MAKE
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Intro to CO_2 Laser Cutting

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About this Training

- Quiz questions are embedded within the video
- You will not be able to skip forward
- You must score a 100% to pass the training
  - Retake individual questions
  - These slides are available for review on the Makerspace website on the equipment page for the individual CO_2 laser cutters

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Training Topics

- What can you do and make with laser cutters?
- Laser Principles and Characterization
- Laser Cutter Design and Theory of Operation
- Laser Cutter Operation Workflow

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What Can You Make with CO_2 Laser Cutters

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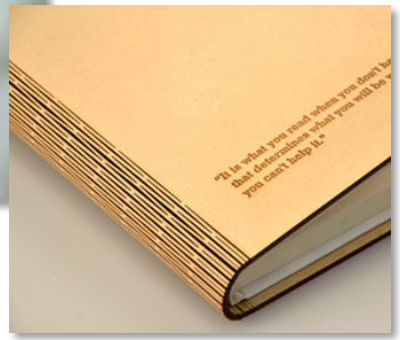
What Can I Do With CO_2 Laser Cutters?



- CO_2 laser cutters and engravers are excellent for making precise 2-dimensional cuts in a variety of materials, as well as engraving
- Engraving is destructive marking of the the surface of the material

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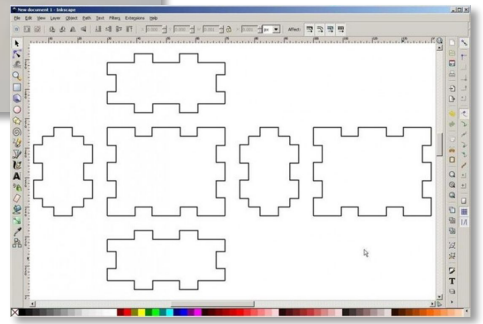
What Can I Do With CO_2 Laser Cutters?



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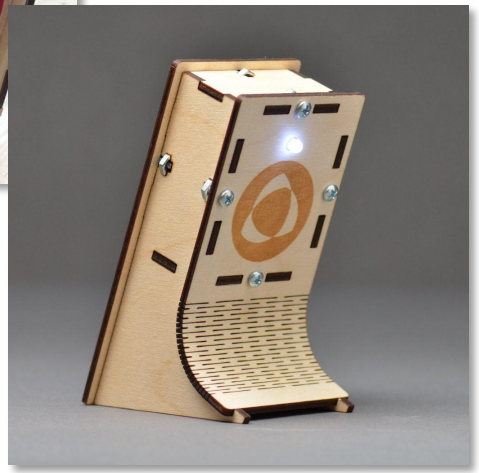
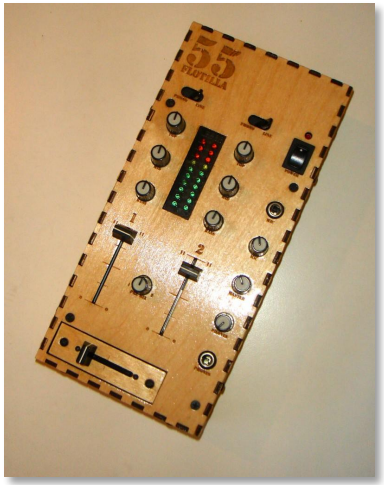
What Can I Do With CO_2 Laser Cutters?

(+ 3D printed parts and off-the-shelf components)





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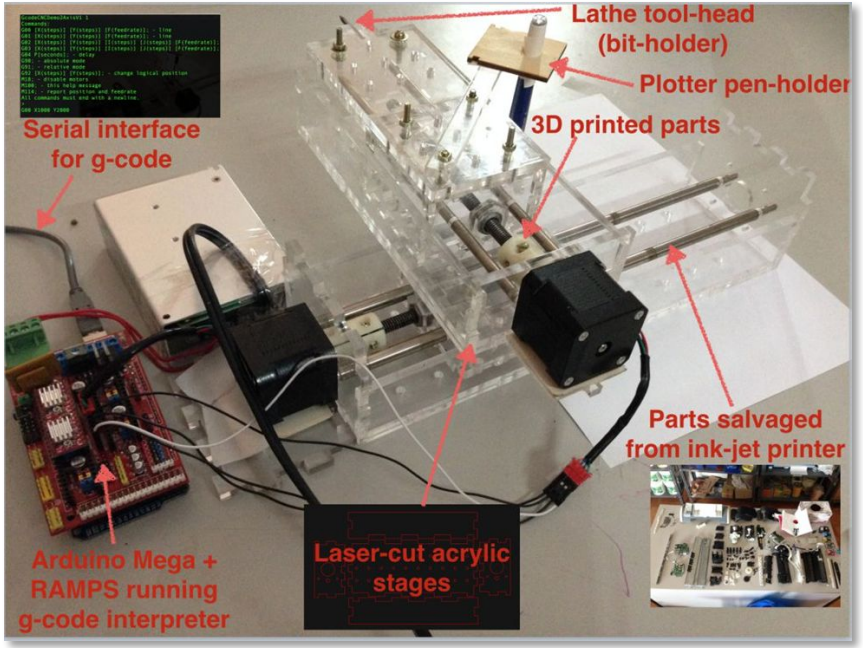
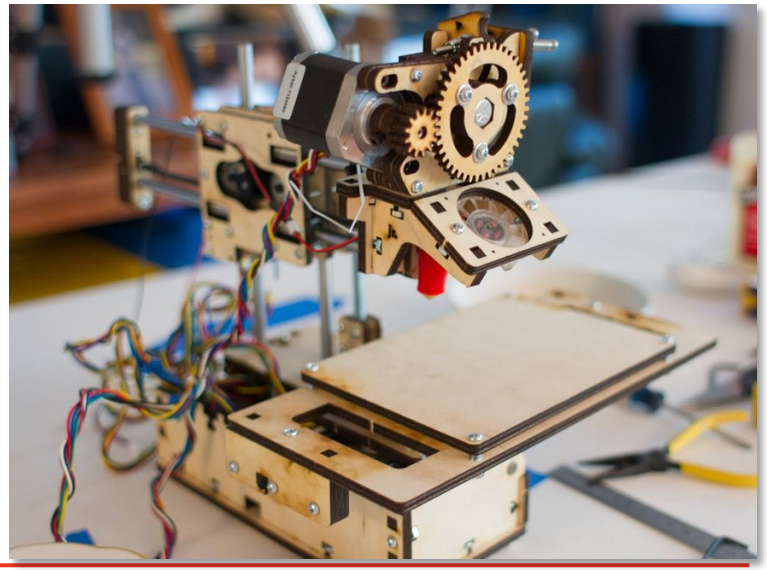
What Can I Do With CO_2 Laser Cutters?

(+ 3D printed parts and off-the-shelf)





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Laser Principles and Characterization

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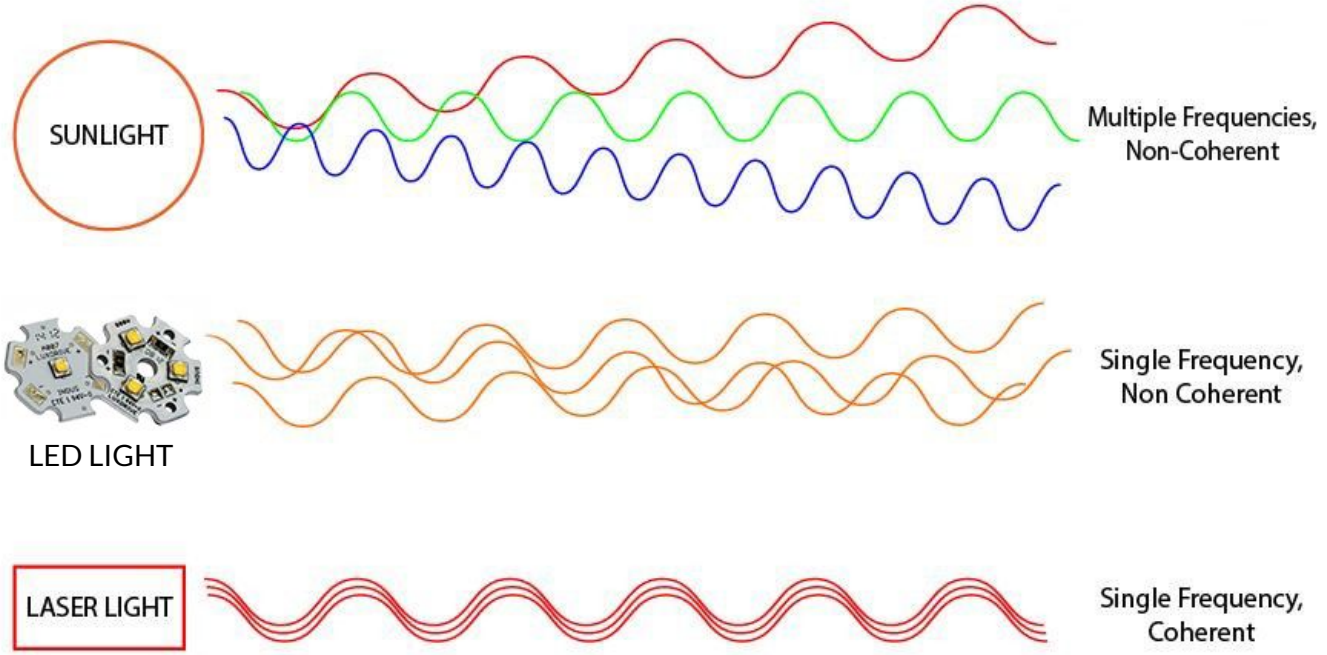
What is Laser Light?



