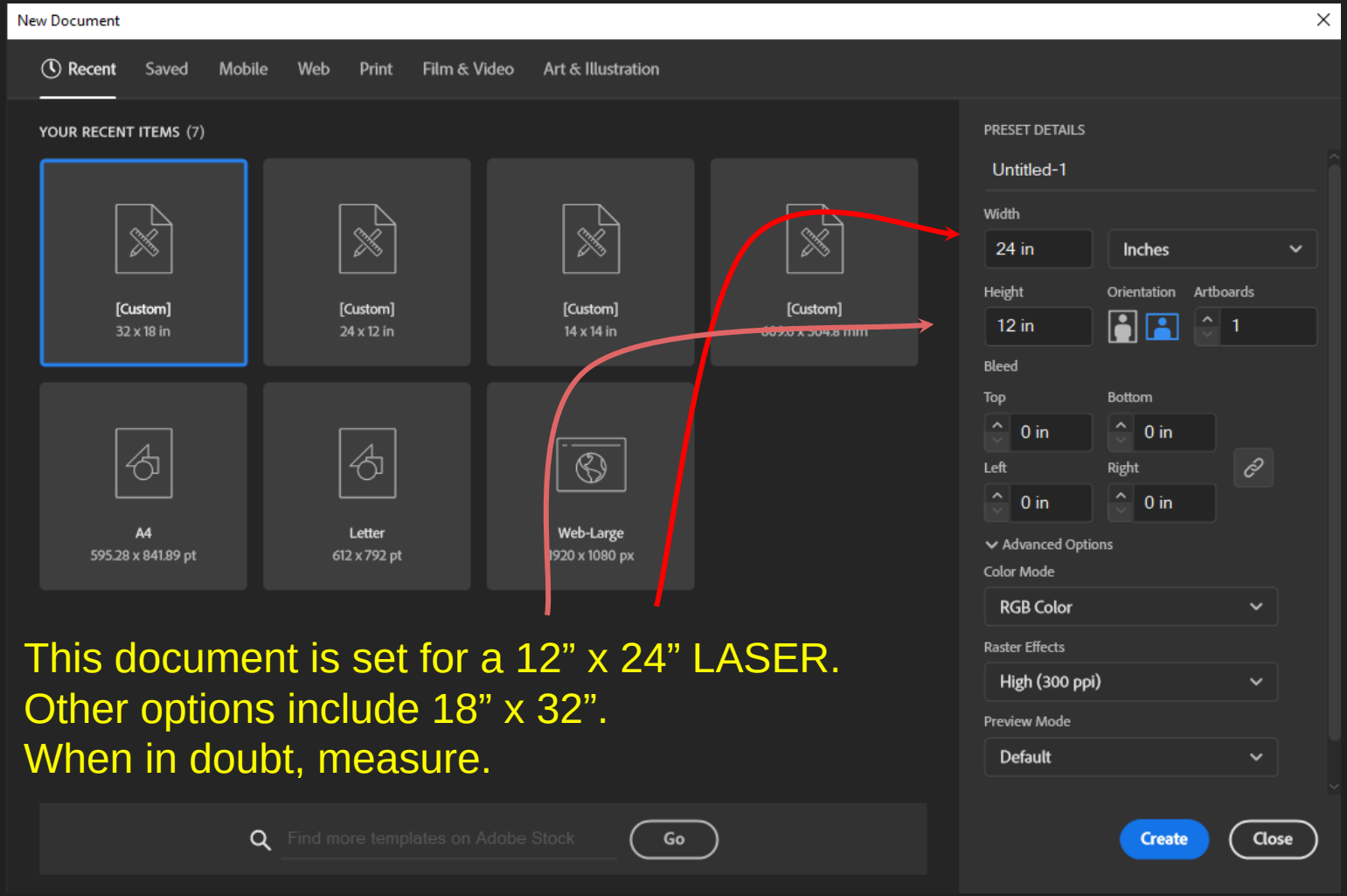
Best Practices

- Make your template the same size as your LASER bed space.

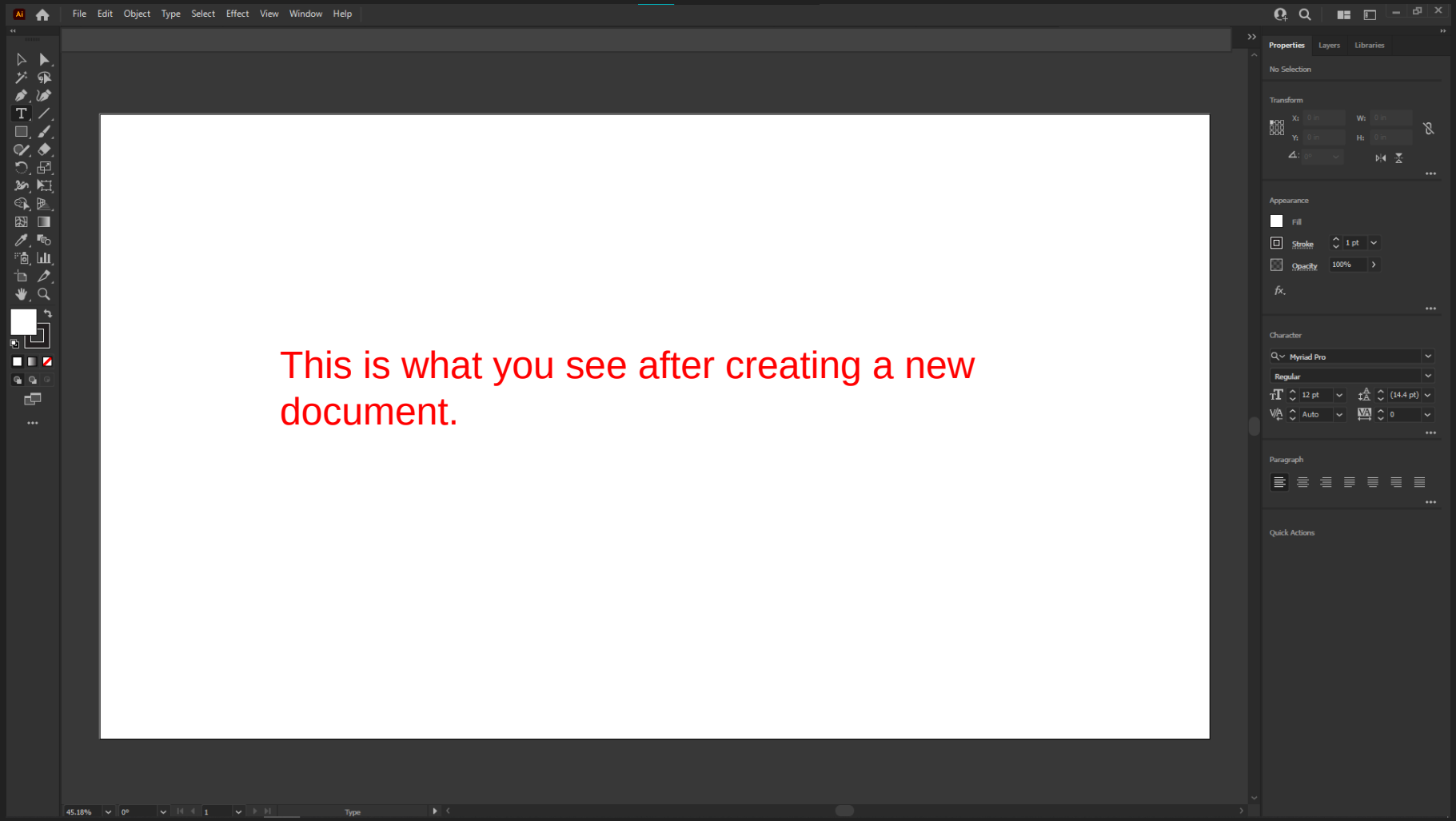
- Set the Color Mode to RGB

- Set Raster Effects to High (300 ppi)

Then, Create



This document is set for a 12” x 24” LASER.
Other options include 18” x 32”.
When in doubt, measure.


File Edit Object Type Select Effect View Window Help
Properties Layers Libraries
No Selection
Transform
Appearance
Fill
Stroke 1 pt
Opacity 100%
Character
Myriad Pro
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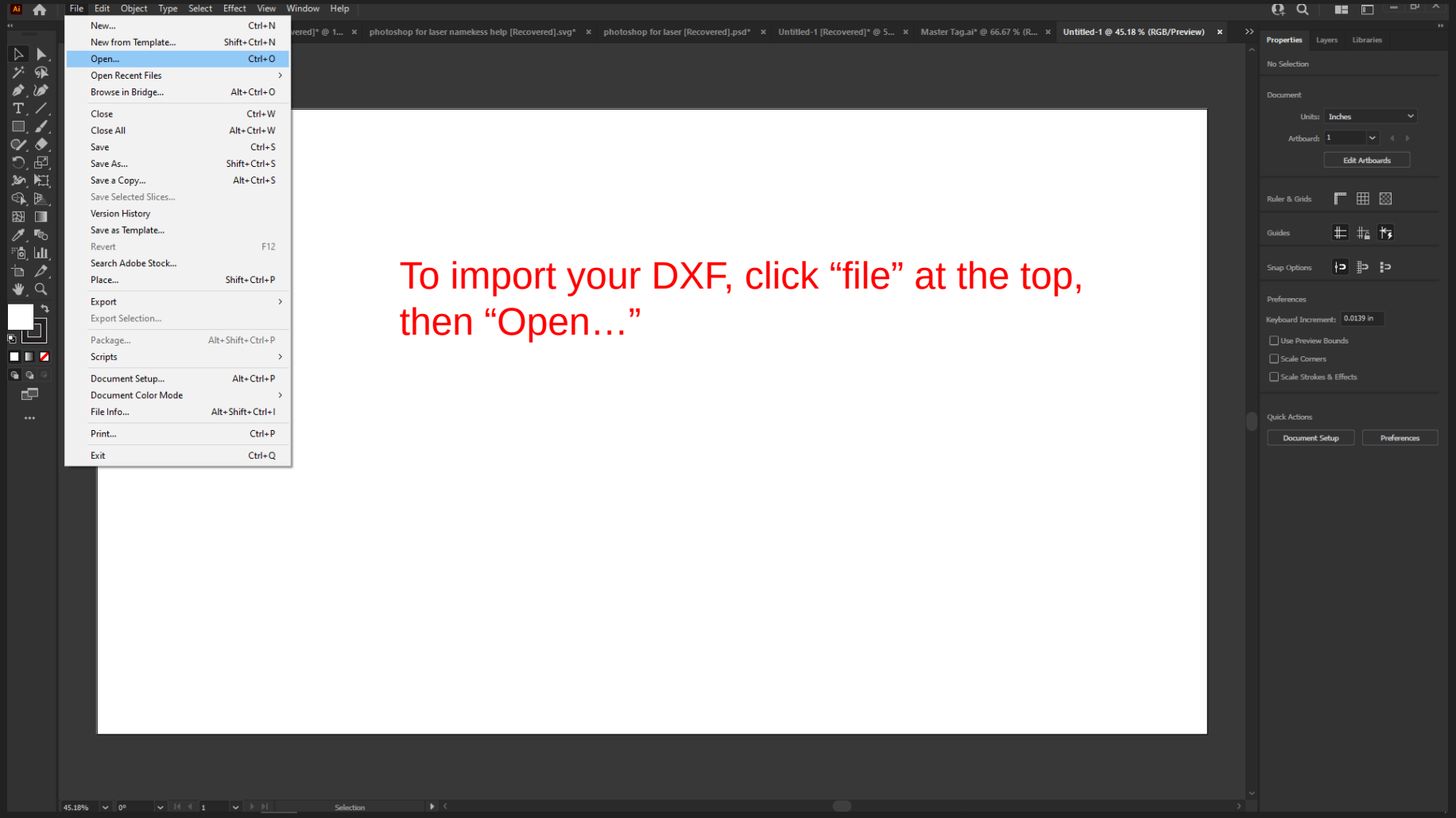
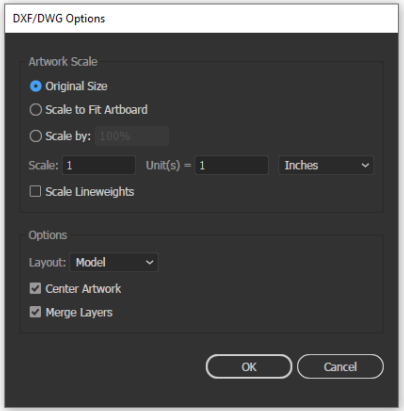
12 pt
(14.4 pt)
Auto
Paragraph
Quick Actions
This is what you see after creating a new document.
45.18%
Type

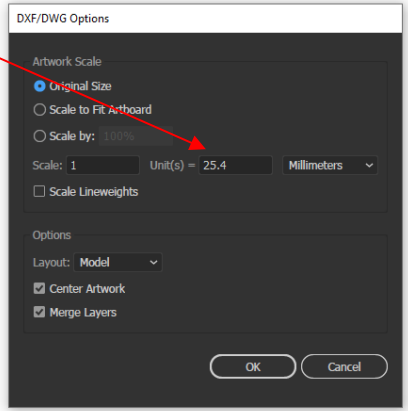

File Edit Object Type Select Effect View Window Help
New... Ctrl+N
New from Template... Shift+Ctrl+N
Open... Ctrl+O
Open Recent Files
Browse in Bridge... Alt+Ctrl+O
Close Ctrl+W
Close All Alt+Ctrl+W
Save Ctrl+S
Save As... Shift+Ctrl+S
Save a Copy... Alt+Ctrl+S
Save Selected Slices...
Version History
Save as Template...
Revert F12
Search Adobe Stock...
Place... Shift+Ctrl+P
Export
Export Selection...
Package... Alt+Shift+Ctrl+P
Scripts
Document Setup... Alt+Ctrl+P
Document Color Mode
File Info... Alt+Shift+Ctrl+I
Print... Ctrl+P
Exit Ctrl+Q
Properties
Layers
Libraries
No Selection
Document
Units: Inches
Artboard: 1
Edit Artboards
Ruler & Grids
Guides
Snap Options
Preferences
Keyboard Increment: 0.0139 in
Use Preview Bounds
Scale Corners
Scale Strokes & Effects
Quick Actions
Document Setup
Preferences
To import your DXF, click “file” at the top, then “Open…”

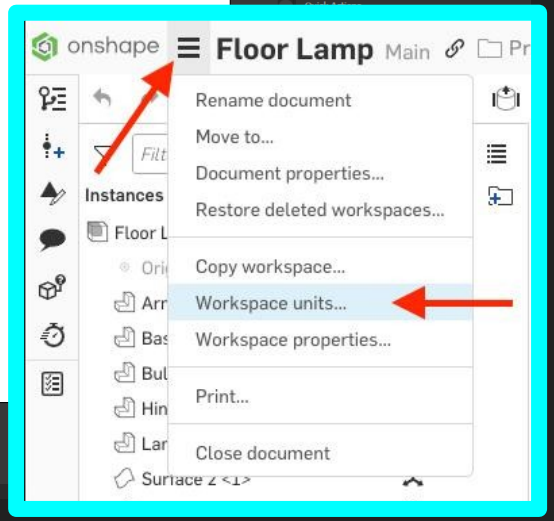
The most important part is “units”

**Use the same units from where your design was created

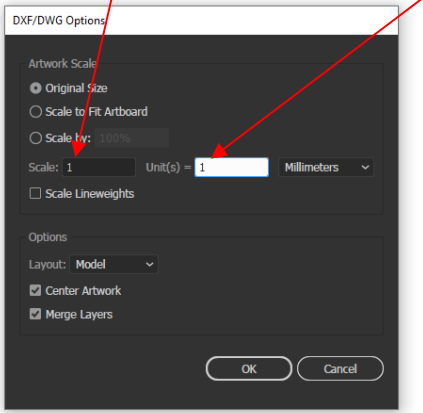


I created my DXF in millimeters, so I changed the units, but the scale is wrong.