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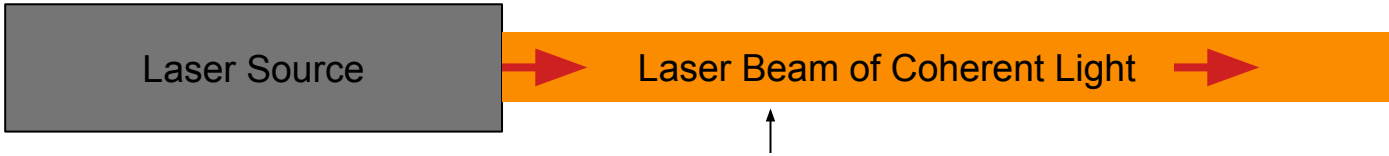
Some Laser Specifications



- Sometimes, lasers are referred to by the type of gas used to excite the photons, this essentially specifies the wavelength of the laser light:
  - For example, a CO_2 laser typically generates a wavelength of between 9,300 and 10,600 nm
- Beam diameter is often referred to as spot size
- Amplitude is often specified by the laser power in Watts
- Most cutting lasers do not stay on 100% of the time, **they pulse on and off at a specified frequency and duty cycle**

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Machine Laser Safety Classification

Laser safety classes for machines that contain a laser source.

(Not for individual laser sources that are not integrated into a machine.)

Machine Laser Safety Class	Description
Class 1	The accessible laser radiation of this class is harmless - even with prolonged radiation, or the laser is housed in a radiation-impervious manner.
Class 2	These comprise visible lasers (e.g. laser pointers with an output below 1mW), which are only safe for the eyes with short-term radiation below 0.25 seconds.
Class 3	The accessible laser radiation is in any case dangerous for the eye. Please also pay particular attention to reflections (e.g. by reflective material surfaces).
Class 4	Damages to eyes and skin can be caused or fires can be triggered within the danger zone of the laser. With this laser class, the user is obliged to fully comply with protection provisions and recommended PPE.

Source: https://www.troteclaser.com/en-us/learn-support/faqs/laser-safety

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Laser Cutter Design and Theory of Operation

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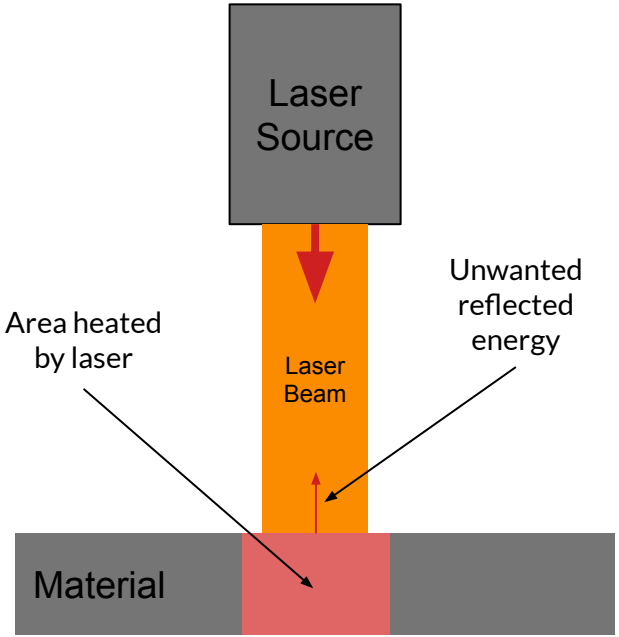
How does a laser cut material?



1. Laser energy is incident on the workpiece material
2. The concentrated energy heats the material
3. The material disintegrates, vaporizes, or melts away

Notice that:

- The heated zone is larger than the beam diameter due to thermal conduction and heat radiation
- There may be some reflected laser energy, this is bad!

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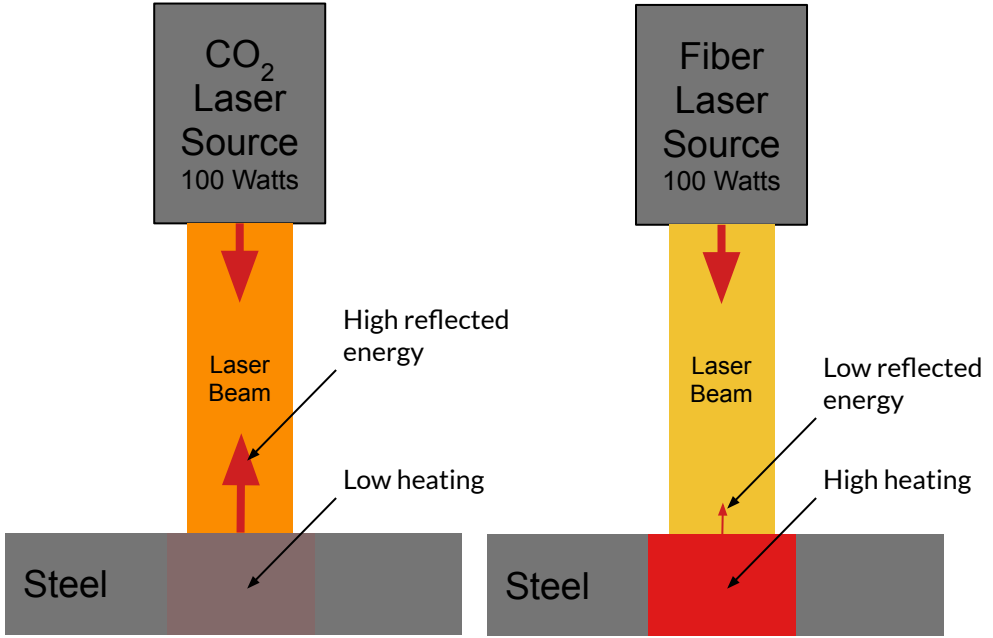
What Determines if Laser Energy is Reflected or Absorbed by the Material?



1. For a given material, the wavelength of the laser determines if the laser beam will be absorbed or reflected
2. This is a function of the material properties
3. This means that a particular type of laser can cut a particular set of materials, and not others

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1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

Usable Materials

The laser cutters covered in this training are CO_2 lasers

CO_2 ONLY

List of Materials		
Material	Cutting	Engraving
Plastics		
Acrylonitrile Butadiene (ABS)	Yes	Yes
Acrylic/PMMA (Plexiglas,Altuglas)	Yes	Yes
Laminate	Yes	Yes
Rubber	Yes	Yes
Polyamide (PA)	Yes	Yes
Polybutylene terephthalate (PBT)	Yes	Yes
Polycarbonate (PC)	Yes	Yes
Polyethylene (PE)	Yes	Yes
Polyester (PES)	Yes	Yes
Polyimide (PI)	Yes	Yes
Polyoxymethylene (POM)-Delrin	Yes	Yes
Polypropylene (PP)	Yes	Yes
Polyphenylene sulfide (PPS)	Yes	Yes
Polystyrene (PS)	Yes	Yes
Polyurethane (PUR)	Yes	Yes
Foam	Yes	Yes

List of Materials		
Material	Cutting	Engraving
Miscellaneous		
Wood	Yes	Yes
Mirror	No	No
Stone	No	Yes
Paper (white)	Yes	Yes
Paper (colored)	Yes	Yes
Food	No	Yes
Leather	Yes	Yes
Fabric	Yes	Yes
Glass	No	Yes
Ceramics	No	No
Cork	Yes	Yes

List of Materials		
Material	Cutting	Engraving /Marking
Metals		
Aluminum, Anodized	No	Yes
Stainless Steel (Thermark)	No	No

This list of materials is also presented on the NJIT Makerspace website!

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1 - 2D Vector File
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Non-Usable Materials

Warning !

Processing of the following materials is not permitted:

Carbon, Polyvinyl chloride PVC, Polyvinyl butyral PVB, Polytetrafluorethylene PTFE (Teflon), carbon fiber, beryllium oxide and materials containing halogen (fluorine, chlo-rine, bromine, iodine and astatine), epoxy- or phenolic resins

Take care when processing the following materials:

Manganese, chromium, nickel, cobalt, yttrium and lead. Material with the naming addition "flame-retarding" since it might contain bromine.

Notice

Any material not listed above may only be processed with written approval of Trotec.

We recommend to run a material processing test with the above mentioned mate-rial using the appropriate

Trotec assumes no responsibility for any consequences of laser processing in any application such as medical or pharmaceutical applications.

NO METALS can be cut on the CO_2 laser cutters!

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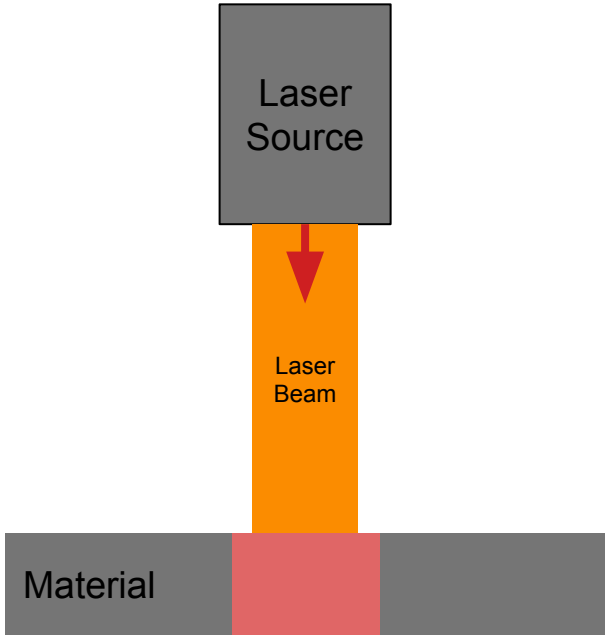
What happens to the material that is cut?



1. The material disintegrates, vaporizes, or melts away. It is usually dispersed into the atmosphere in the process chamber inside the machine.
2. Laser cutters have exhaust systems to pull away vaporized material.
3. If you can smell the cut material while cutting, you are inhaling the vaporized material and this can be hazardous.
4. Verify that exhaust systems are functioning properly while cutting and do not cut hazardous materials.

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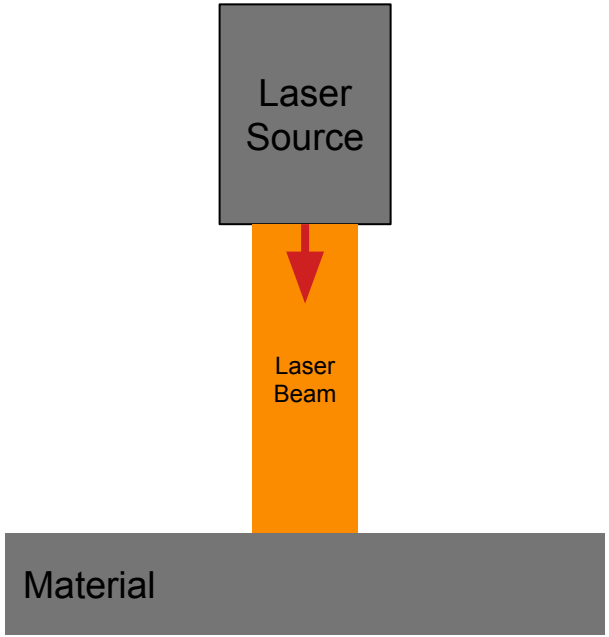
Laser Power and Energy Concentration



1. Most laser cutting systems to not have enough power to operate as shown to the left.

2. The energy concentration is not high enough to heat the material enough to cut it.

3. To cut effectively, the system will need a high laser power or higher energy concentration.

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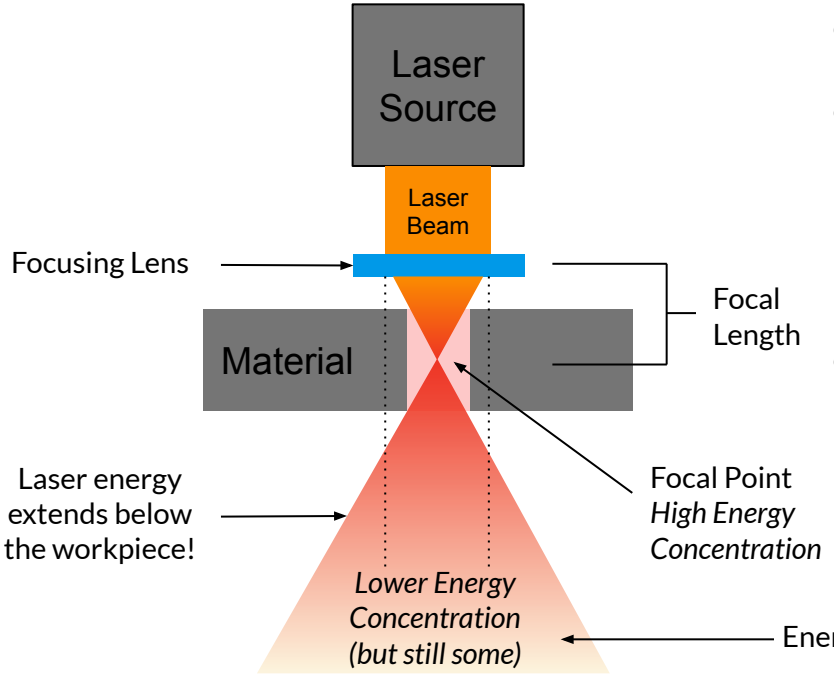
Increasing Laser Cutter Energy Concentration



- A lens is used to focus the energy onto a convergence point. This is called the **focal point**.
- The linear distance between the lens and the focal point is called the **focal length.**
    a. Laser energy is **more** concentrated closer to the focal point
    b. Laser energy is **less** concentrated further from the focal point
- For a cut to succeed, the laser energy must have a high enough concentration within the entire material.
    a. If the energy concentration is to low, the laser **will not cut the material**, even with repeated cutting passes.

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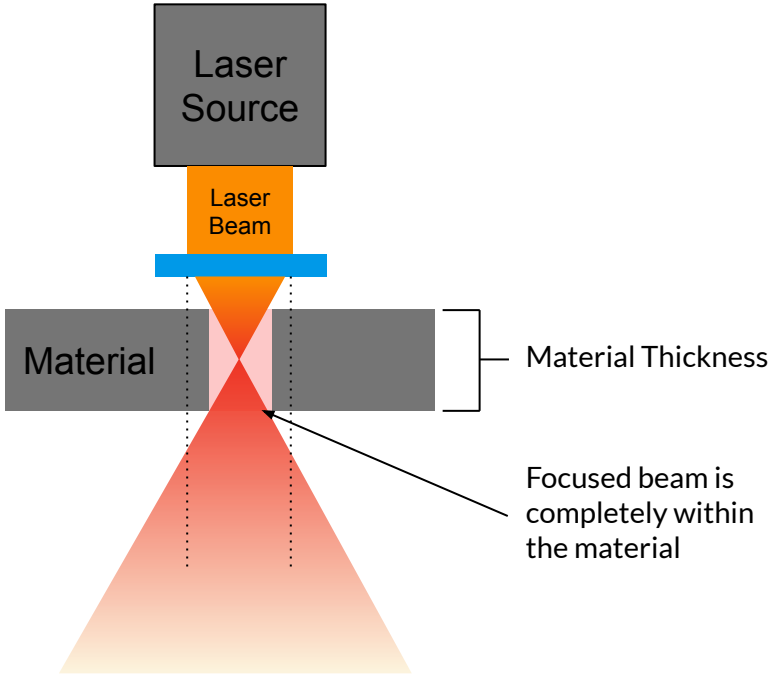
For a Successful Cut