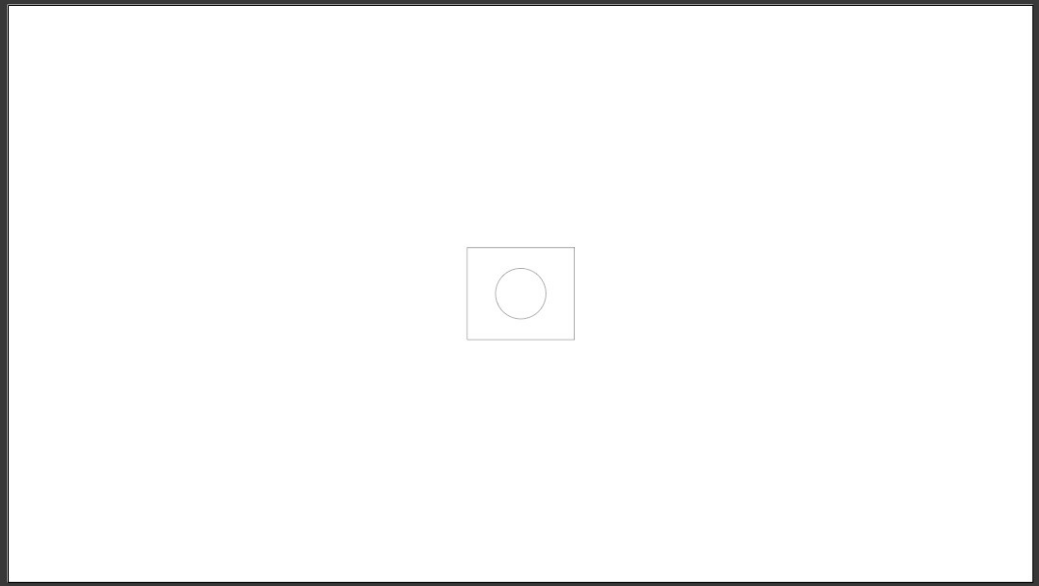


Change the scale to: Scale: 1 and Unit(s) = 1

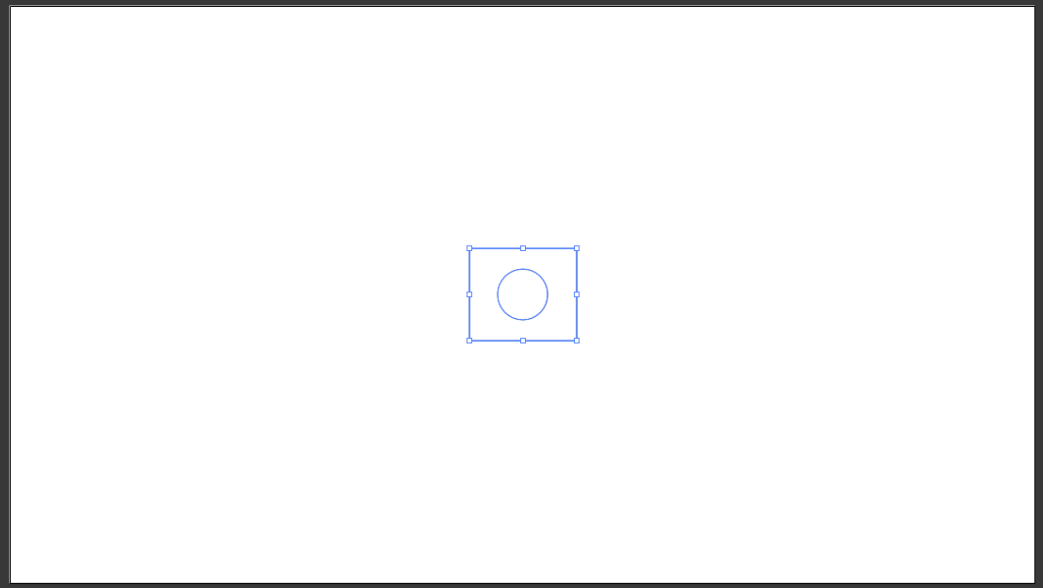


Then, click “OK”

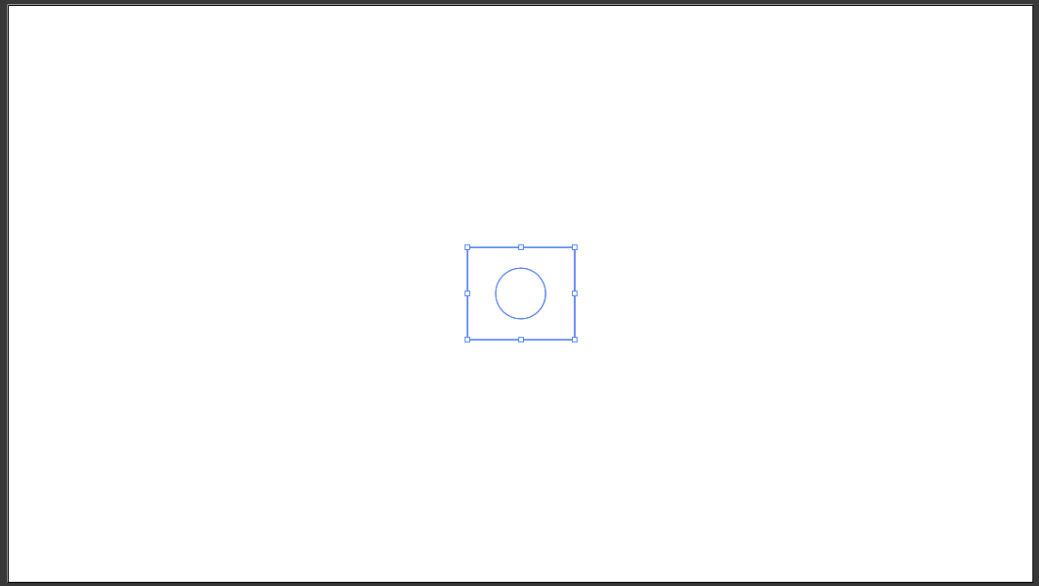
Here's the DXF file I created in Onshape, which has the same dimensions from the original design.



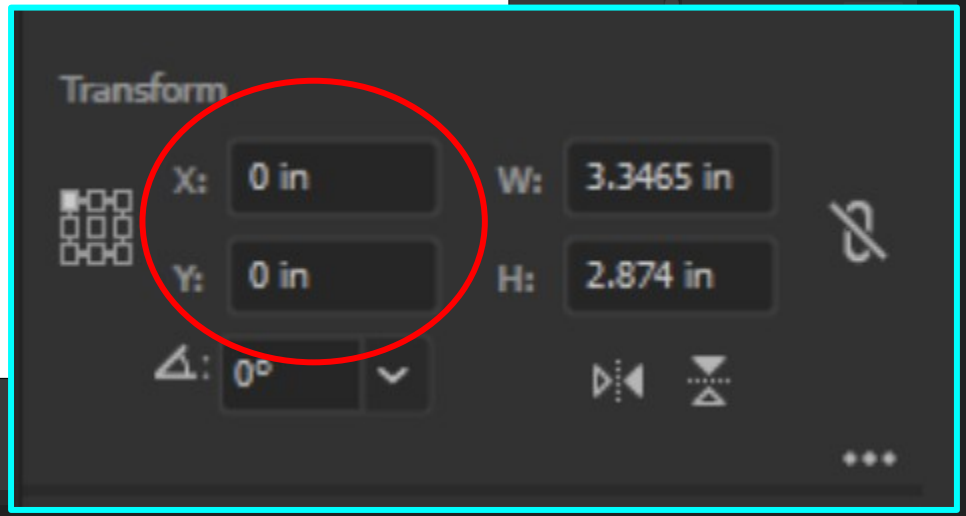
Currently, it's centered on the template as default.



Because I made the template the same size as my LASER bed, the vectors will be cut or engraved exactly where I place it on the template

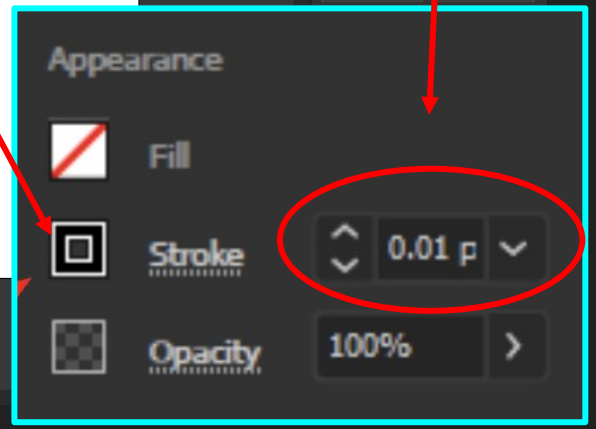


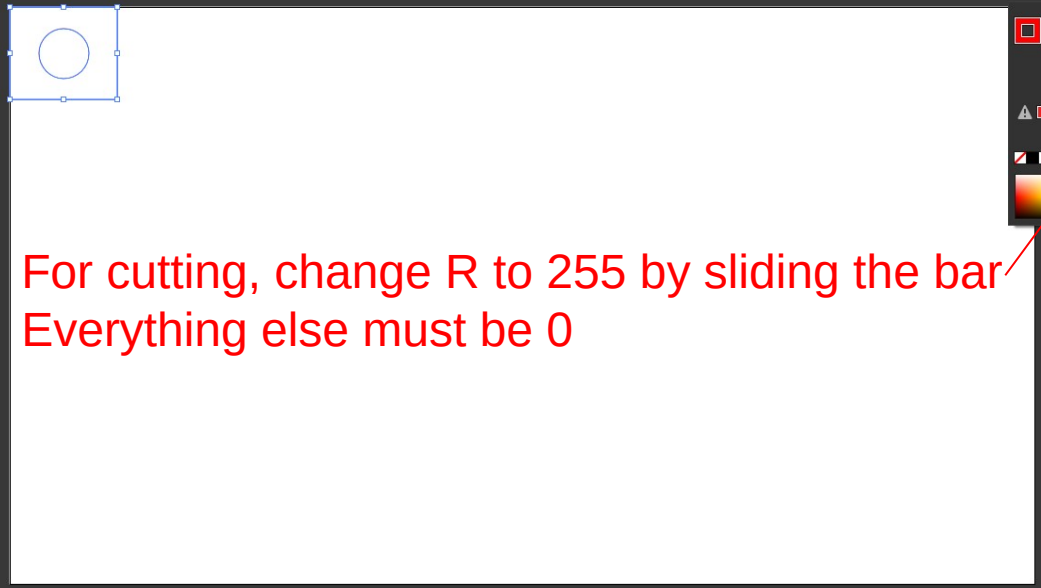
If I want to cut the square and circle in the top left of my LASER (X0, Y0), then select everything and move it to that coordinate by changing this

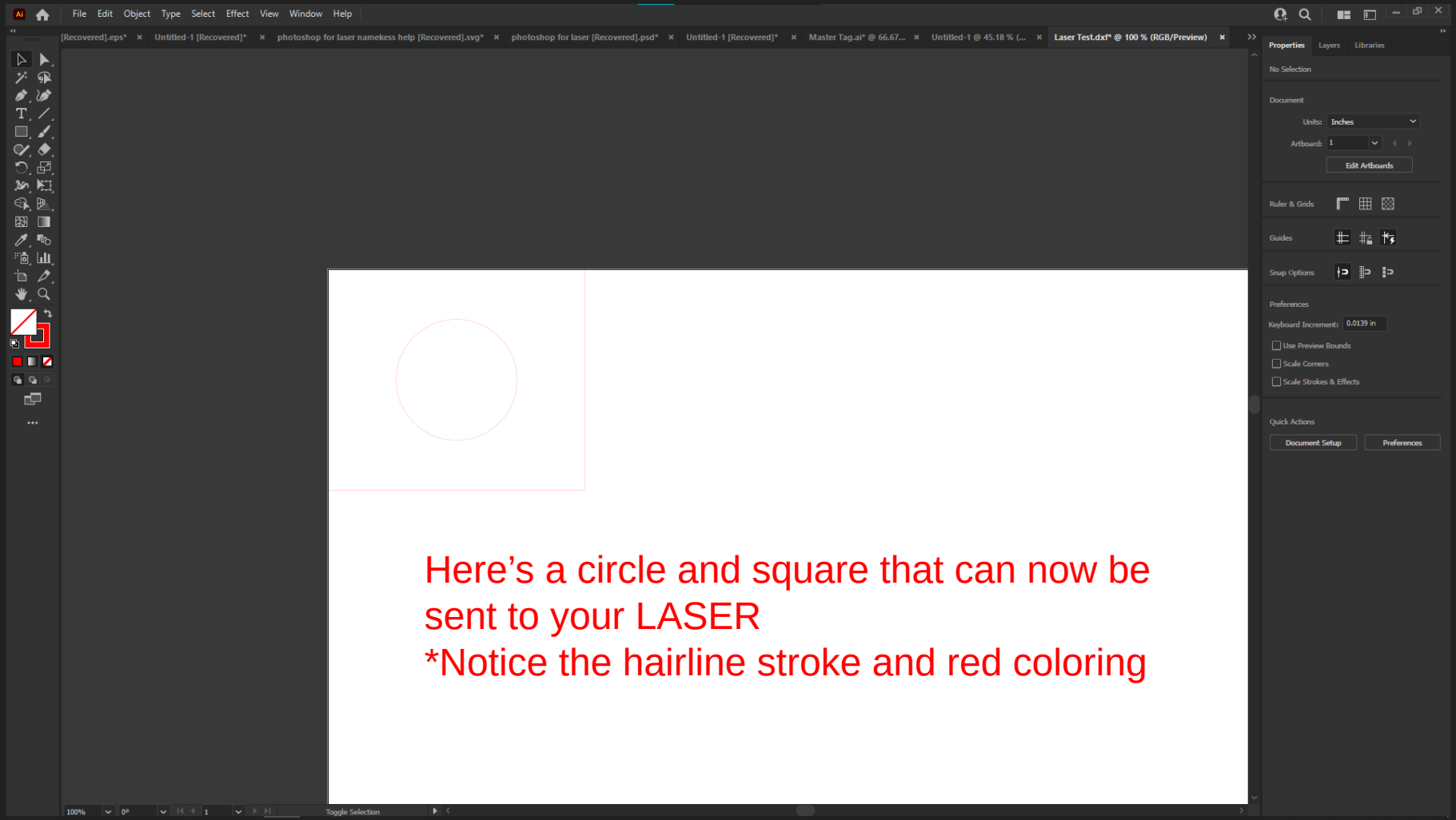


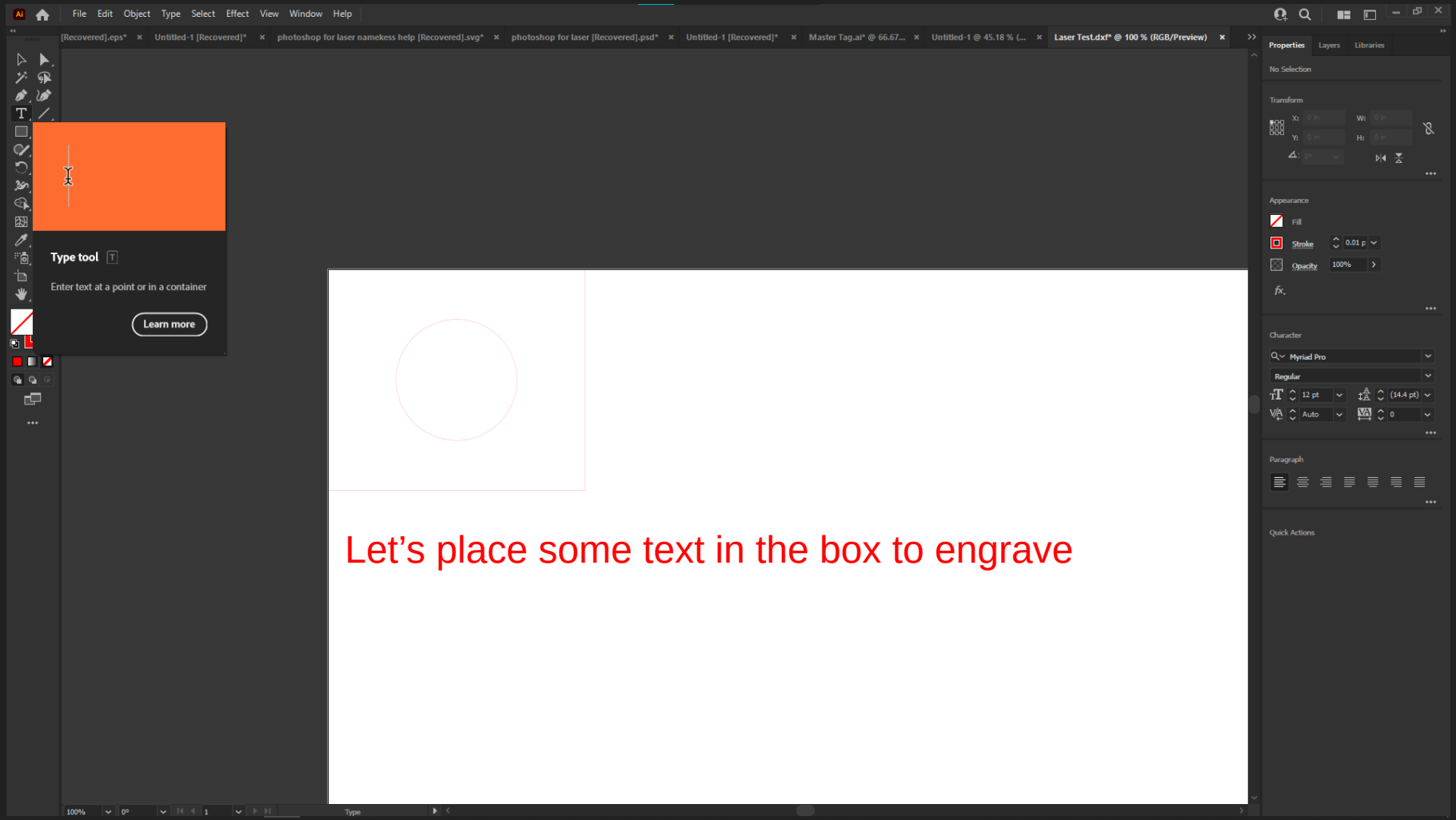
If I want to cut the square and circle, then select everything I want and change the stroke to (.01 pt)