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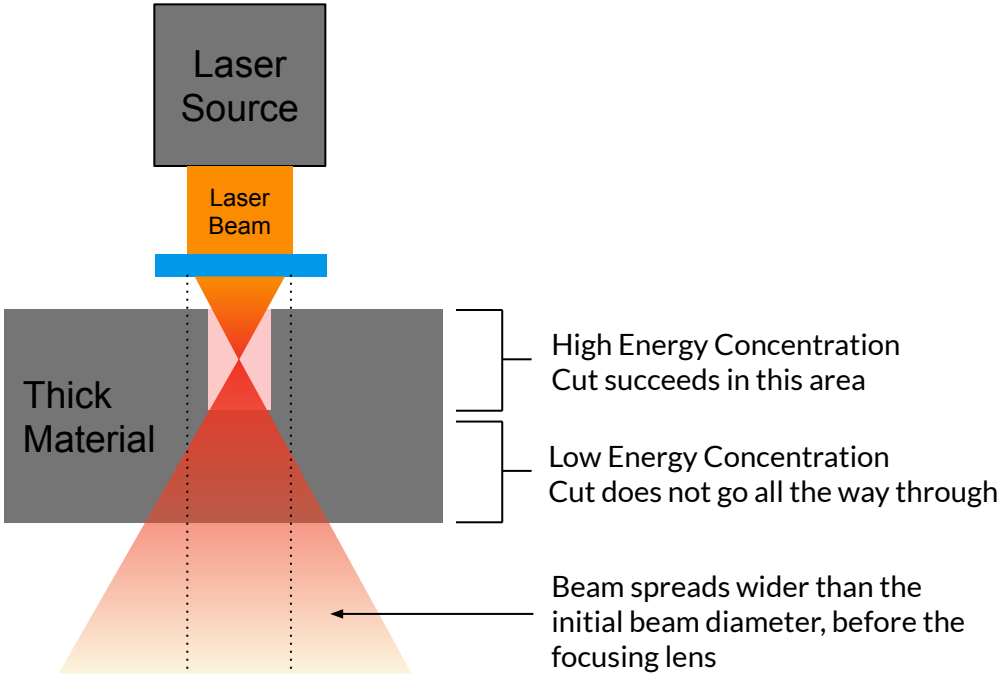
Problems with Thicker Material



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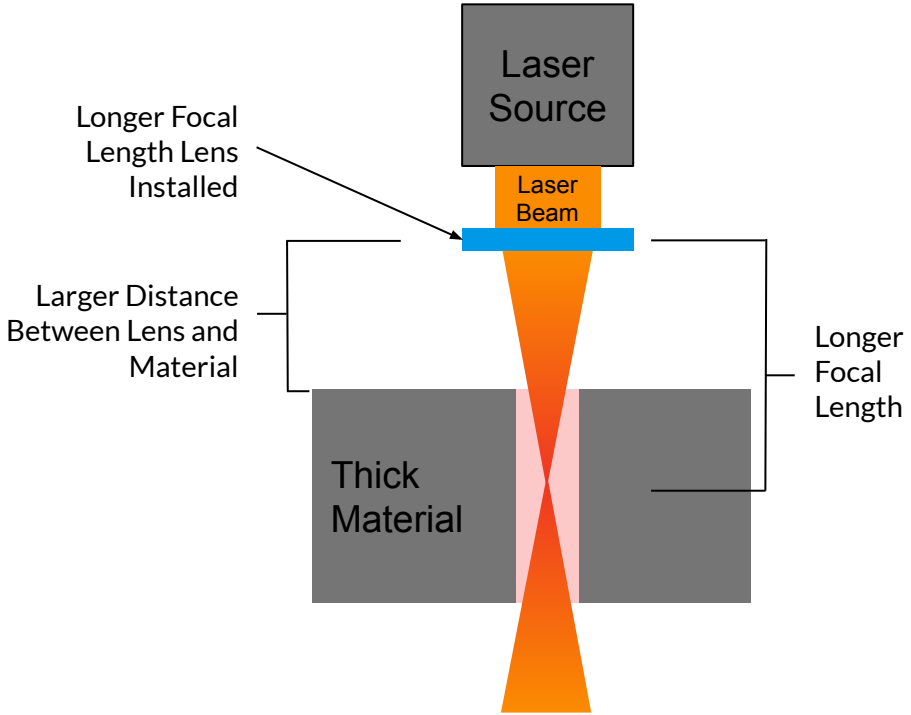
Thicker Material = Longer Focal Length



- Many cutting lasers have interchangeable focusing lenses that are used when cutting material of different thicknesses.
- In general
  - Thinner Material -> shorter lense
  - Thicker Material -> longer lense

- Speedy100 - Has a fixed 1.5” lens

- Speedy400 - Has interchangeable lenses
  - If you have thick material to cut, over 0.5” thickness, use the Speedy400 and ask the staff to help install a long focal length lens

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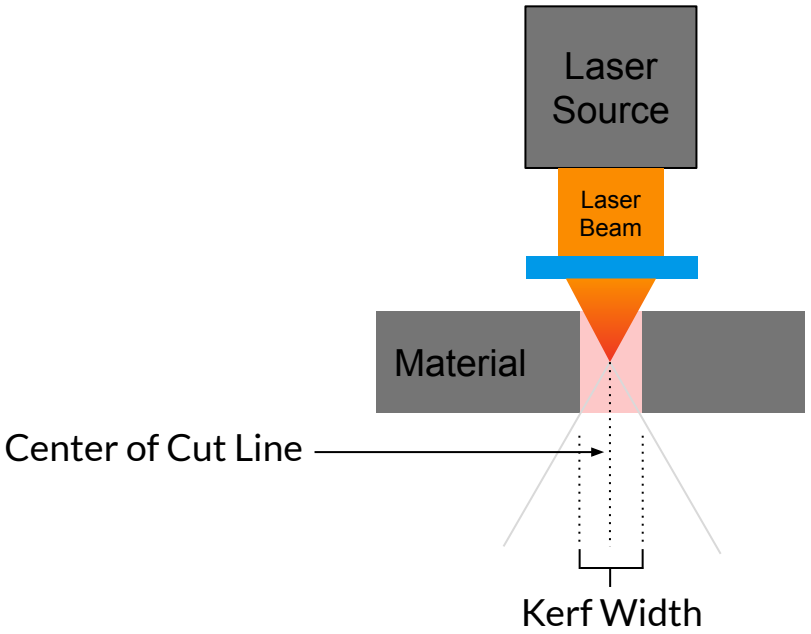
Laser Kerf Width



- When cutting, most lasers follow the center of the designed path.
- The laser will cut a path through the material with a width, referred to as the **kerf width.**
  - When cutting the outside of a feature, the resulting feature will be slightly smaller than design specifies
  - When cutting the inside a feature, the resulting feature will be slightly larger than design specifies
- Kerf width will vary from material to material, by laser settings, lens selection, and slightly from machine to machine.
- If your parts require high precision, cut a test piece and measure the kerf with a caliper.

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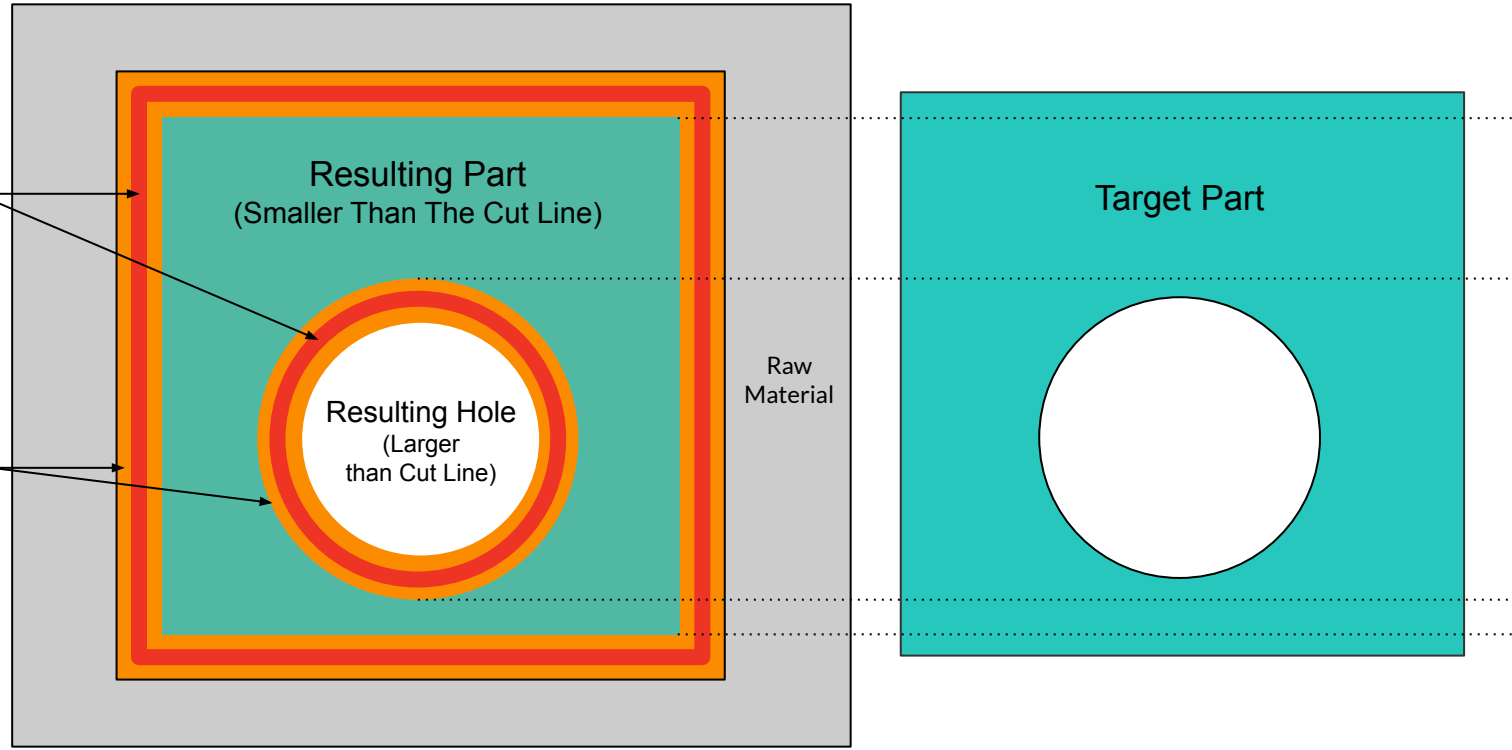
Laser Kerf Example - Top Down View

The laser cuts along the **red** path

The laser also removes material on both sides of the cut line. (**Orange Material**) (Exaggerated for Example) *Usually this is a few thousandths of an inch.*



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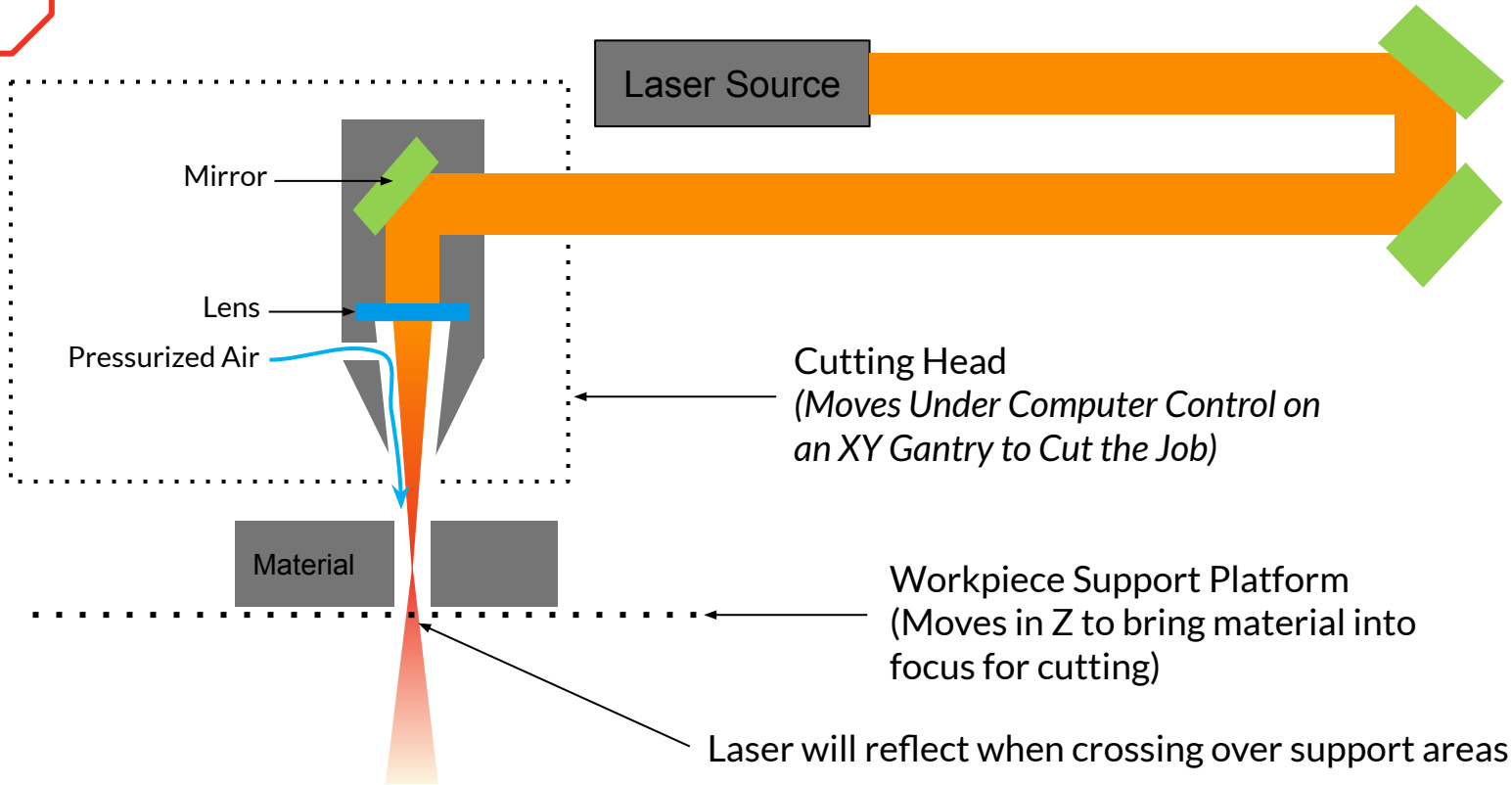
Typical Cutting Laser Setup and Cutting Head



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Laser Cutter Operation Workflow

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Laser Cutter Operation Workflow

1. 2D File Design or Acquisition
    - Files can be designed in any CAD or vector design software or can be downloaded from project websites
2. File Preparation for Laser Cutting
    - Files are modified using Adobe Illustrator or CorelDraw to indicate which lines are cut lines, engrave lines, etc…
3. Specify the Cut Parameters for the Machine and Material
    - Done in print dialog and preferences page
4. Verify Setup is Appropriate and Setup the Machine
    - Material Type
    - Lens
    - Focus
    - Job start location
5. Cut the Job and Wait for it to Finish
6. Clean Up

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1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
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Step 1: 2D File Design or Acquisition

- Laser cutters are controlled from a 2D design file, often called a vector file. 2D files are flat line drawings in a single plane.
- There are many ways to make 2D design files, some available software packages are:
  - Solid Works
  - Fusion360
  - CorelDRAW
  - Adobe Illustrator
- Or, download existing 2D files from websites like:
  - Make, GrabCad, Thingaverse, Pinterest, etc…
- Common 2D file formats:
  - .dxf .ai .pdf .svg

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1 - 2D Vector File
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Step 2: File Preparation for Laser Cutting

- Since laser cutters can engrave, mark, and cut material, the design file must specify which lines are to be engraved and which lines are to be cut.
- Laser software uses line color and line width to distinguish between engrave lines and cut lines
- To indicate to the laser how to treat a particular line, there are specific line widths and line colors that must be applied
  - In general:
    - **Red** lines with minimum thickness are cut lines
    - **Black** lines are engrave lines

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Step 2: Notes on Color Representation

- Colors are represented with RGB color values
- Each color is represented using 3 numbers
  - (**Red Value**, **Green Value**, **Blue Value**)
  - Each number ranges from 0 to 255
    - 0 means none of the color
    - 255 means 100% of the color

(255,128,0)	100% Red	50% Green	0% Blue -> **Orange**
(0,0,0)	0% Red	0% Green	0% Blue -> **Black**
(0,0,255)	0% Red	0% Green	100% Blue -> **Blue**
(0,255,0)	0% Red	100% Green	0% Blue -> **Green**
(255,0,0)	100% Red	0% Green	0% Blue -> **Red**