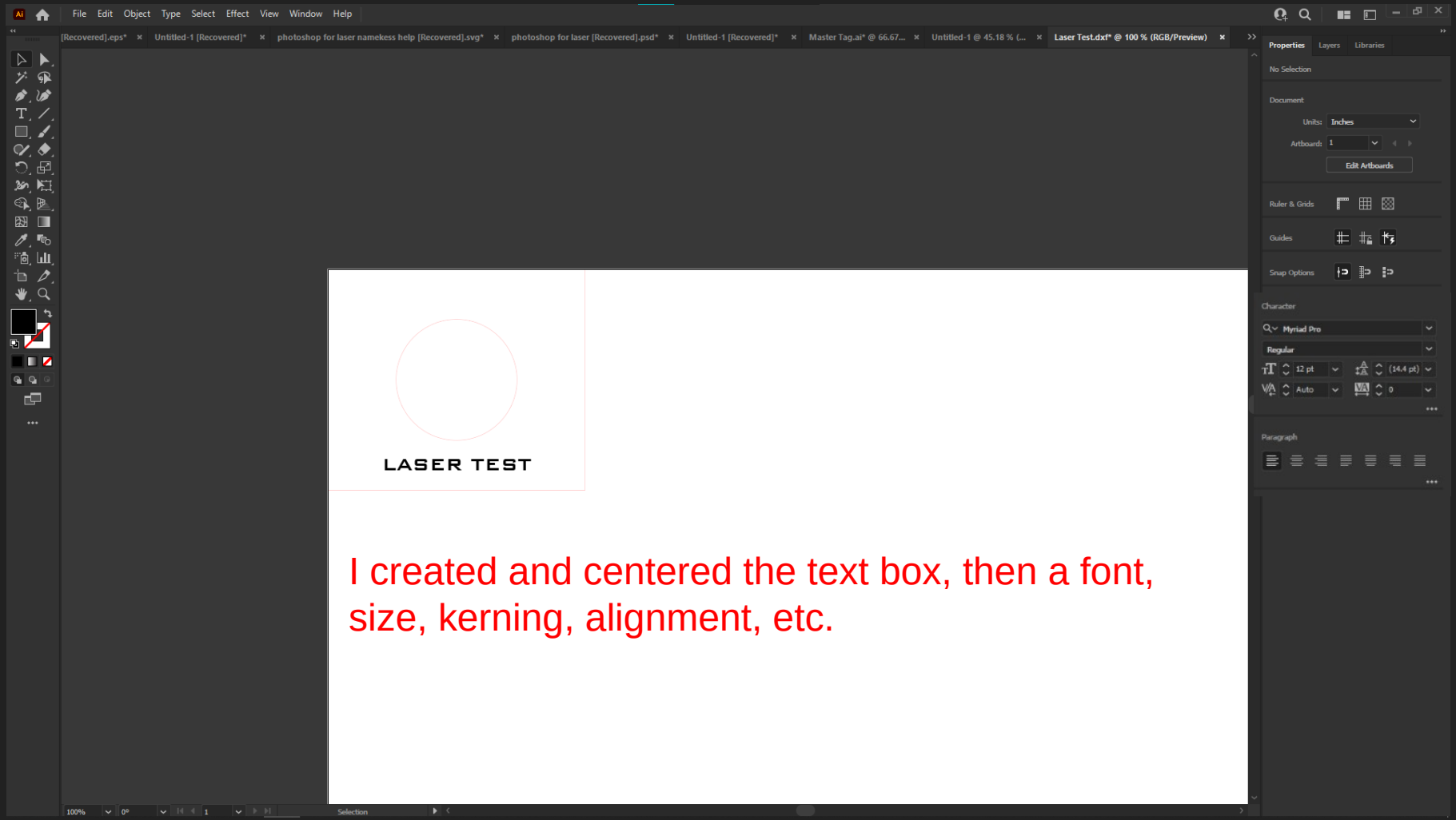
Then, click on the black square box

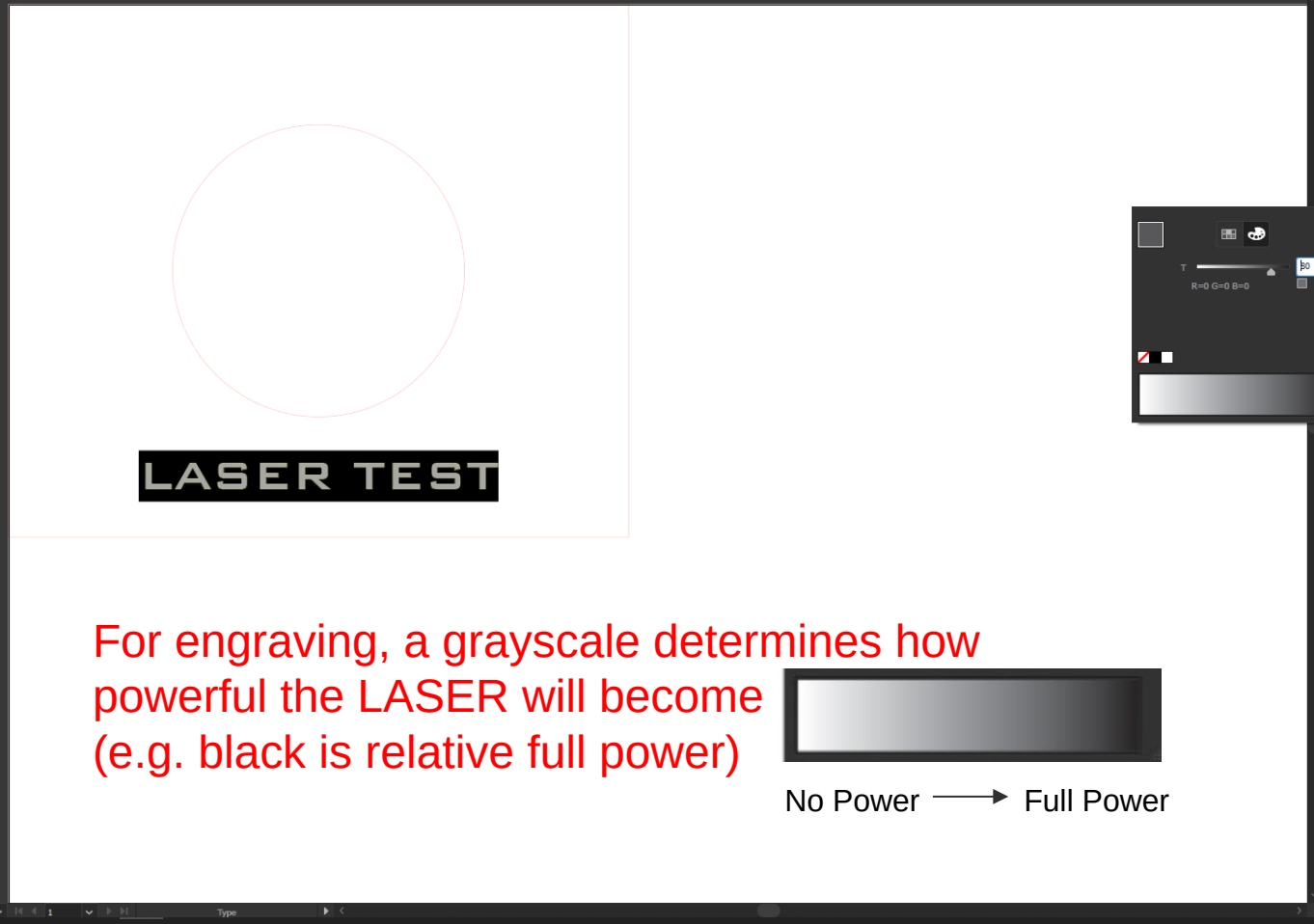


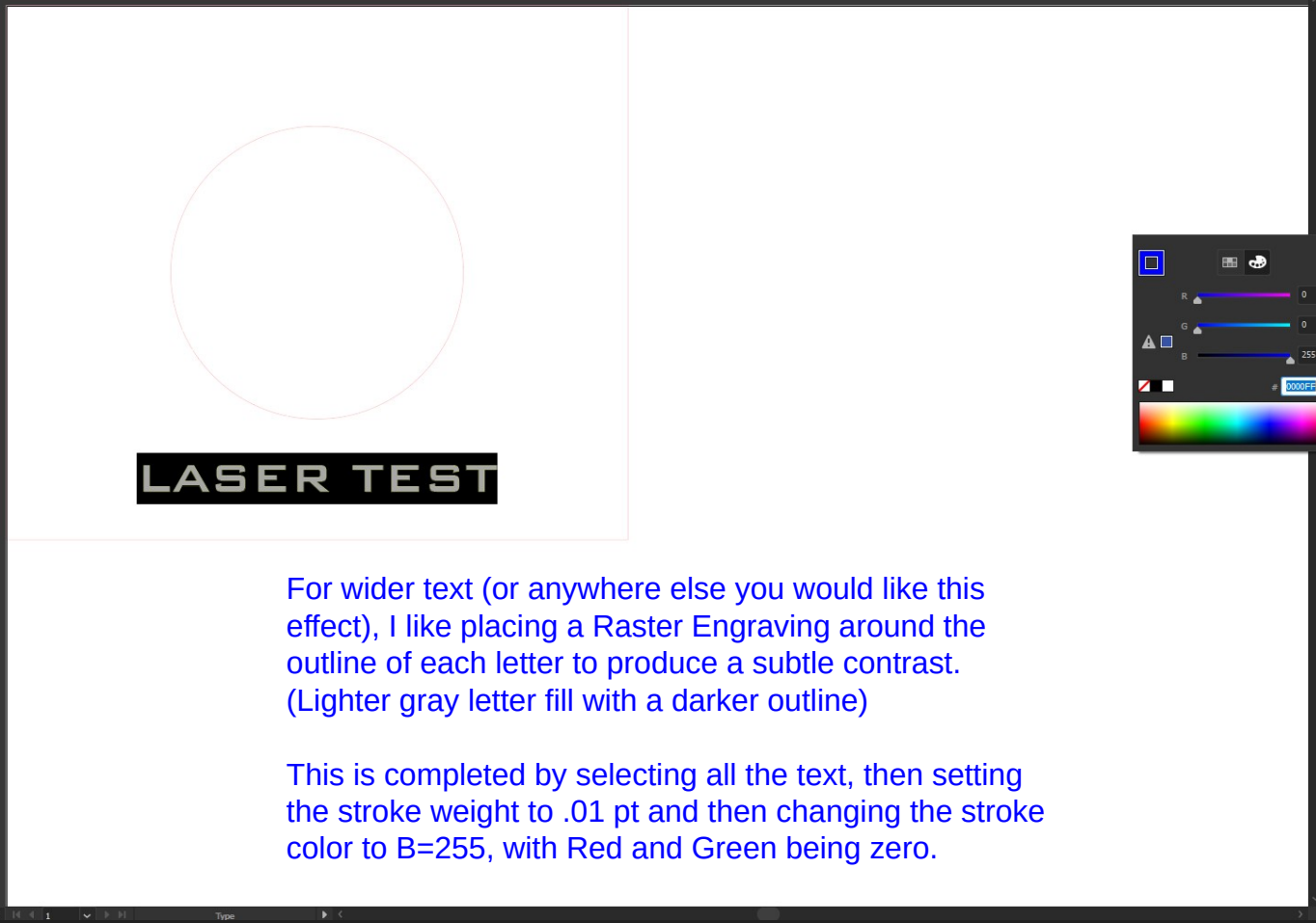

For cutting, change R to 255 by sliding the bar
Everything else must be 0


File Edit Object Type Select Effect View Window Help
[Recovered].eps*
Untitled-1 [Recovered]*
photoshop for laser namekess help [Recovered].svg*
photoshop for laser [Recovered].psd*
Untitled-1 [Recovered]*
Master Tag.ai* @ 66.67...
Untitled-1 @ 45.18 % (...
Laser Test.dxf* @ 100 % (RGB/Preview)
Properties
Layers
Libraries
No Selection
Document
Units: Inches
Artboard: 1
Edit Artboards
Ruler & Grids
Guides
Snap Options
Preferences
Keyboard Increment: 0.0139 in
Use Preview Bounds
Scale Corners
Scale Strokes & Effects
Quick Actions
Document Setup
Preferences
Here's a circle and square that can now be sent to your LASER
*Notice the hairline stroke and red coloring
100%
0°
Toggle Selection


File Edit Object Type Select Effect View Window Help
[Recovered].eps*
Untitled-1 [Recovered]*
photoshop for laser namekess help [Recovered].svg*
photoshop for laser [Recovered].psd*
Untitled-1 [Recovered]*
Master Tag.ai* @ 66.67...
Untitled-1 @ 45.18 % (...
Laser Test.dxf* @ 100 % (RGB/Preview)
Properties
Layers
Libraries
No Selection
Transform
Appearance
Fill
Stroke
Opacity
100%
Character
Myriad Pro
Regular
12 pt
(14.4 pt)
Auto
Paragraph
Quick Actions
Type tool
Enter text at a point or in a container
Learn more
Let’s place some text in the box to engrave
100%
Type


File Edit Object Type Select Effect View Window Help
[Recovered].eps*
Untitled-1 [Recovered]*
photoshop for laser namekess help [Recovered].svg*
photoshop for laser [Recovered].psd*
Untitled-1 [Recovered]*
Master Tag.ai* @ 66.67...
Untitled-1 @ 45.18 % (...
Laser Test.dxf* @ 100 % (RGB/Preview)
Properties
Layers
Libraries
No Selection
Document
Units: Inches
Artboard: 1
Edit Artboards
Ruler & Grids
Guides
Snap Options
Character
Myriad Pro
Regular
12 pt
(14.4 pt)
Auto
0
Paragraph
LASER TEST
I created and centered the text box, then a font, size, kerning, alignment, etc.
100%
0°
Selection


LASER TEST
For engraving, a grayscale determines how powerful the LASER will become (e.g. black is relative full power)
No Power
Full Power



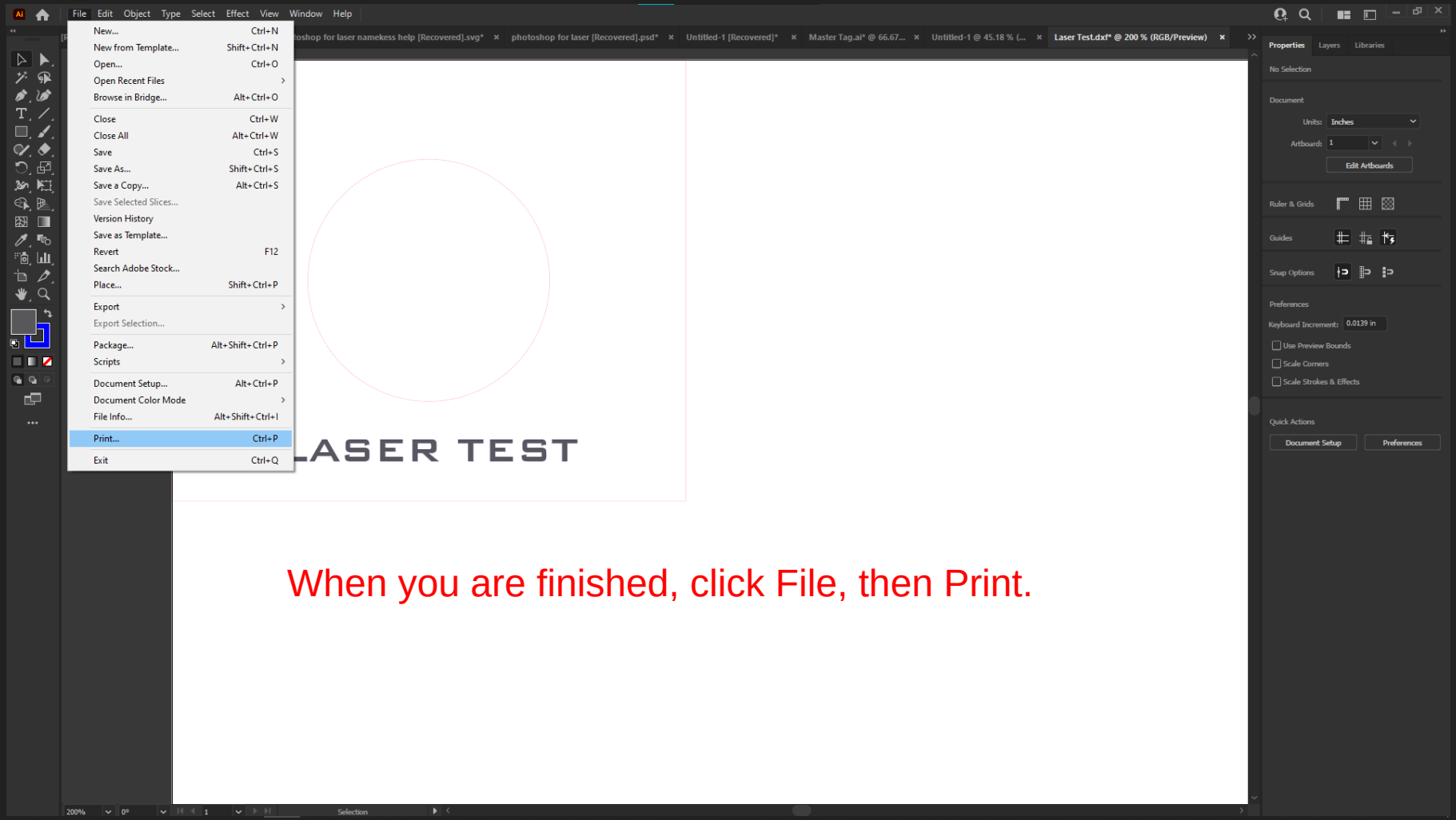
For wider text (or anywhere else you would like this effect), I like placing a Raster Engraving around the outline of each letter to produce a subtle contrast. (Lighter gray letter fill with a darker outline)

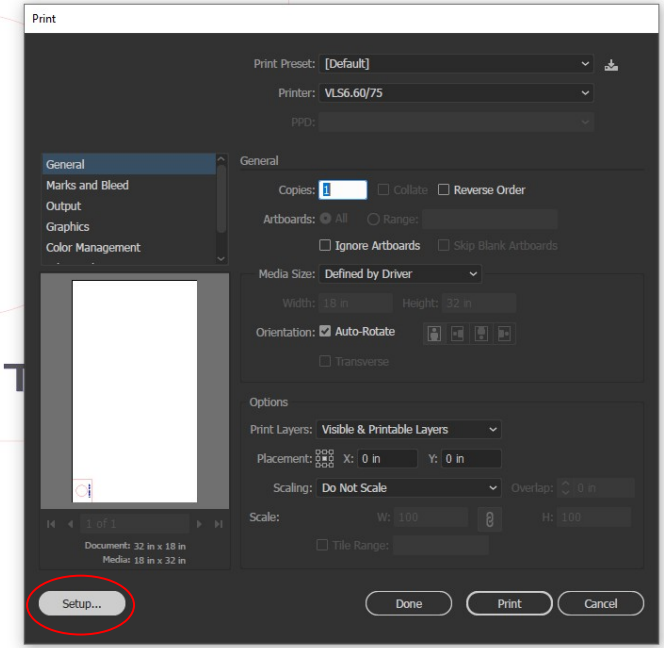
This is completed by selecting all the text, then setting the stroke weight to .01 pt and then changing the stroke color to B=255, with Red and Green being zero.