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1 - 2D Vector File
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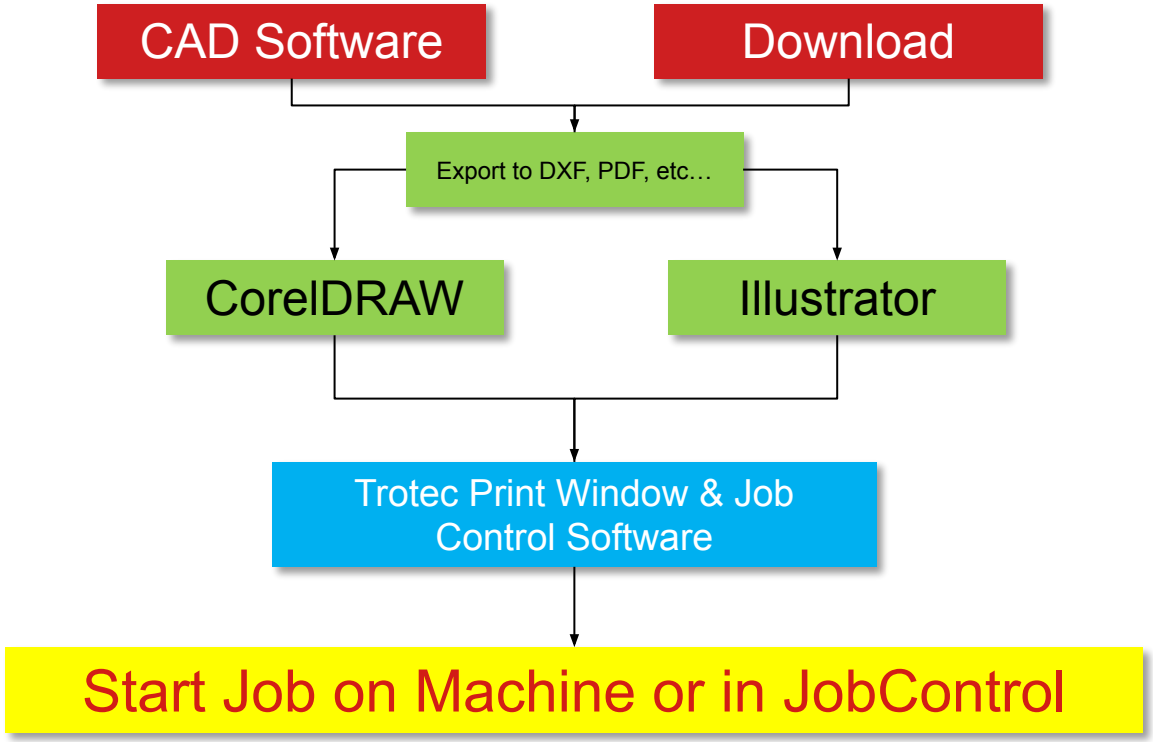
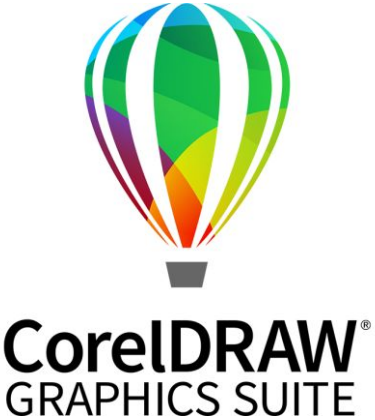
Step 2: Software Workflow



What are CorelDRAW and Adobe Illustrator?



- CorelDRAW and Adobe Illustrator are vector based design softwares
- Use them to scale, colorize, and position designs to be cut and engraved
- Set line colors and widths to specify if they are cut or engrave lines

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1 - 2D Vector File
2 - File Prep - Corel
3 - Cut Parameters
4 - Machine Setup
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File Prep in CorelDRAW

CorelDRAW® GRAPHICS SUITE

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1 - 2D Vector File
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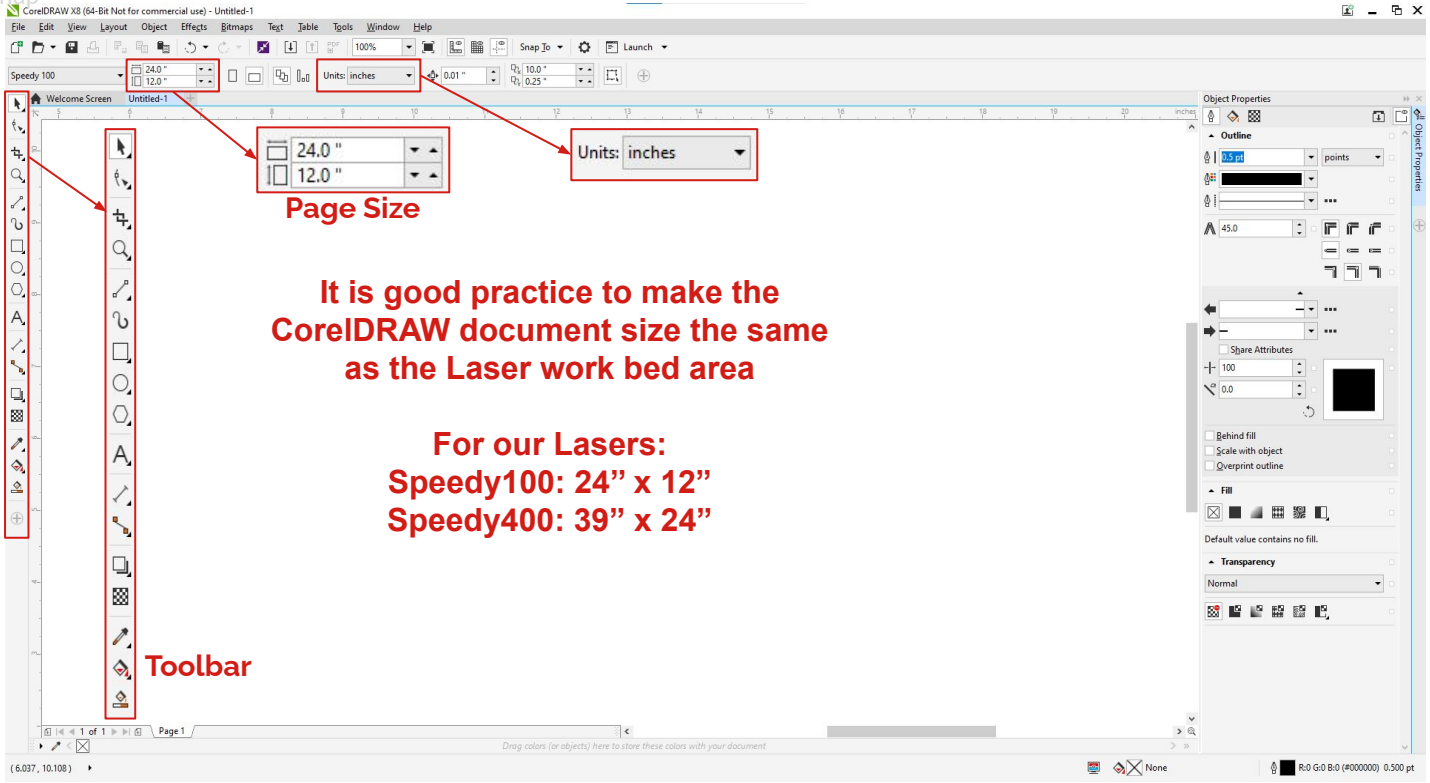
6 - Cleanup

CorelDRAW Workspace

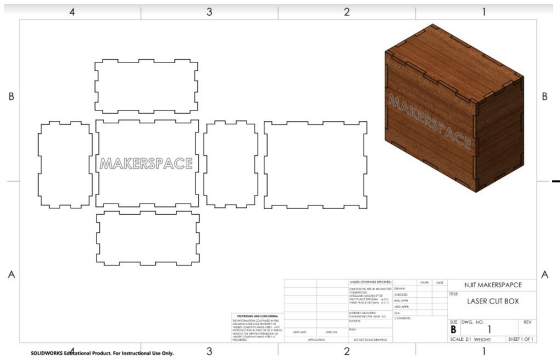


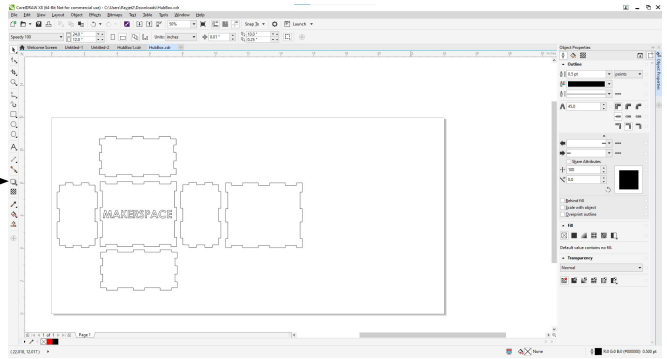
It is good practice to make the CorelDRAW document size the same as the Laser work bed area

For our Lasers:
Speedy100: 24” x 12”
Speedy400: 39” x 24”

CorelDRAW Process Example

To create this box and engrave the word makerspace on the front.

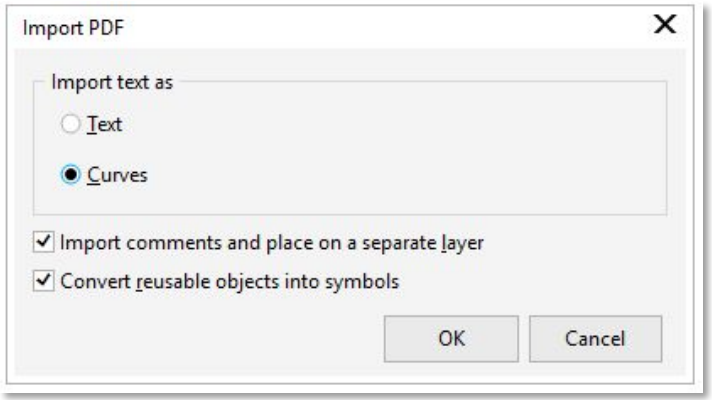




- Export drawing from CAD and save as a .pdf or .dxf file.
- Open the file in CorelDRAW using the import or open tool.

Open File in CorelDRAW

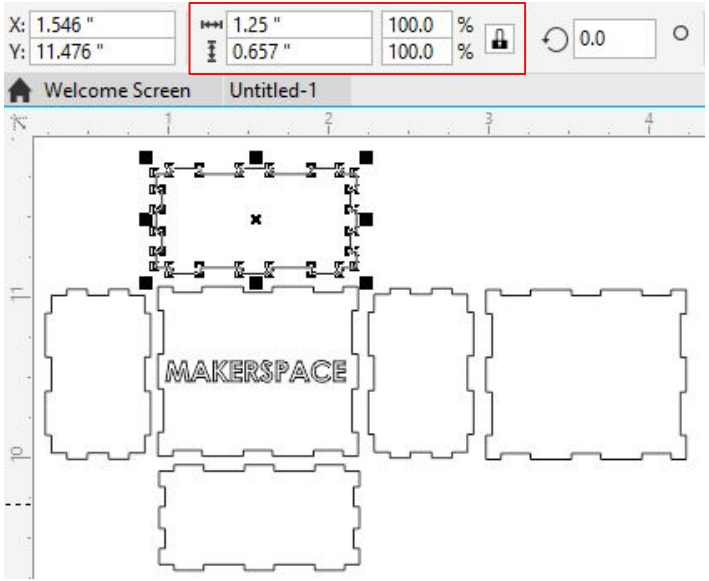
- File -> Open or File -> Import and select your CAD drawing saved as a PDF or DXF.
- Click “OK”.



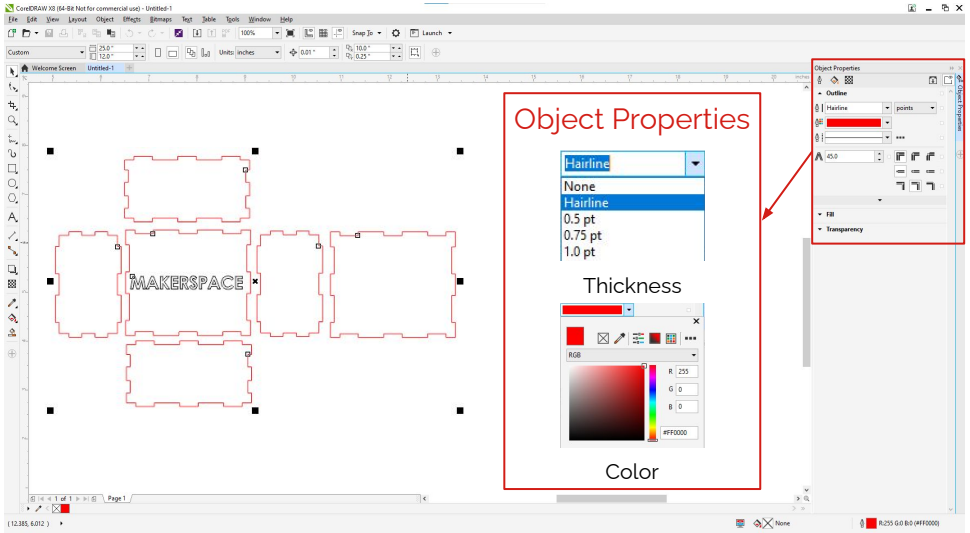
Verify the Imported Drawing is to Scale

When moving from one software to another, scale often changed. **Verify Dimensions!**

- It is critical to know the **overall dimension in either the x or y-axis** to set the proper scale.
- **Click the lock** to ensure the that x and y dimensions scale in the original ratio of the drawing.
- Input either the overall x or y dimension to properly scale the drawing

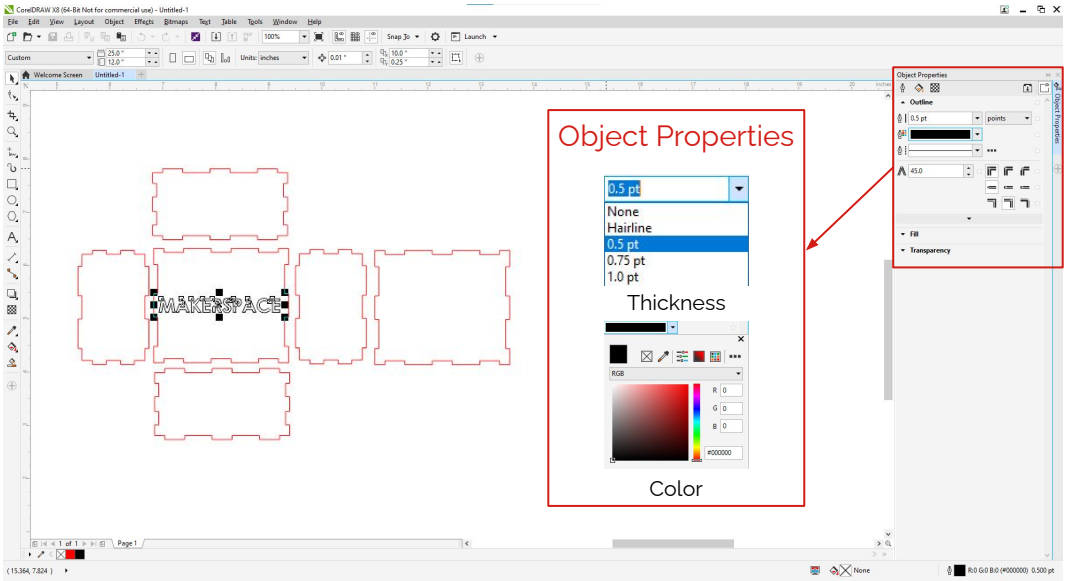


Set Cutting Lines



- Highlight all lines to be cut and change the line color using the "object properties" window on the right.
  - Press “alt+enter” if it is not visible.
- Lines must be RGB color with a value of **(255,0,0) Red**.
- Lines must have a thickness of **“Hairline”.**

Set Engraving Lines



- Engraving **lines or areas** must be RGB color **(0,0,0) Black**
- Engraving **lines or areas** can have **any thickness.**

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1 - 2D Vector File
2 - File Prep - AI
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File Prep in Adobe Illustrator

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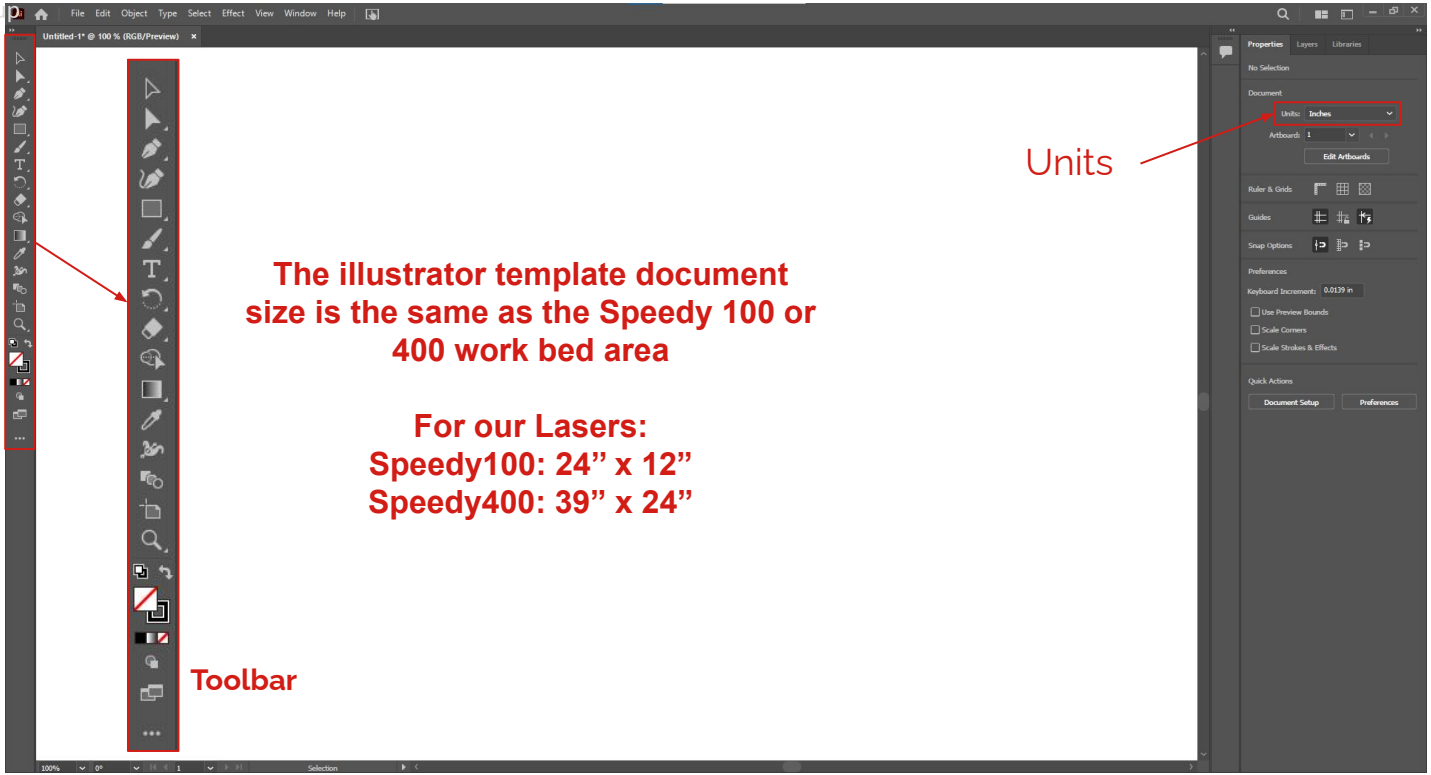
Illustrator Workspace