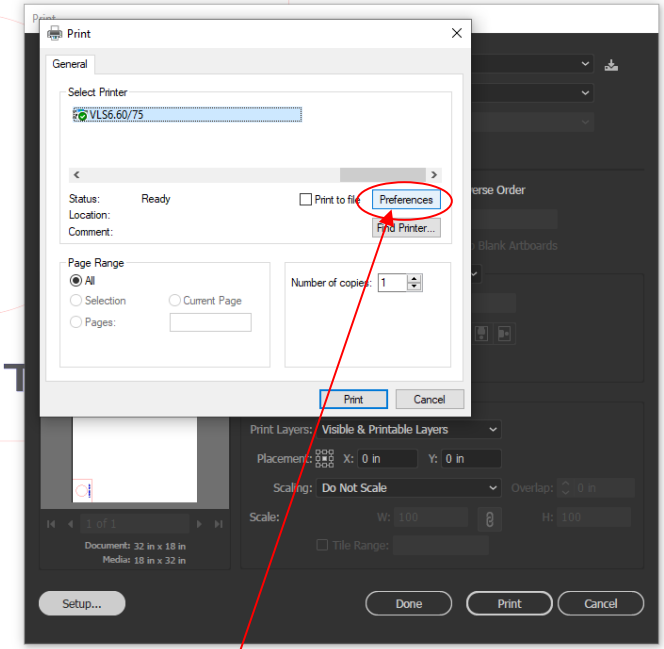
How to Send to UCP



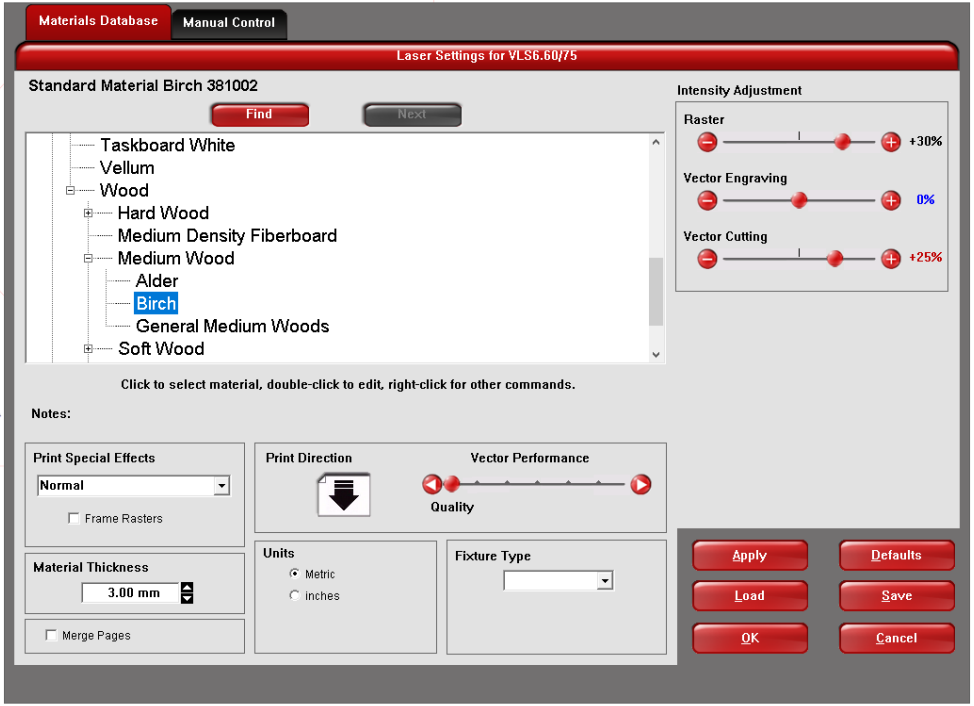

File Edit Object Type Select Effect View Window Help
New... Ctrl+N
New from Template... Shift+Ctrl+N
Open... Ctrl+O
Open Recent Files
Browse in Bridge... Alt+Ctrl+O
Close Ctrl+W
Close All Alt+Ctrl+W
Save Ctrl+S
Save As... Shift+Ctrl+S
Save a Copy... Alt+Ctrl+S
Save Selected Slices...
Version History
Save as Template...
Revert F12
Search Adobe Stock...
Place... Shift+Ctrl+P
Export
Export Selection...
Package... Alt+Shift+Ctrl+P
Scripts
Document Setup... Alt+Ctrl+P
Document Color Mode
File Info... Alt+Shift+Ctrl+I
Print... Ctrl+P
Exit Ctrl+Q
LASER TEST
When you are finished, click File, then Print.



Then, select “Setup…”

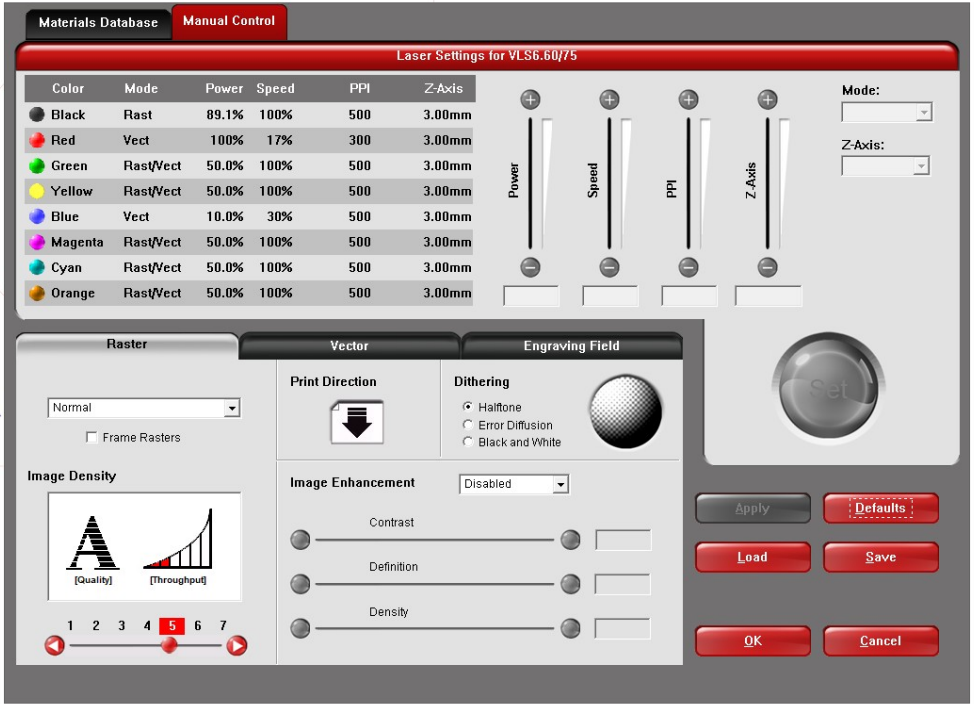


Then, select “Preferences”

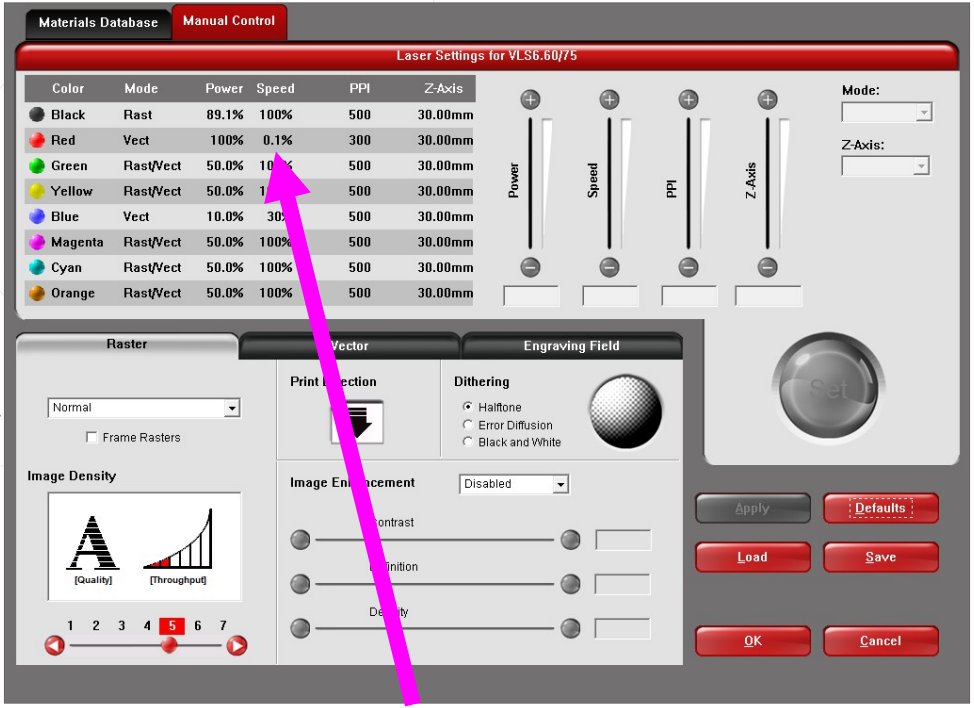


The LASER Settings should open, which is where you will decide on speed, power, and Material Thickness

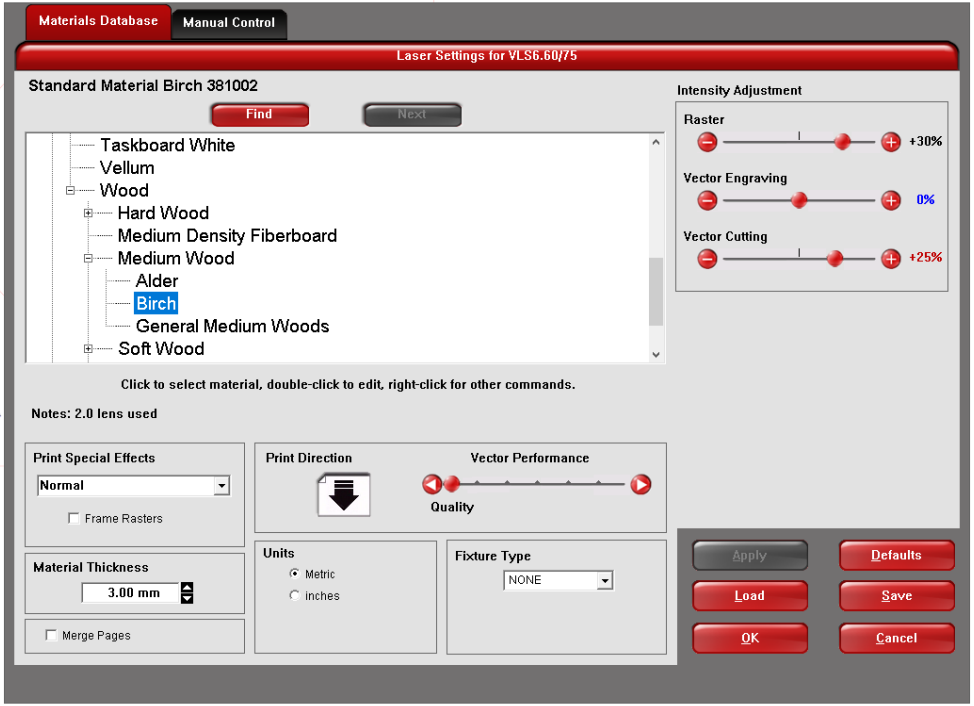
(The Materials Database is a great place to start)



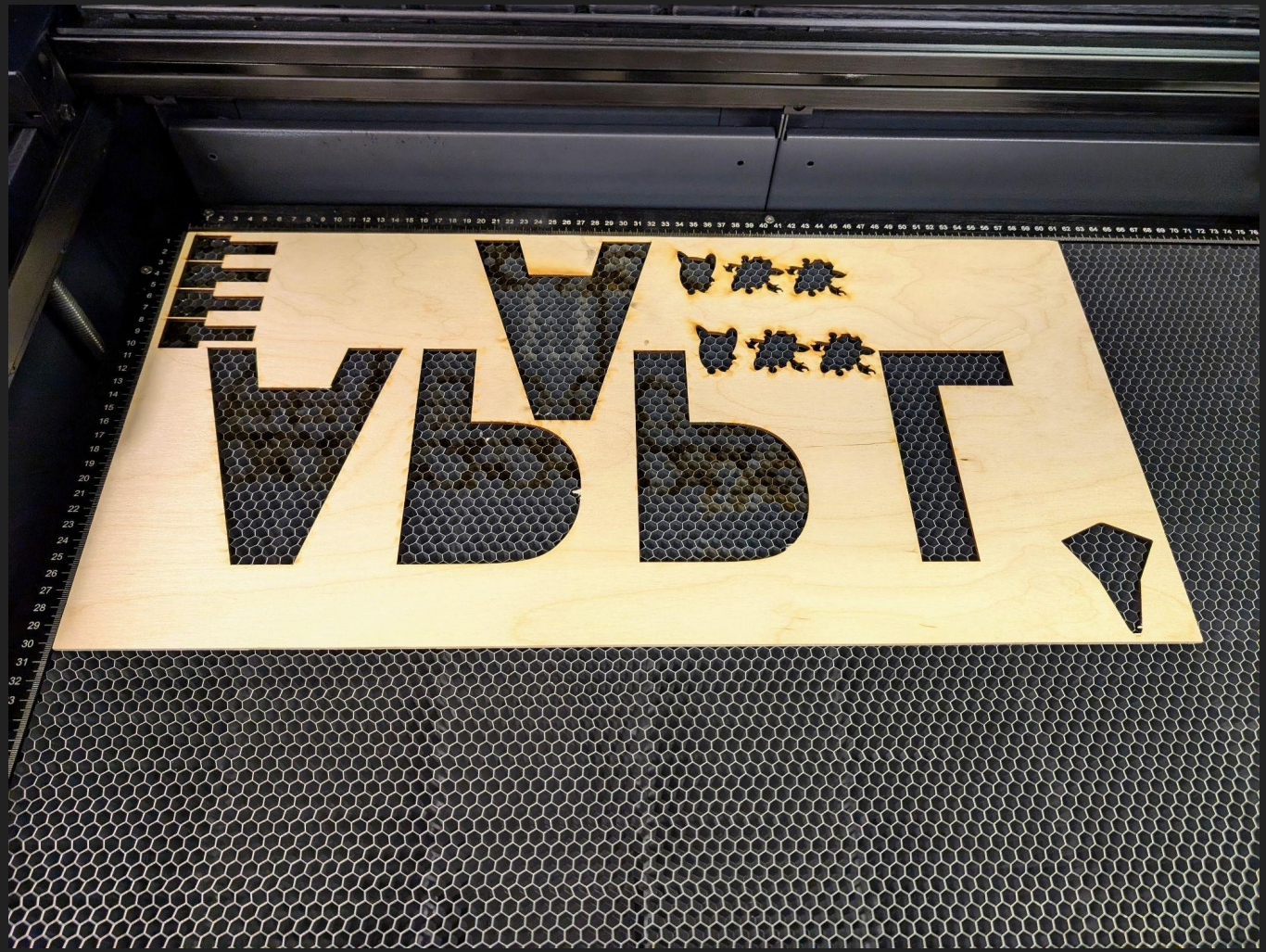
Manual Control offers a finer resolution of setup



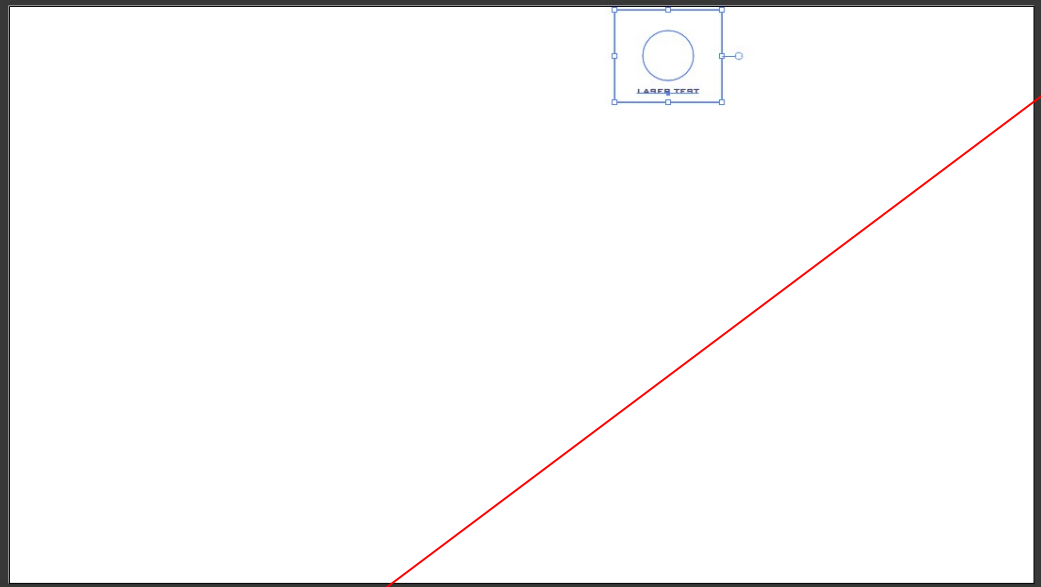
Notice how changing the material thickness also changed the speed of your machine



Whatever you choose, remember to never click “Enter” on your keyboard. You must first click “Apply”, then “OK”

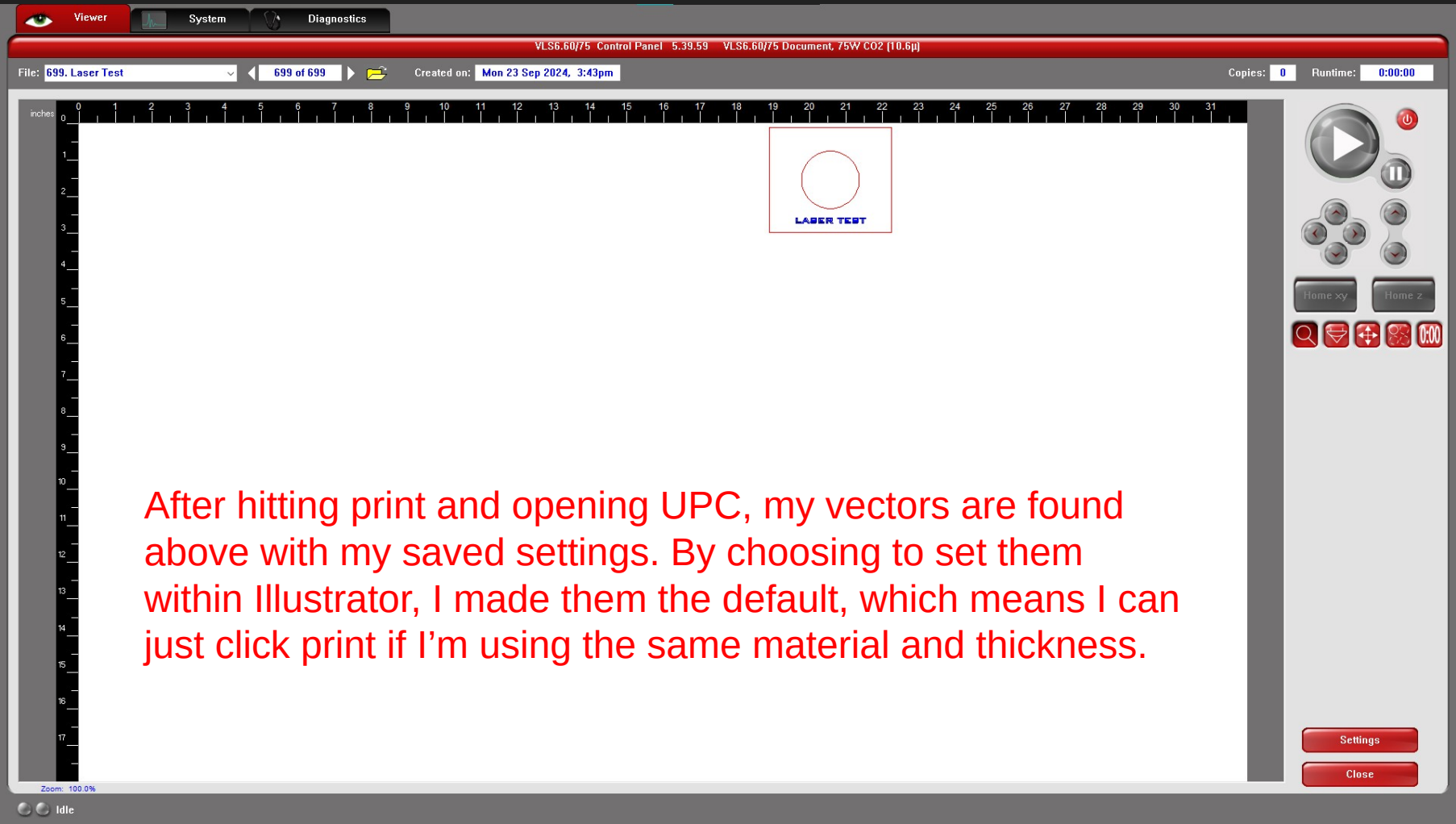


My material shows that I can place the graphic in the top right or between 70 and 180 mm.

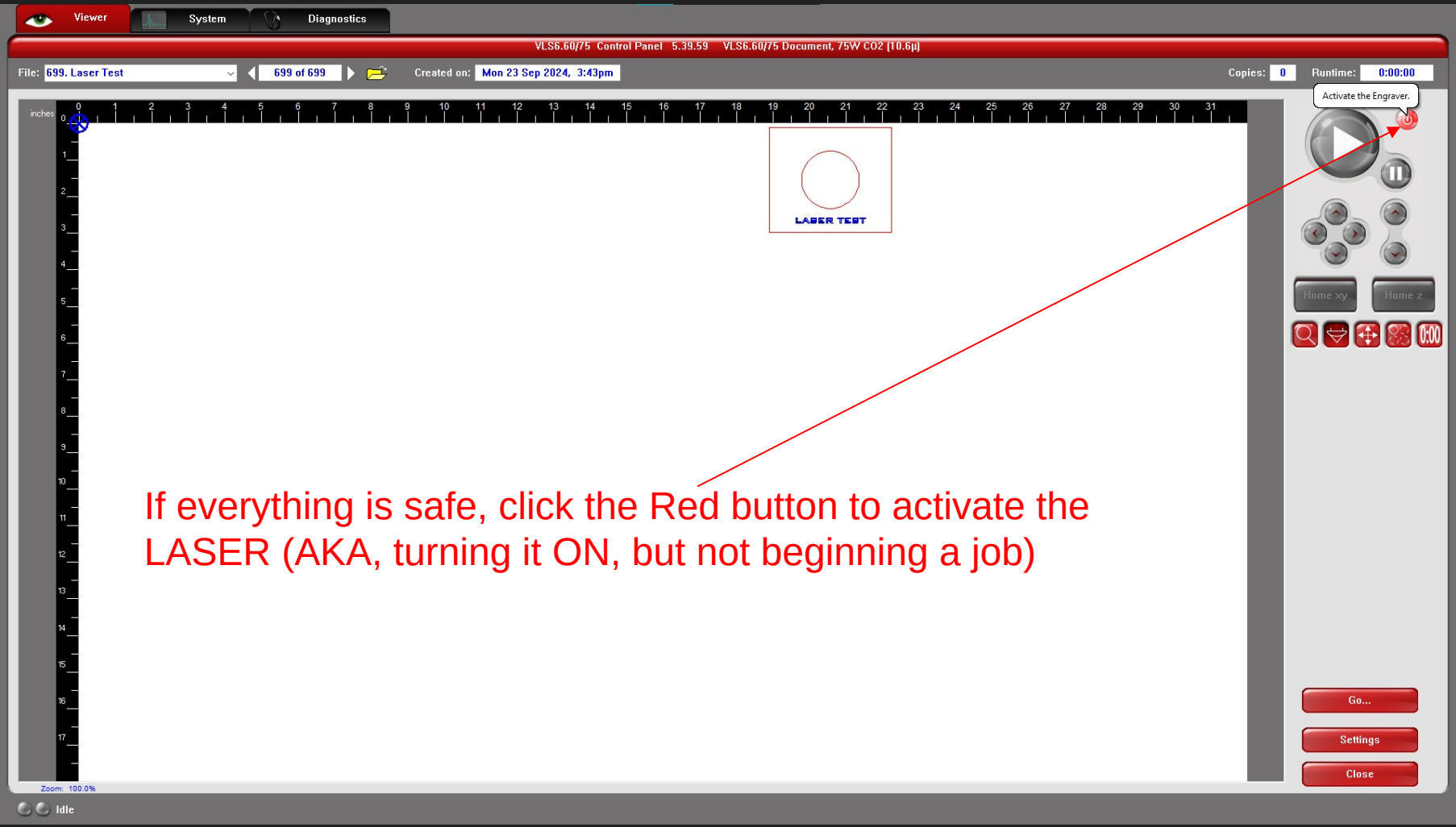


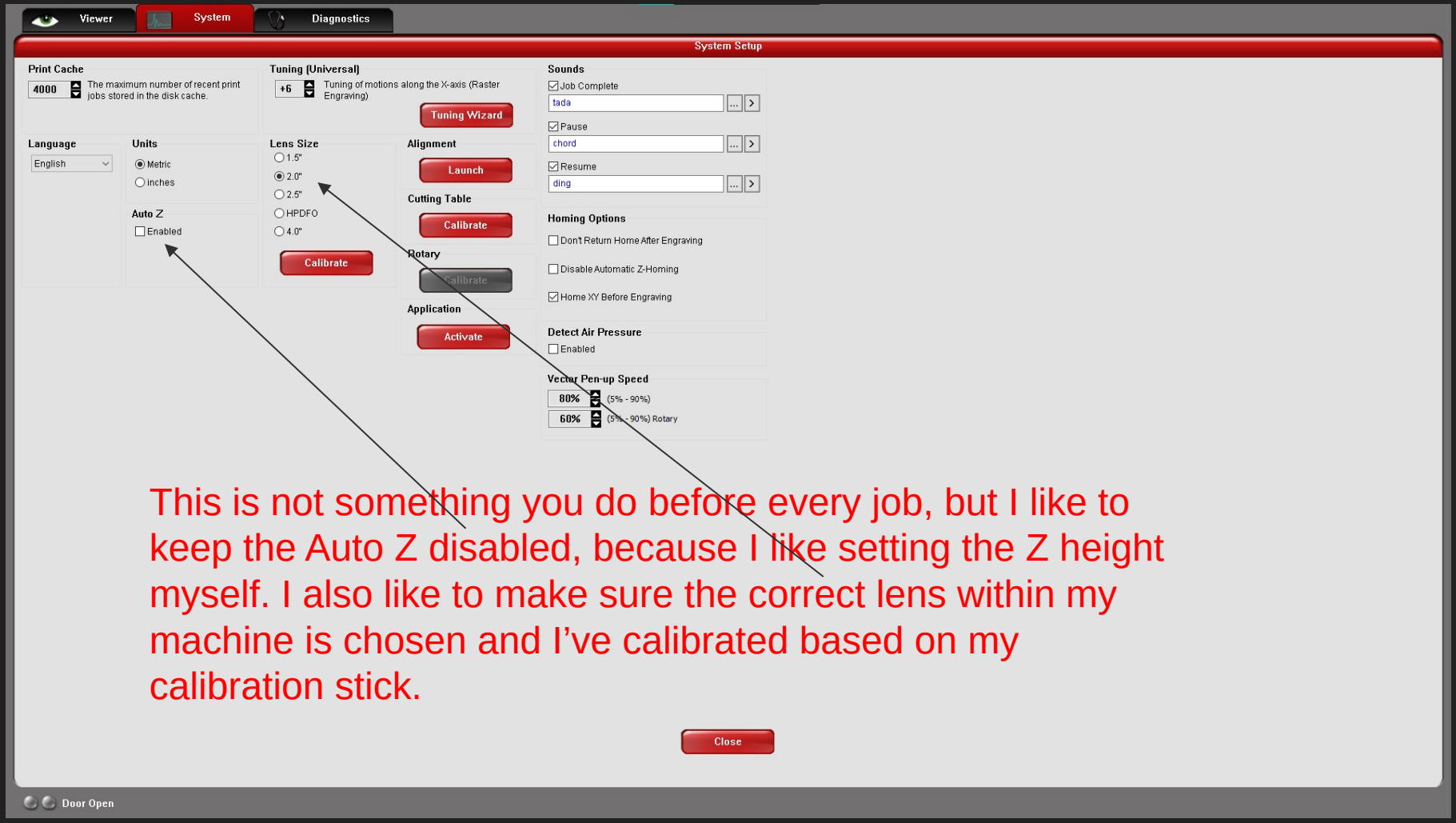
I'll move the graphic to the top right of my material by changing the X coordinate, then .1 in from the top of Y.

(Slightly moving the Y down keeps the Laser from attempting to cut between the edge of my material and the ruler.)

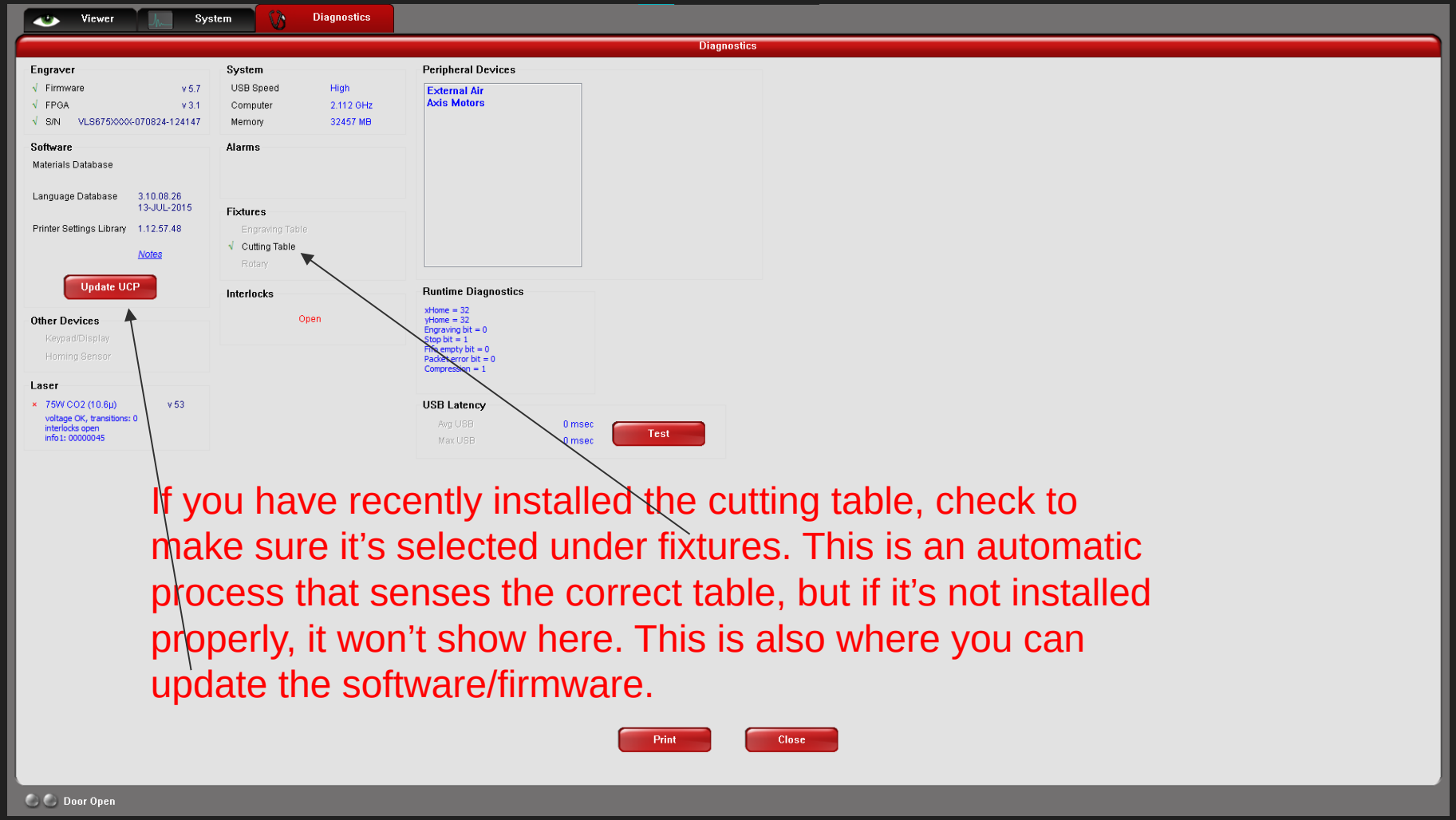


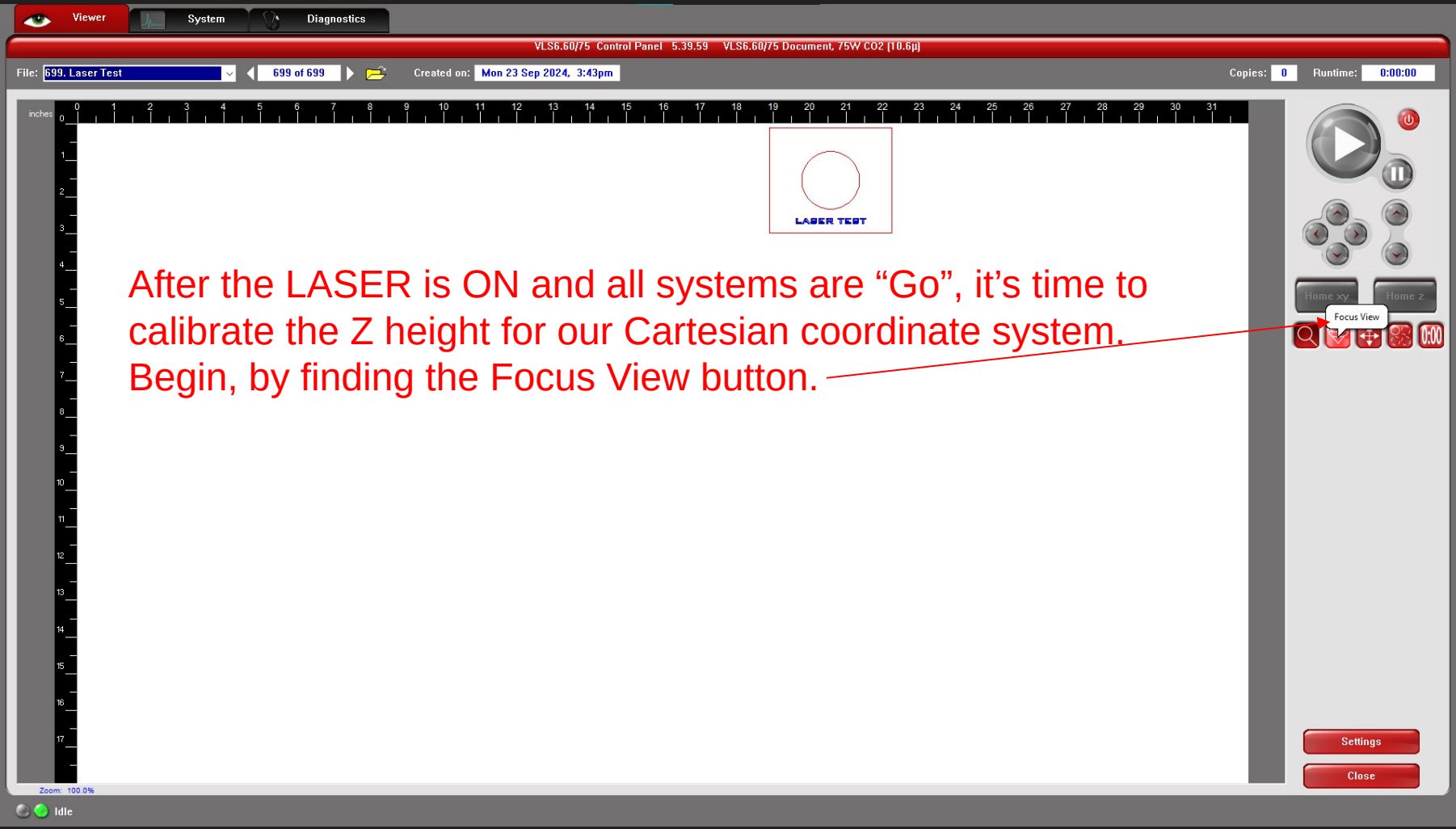
After hitting print and opening UPC, my vectors are found above with my saved settings. By choosing to set them within Illustrator, I made them the default, which means I can just click print if I'm using the same material and thickness.

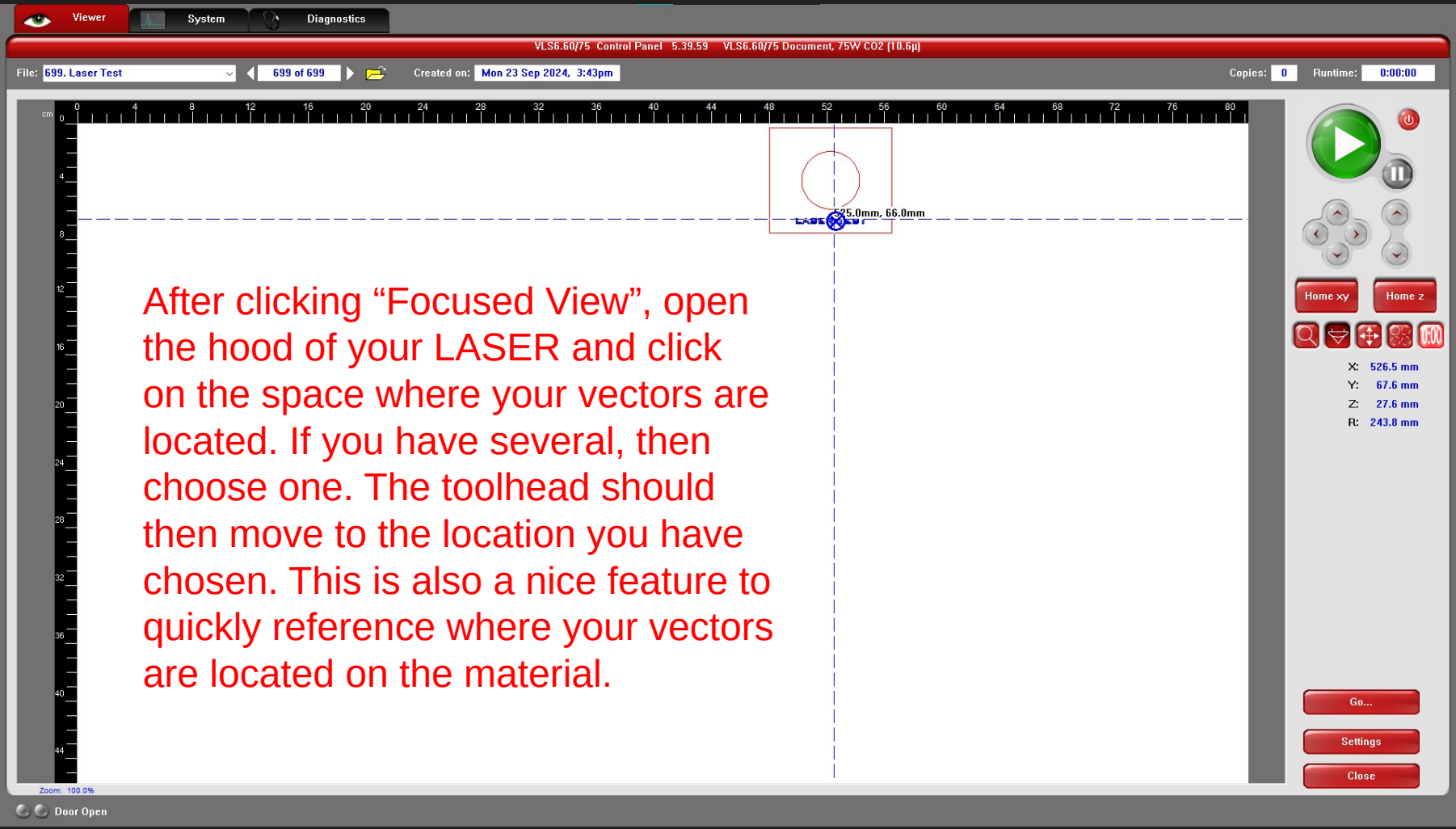

Viewer
System
Diagnostics
VLS6.60/75 Control Panel 5.39.59 VLS6.60/75 Document, 75W CO2 (10.6µ)
File: 699. Laser Test
699 of 699
Created on: Mon 23 Sep 2024, 3:43pm
Copies: 0
Runtime: 0:00:00
Activate the Engraver.
inches
LASER TEST
Home xy
Home z
0:00
Go...
Settings
Close
Zoom: 100.0%
Idle
If everything is safe, click the Red button to activate the LASER (AKA, turning it ON, but not beginning a job)



This is not something you do before every job, but I like to keep the Auto Z disabled, because I like setting the Z height myself. I also like to make sure the correct lens within my machine is chosen and I've calibrated based on my calibration stick.


Viewer
System
Diagnostics
Diagnostics
Engraver
Firmware v 5.7
FPGA v 3.1
S/N VLS675XXXX-070824-124147
Software
Materials Database
Language Database 3.10.08.26 13-JUL-2015
Printer Settings Library 1.12.57.48
Notes
Update UCP
Other Devices
Keypad/Display
Homing Sensor
Laser
75W CO2 (10.6µ) v 53
voltage OK, transitions: 0
interlocks open
info1: 00000045
System
USB Speed High
Computer 2.112 GHz
Memory 32457 MB
Alarms
Fixtures
Engraving Table
Cutting Table
Rotary
Interlocks
Open
Peripheral Devices
External Air
Axis Motors
Runtime Diagnostics
xHome = 32
yHome = 32
Engraving bit = 0
Stop bit = 1
FIFO empty bit = 0
Packet error bit = 0
Compression = 1
USB Latency
Avg USB 0 msec
Max USB 0 msec
Test
If you have recently installed the cutting table, check to make sure it's selected under fixtures. This is an automatic process that senses the correct table, but if it's not installed properly, it won't show here. This is also where you can update the software/firmware.
Print
Close
Door Open


Viewer
System
Diagnostics
VLS6.60/75 Control Panel 5.39.59 VLS6.60/75 Document, 75W CO2 (10.6µ)
File: 699. Laser Test
699 of 699
Created on: Mon 23 Sep 2024, 3:43pm
Copies: 0
Runtime: 0:00:00
inches
LASER TEST
After the LASER is ON and all systems are “Go”, it’s time to calibrate the Z height for our Cartesian coordinate system. Begin, by finding the Focus View button.
Home xy
Home z
Focus View
0:00
Settings
Close
Zoom: 100.0%
Idle


Viewer
System
Diagnostics
VLS6.60/75 Control Panel 5.39.59 VLS6.60/75 Document, 75W CO2 (10.6µ)
File: 699. Laser Test
699 of 699
Created on: Mon 23 Sep 2024, 3:43pm
Copies: 0
Runtime: 0:00:00
25.0mm, 66.0mm
After clicking “Focused View”, open the hood of your LASER and click on the space where your vectors are located. If you have several, then choose one. The toolhead should then move to the location you have chosen. This is also a nice feature to quickly reference where your vectors are located on the material.
Home xy
Home z
X: 526.5 mm
Y: 67.6 mm
Z: 27.6 mm
R: 243.8 mm
Go...
Settings
Close
Zoom: 100.0%
Door Open



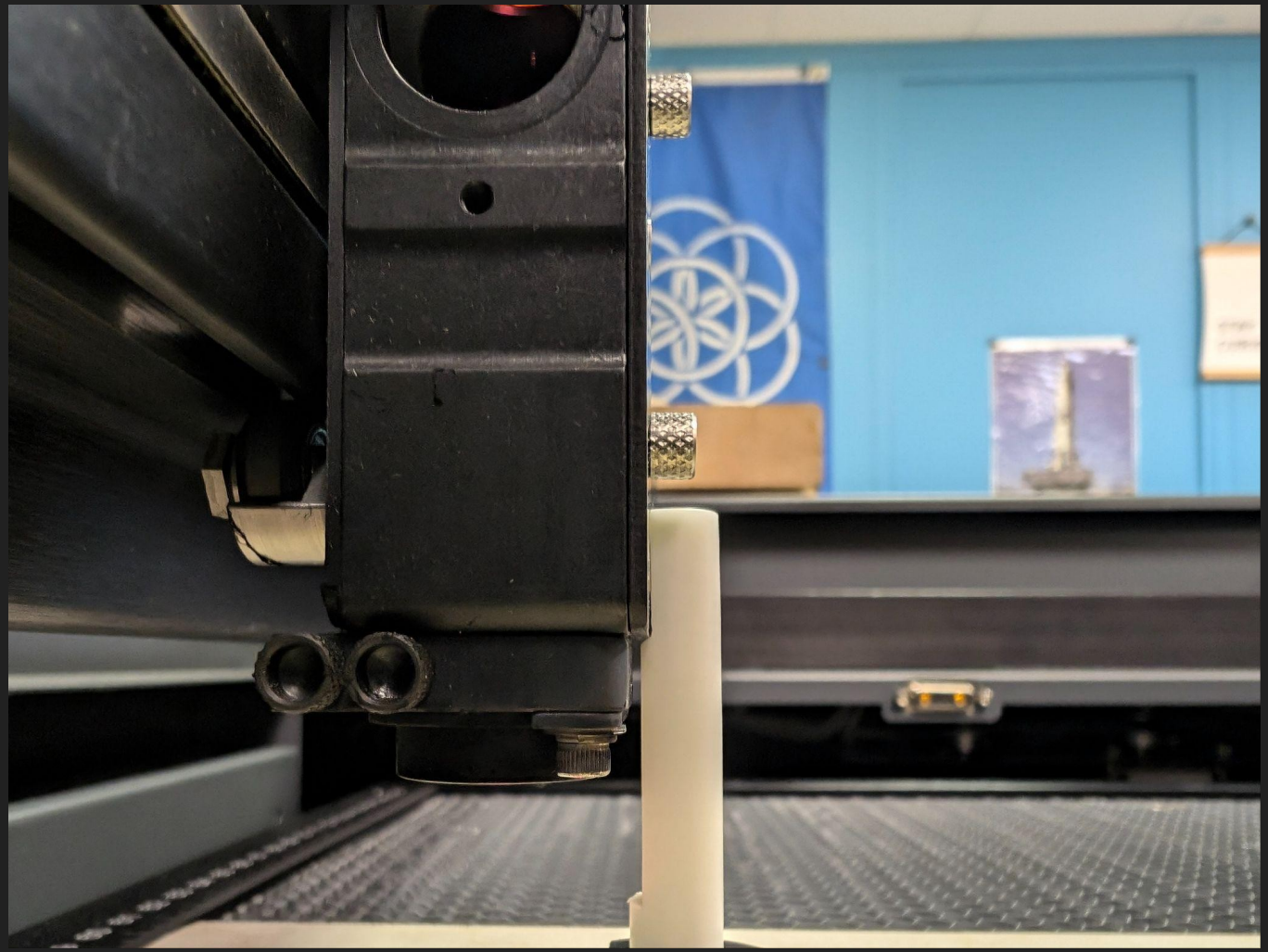
How to Calibrate Laser



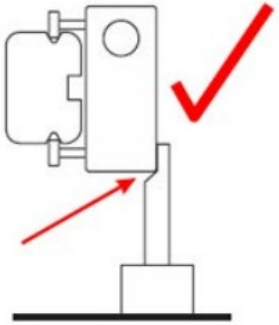


Notice that an improperly focused LASER creates a red light on the material that is not circular or “crisp”.

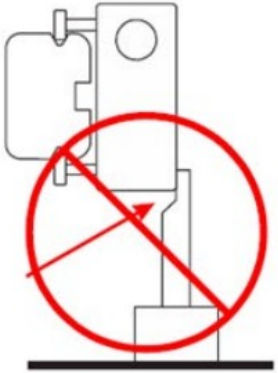
Instead, it’s an oval and full of noise.



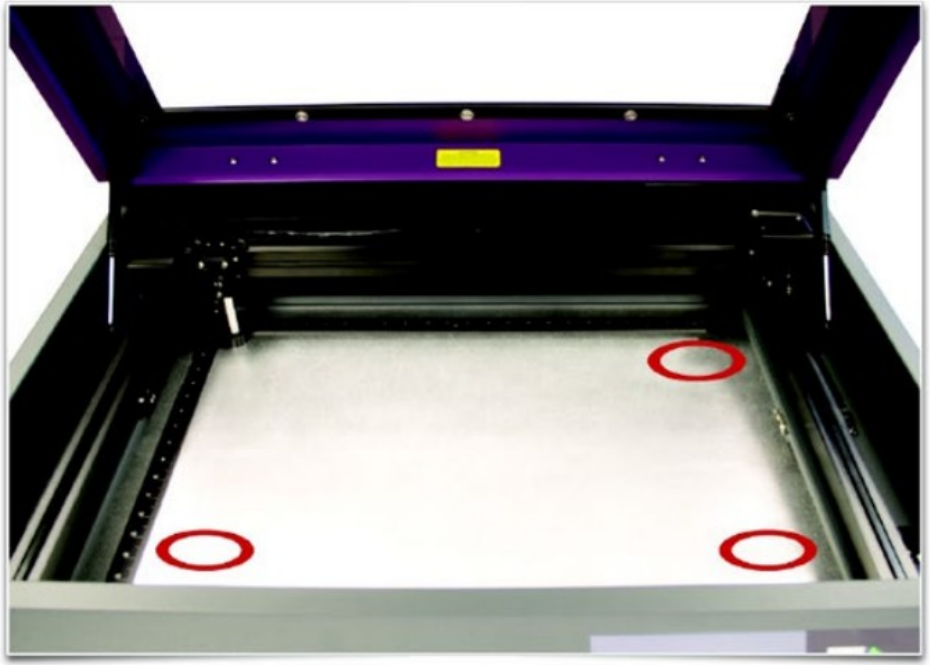
To calibrate, place the calibration stick on top of the material, then move the LASER bed up and down with the arrows on the machine until the bottom of lens cover is aligned with the vertex of the diagonal and vertical space.

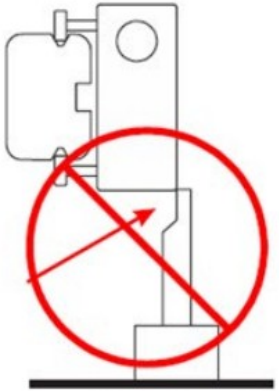


Perfect Fit

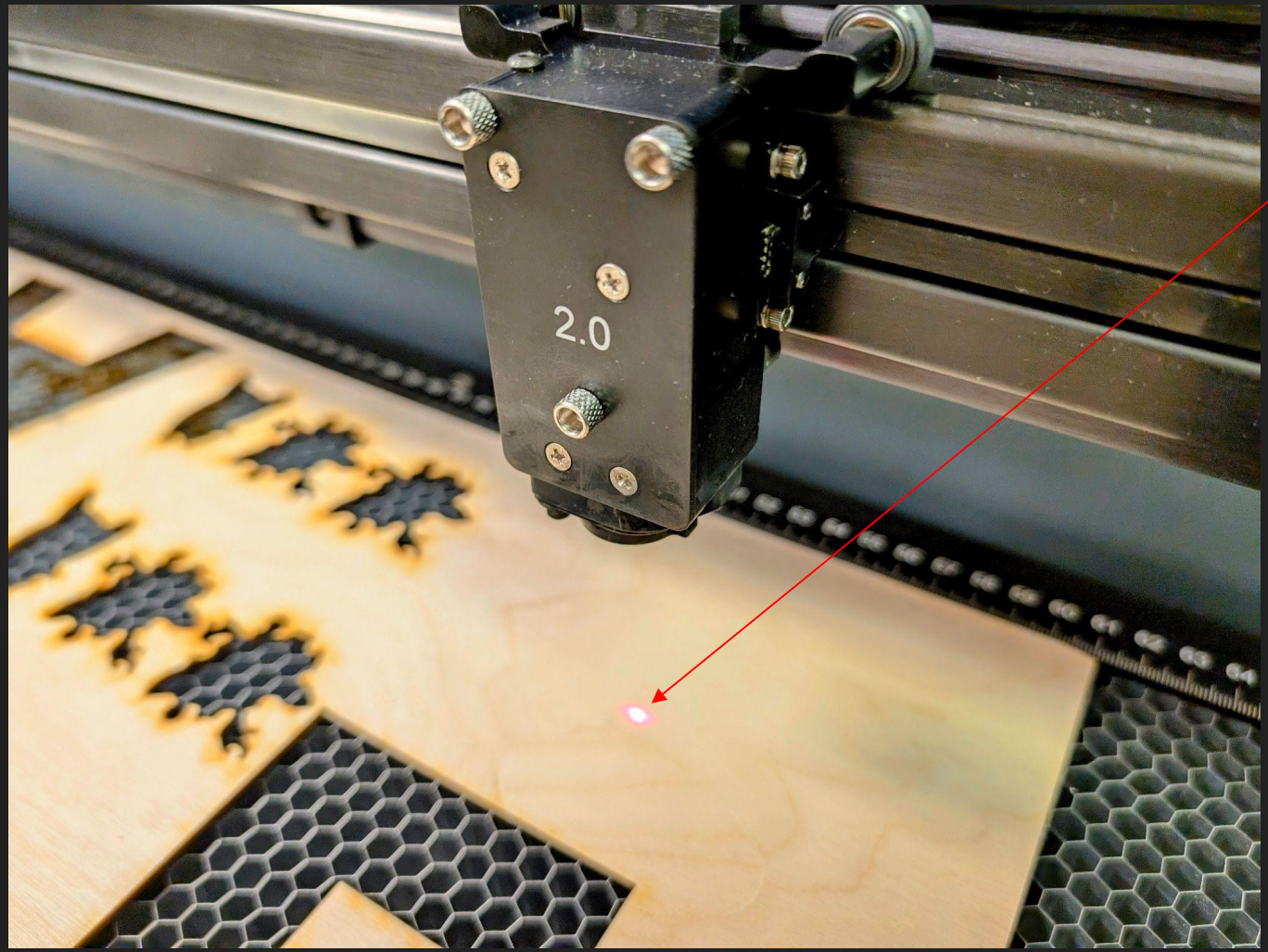


Gap too big

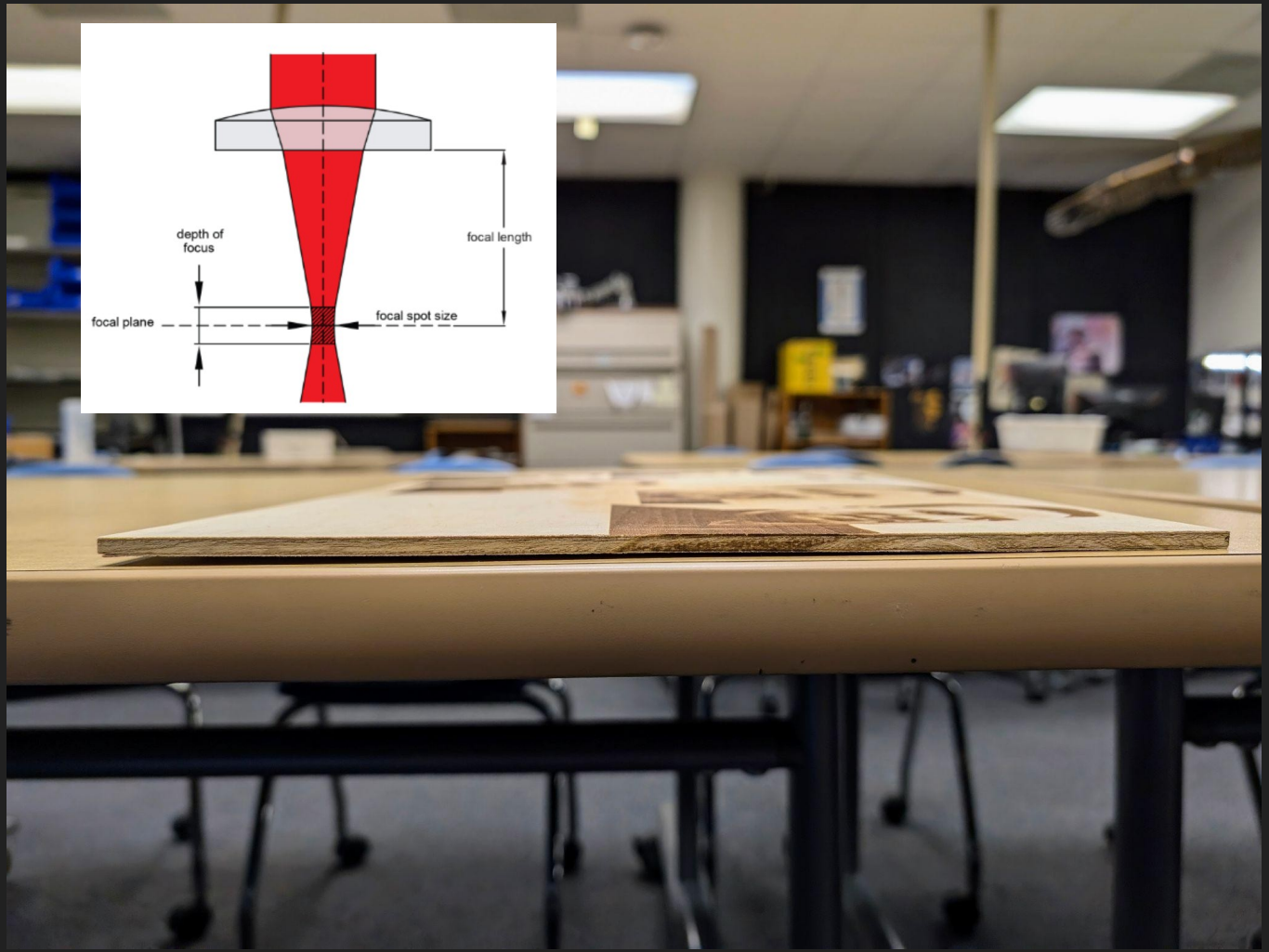




Gap too big



Here is a properly calibrated beam that is “crisp” and round.

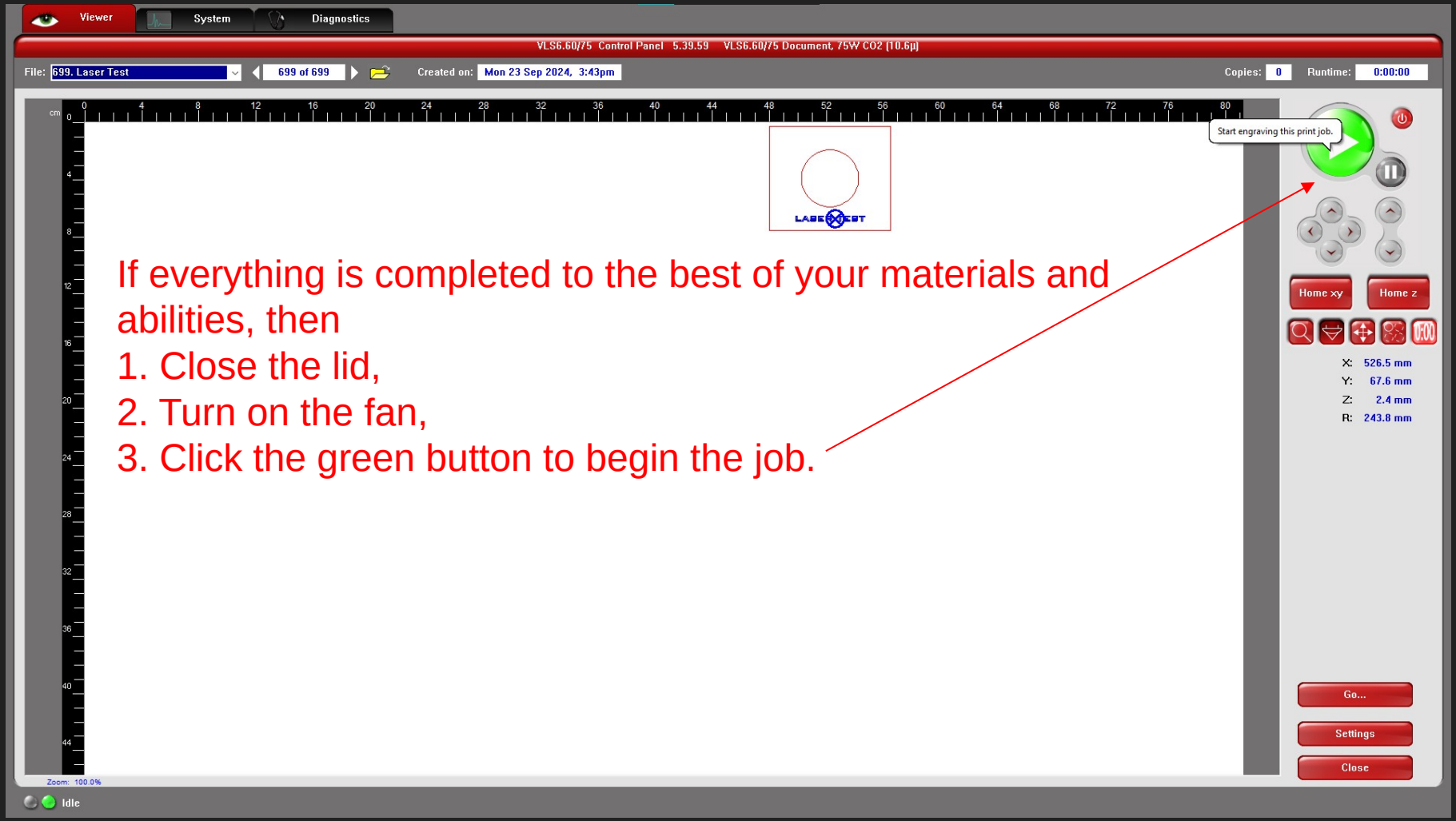


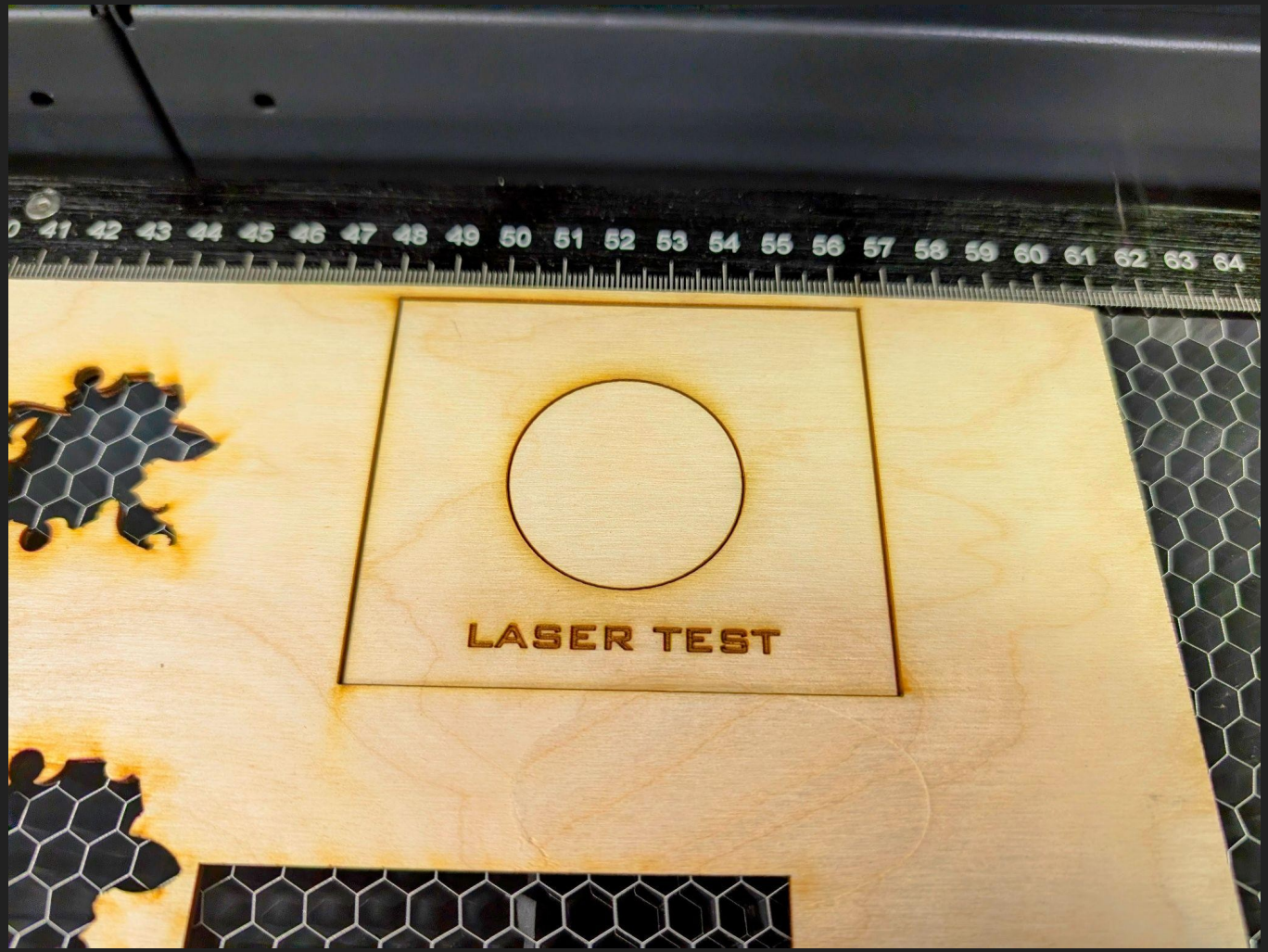
Something that can diminish all precision and accuracy of attaining the perfect cut/engraving is warped material.

This means the lens is suddenly closer and out of focus from the calibrated position.

To fix this, you can try double sided tape on the engraving plate or higher quality materials.

For a Universal Laser System (ULS) with a 2.0" lens, the depth of focus is typically around 0.05 to 0.1 inches (approximately 1.3 to 2.5 mm). This range defines how much variance in the material's surface height can occur while still maintaining a high-quality cut or engraving.


Viewer
System
Diagnostics
VLS6.60/75 Control Panel 5.39.59 VLS6.60/75 Document, 75W CO2 (10.6µ)
File: 699. Laser Test
699 of 699
Created on: Mon 23 Sep 2024, 3:43pm
Copies: 0
Runtime: 0:00:00
Start engraving this print job.
Home xy
Home z
X: 526.5 mm
Y: 67.6 mm
Z: 2.4 mm
R: 243.8 mm
Go...
Settings
Close
Zoom: 100.0%
Idle
If everything is completed to the best of your materials and abilities, then
1. Close the lid,
2. Turn on the fan,
3. Click the green button to begin the job.



This is the first prototype:

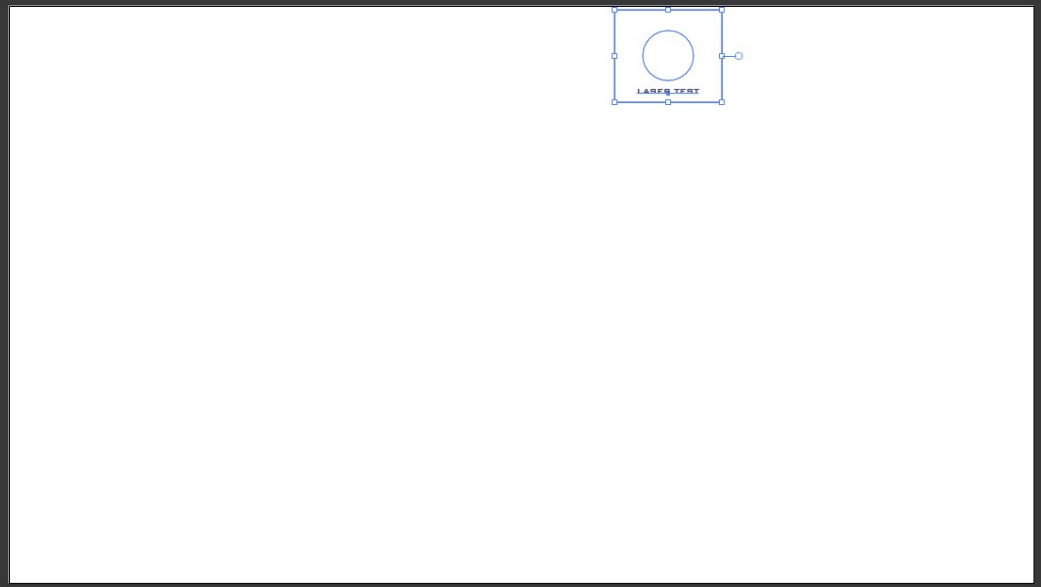
1. The edges are discolored because the settings are not dialed: power too high or speed too slow

2. I don’t like the size of the text, which seems too small and the raster engraving does more burning to the inside, then providing a nice contrast.

And

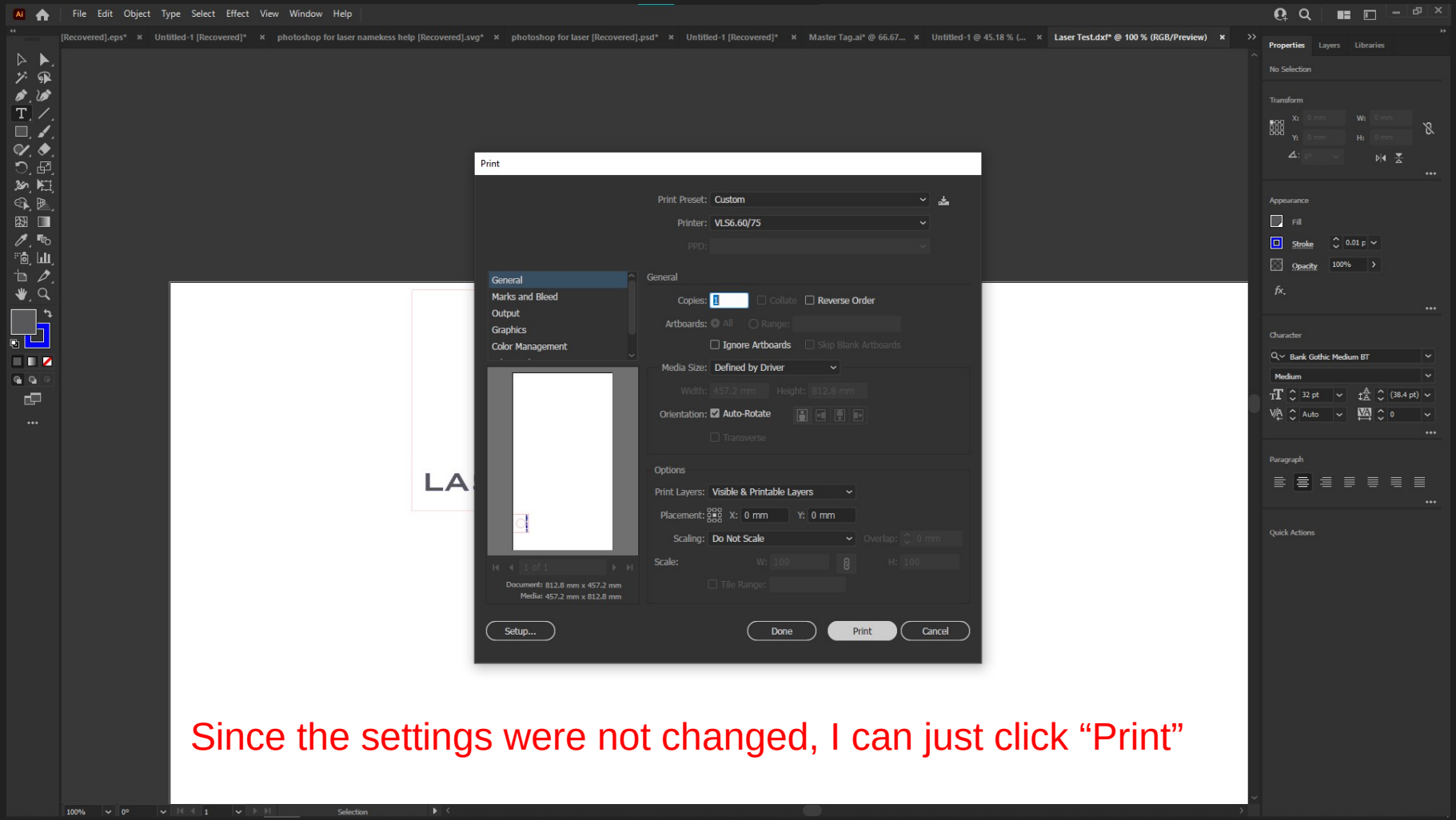
3. This is wood and we are essentially creating a controlled bonfire within an extremely small space.

Now to prototype 2…


LASER TEST



I moved the vectors into a position where there's space on the material, increased the letter size, and placed green painters tape onto the material.

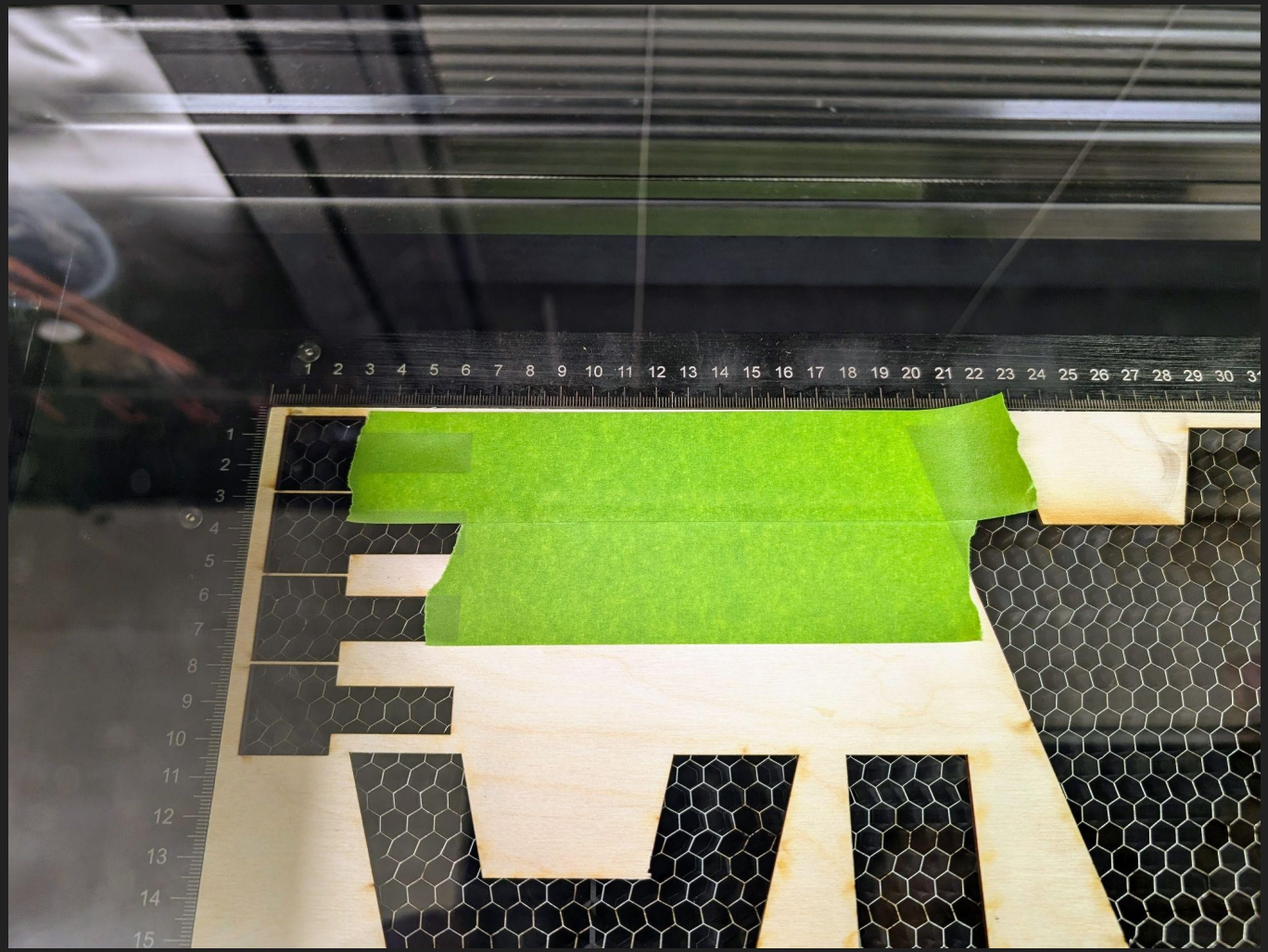


Since the settings were not changed, I can just click “Print”



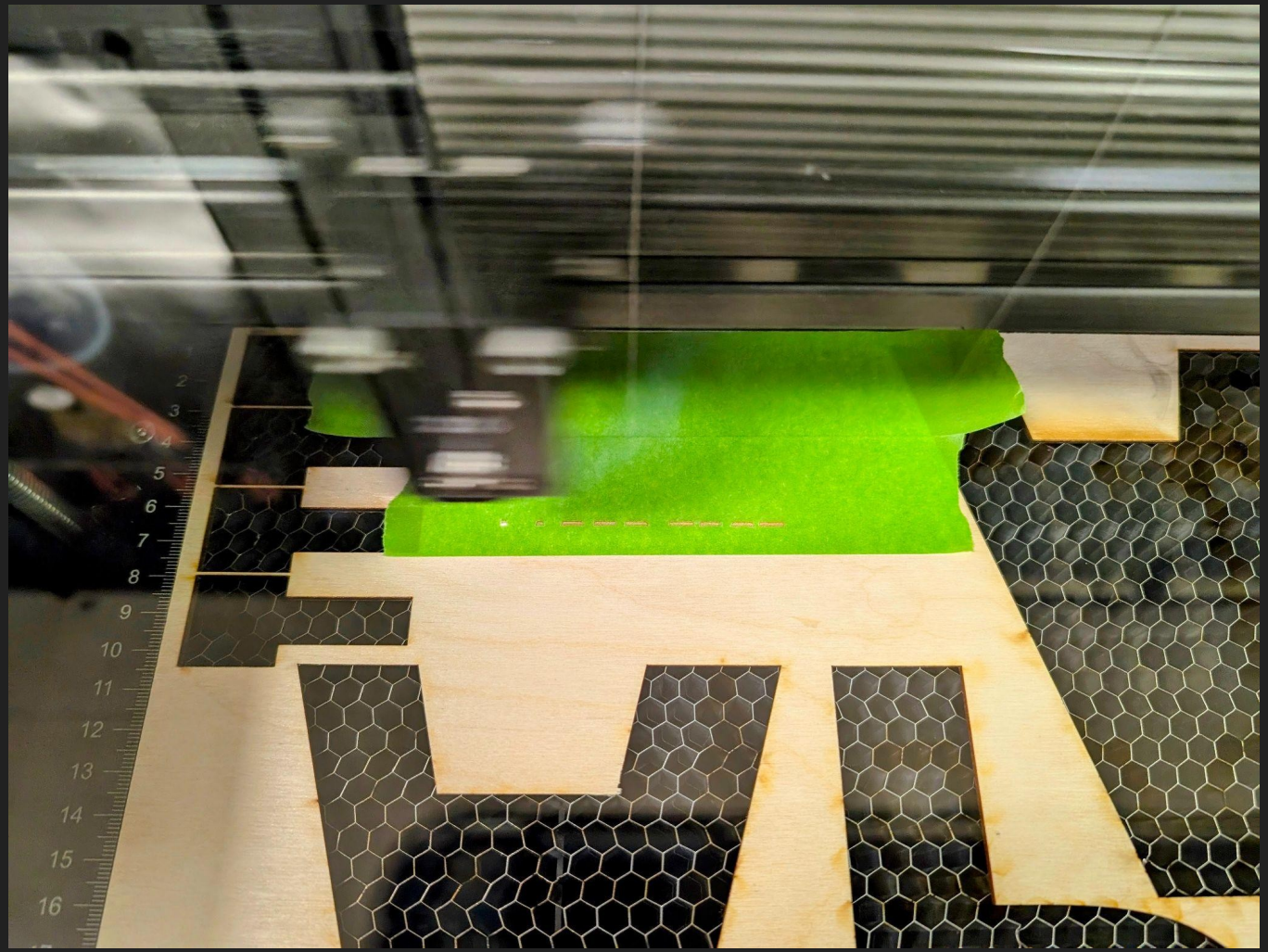
How to Masking Tape

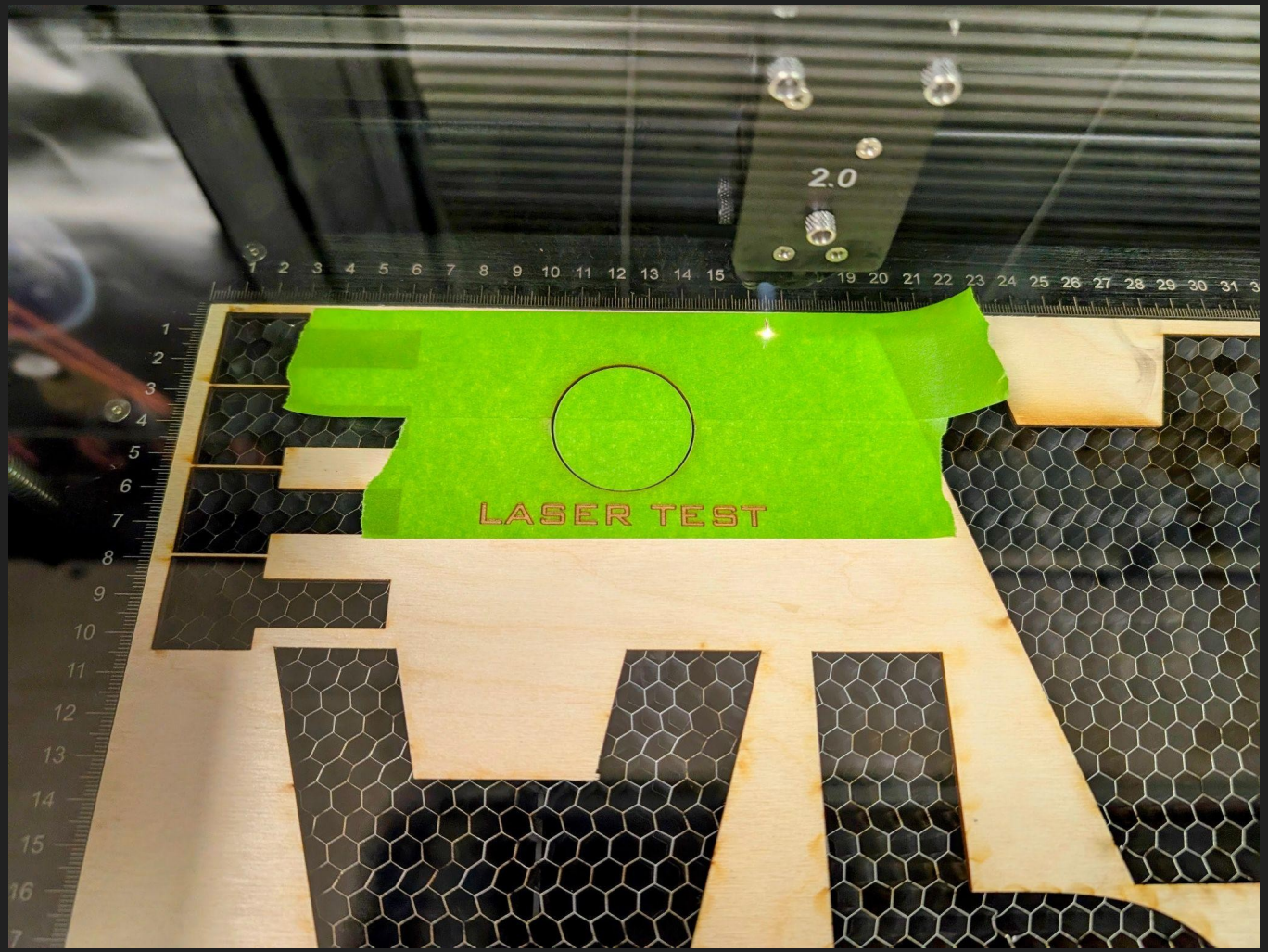


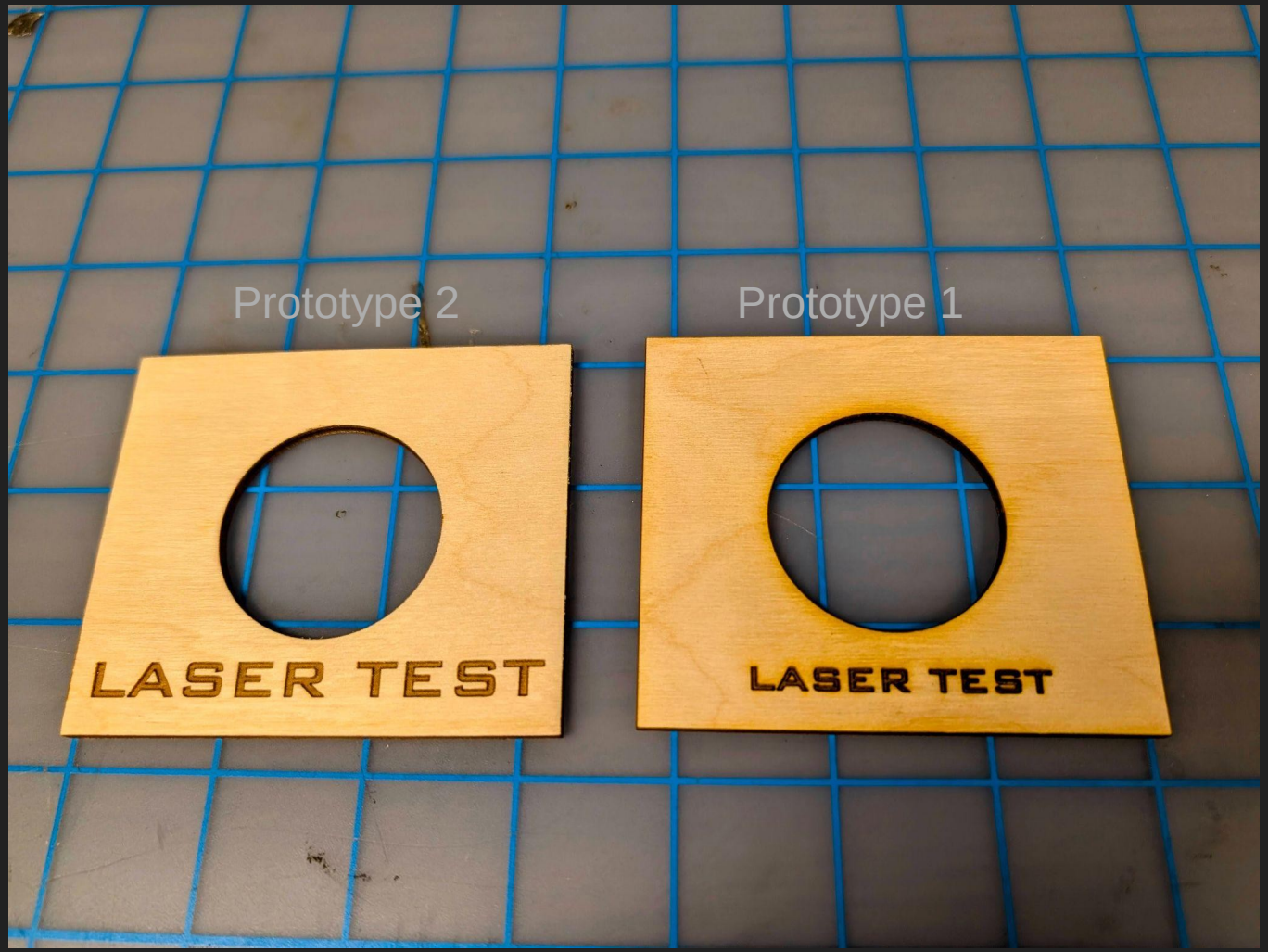


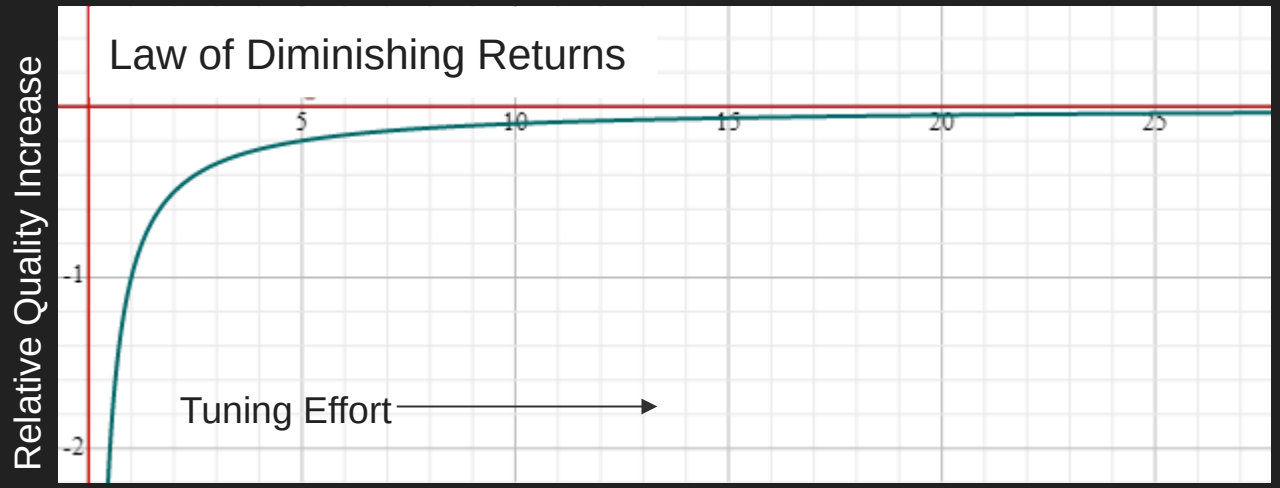
Green Painters Tape:

Protects the edges from becoming discolored and also decreases the photonic energy at the wood surface.




2.0
LASER TEST


Prototype 2
Prototype 1
LASER TEST
LASER TEST



At first, small efforts lead to large improvements, but as you get closer to perfection, additional effort results in much smaller gains. This concept highlights that the closer you are to an optimal outcome, the harder it is to achieve further improvements. This holds for all tools, processes, and systems.