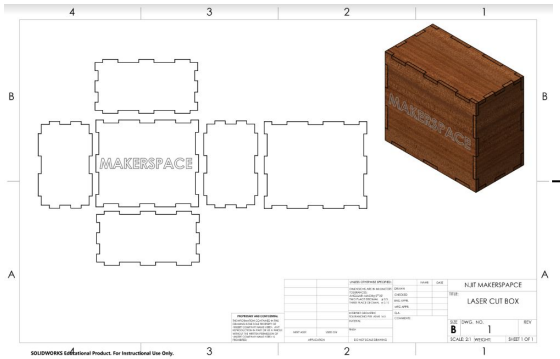


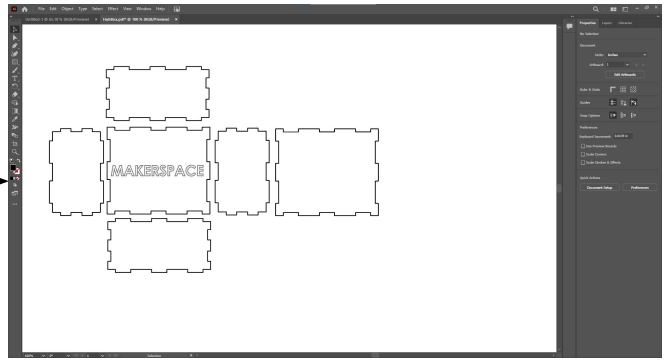
The illustrator template document size is the same as the Speedy 100 or 400 work bed area

For our Lasers:
Speedy100: 24” x 12”
Speedy400: 39” x 24”

Illustrator Process Example

To create this box and engrave the word makerspace on the front.



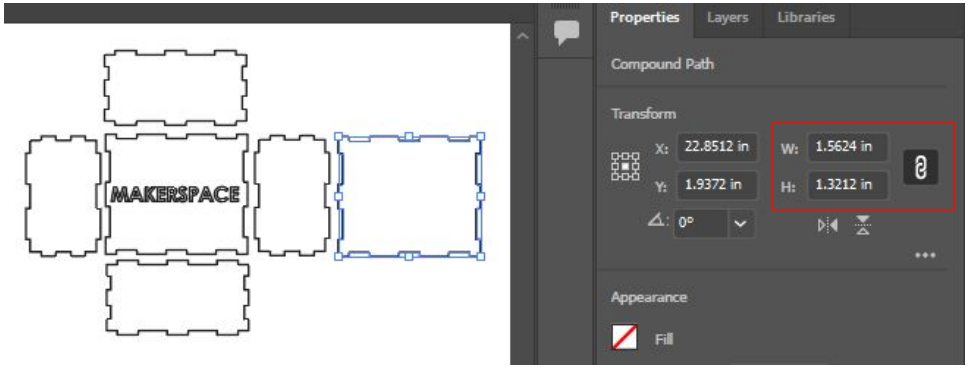


- Export drawing from CAD and save as a .pdf or .dxf file.
- Open the file in Adobe Illustrator using the import or open tool.

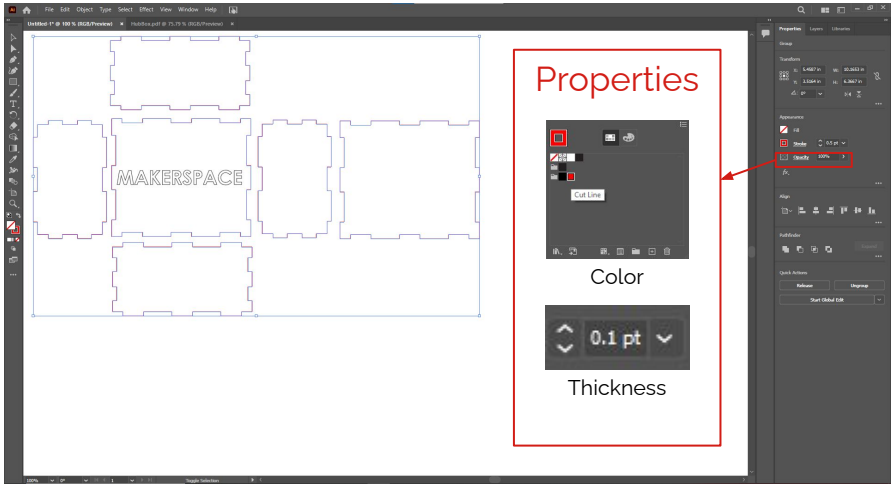
Verify the Imported Drawing is to Scale

When moving from one software to another, scale often changed. **Verify Dimensions!**

- It is critical to know the **overall dimension in either the x or y-axis** to set the proper scale.
- **Click the lock** to ensure the that x and y dimensions scale in the original ratio of the drawing.
- Input either the overall x or y dimension to properly scale the drawing.

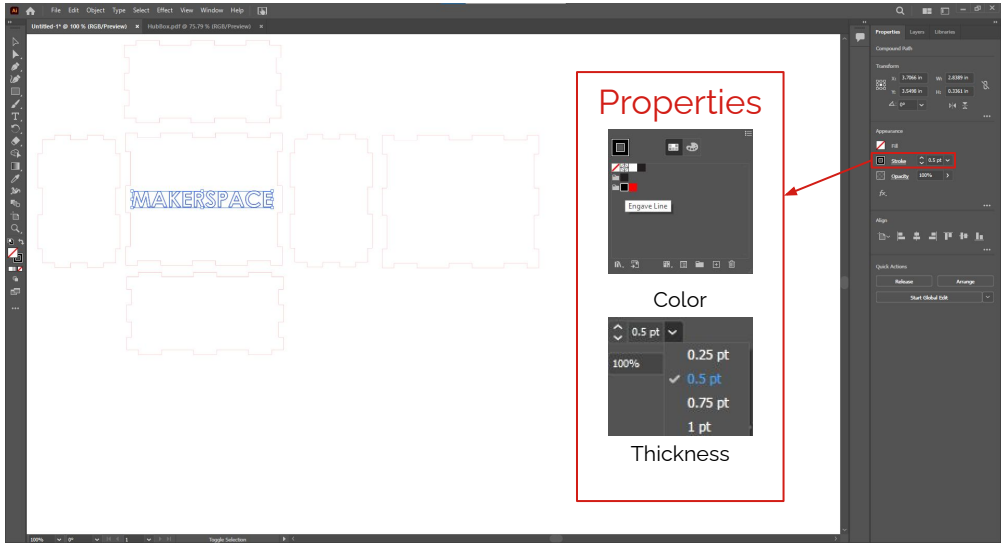


Set Cutting Lines



- Change the line color using the “stroke” tab on the "properties" window on the right.
- Lines must be RGB color **(255,0,0) Red.**
- Lines must have a thickness of **“0.001 mm”.**

Set Engraving Lines



- Engraving **lines or areas** must be RGB color **(0,0,0) Black**.
- Engraving **lines or areas** can have **any thickness**

MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

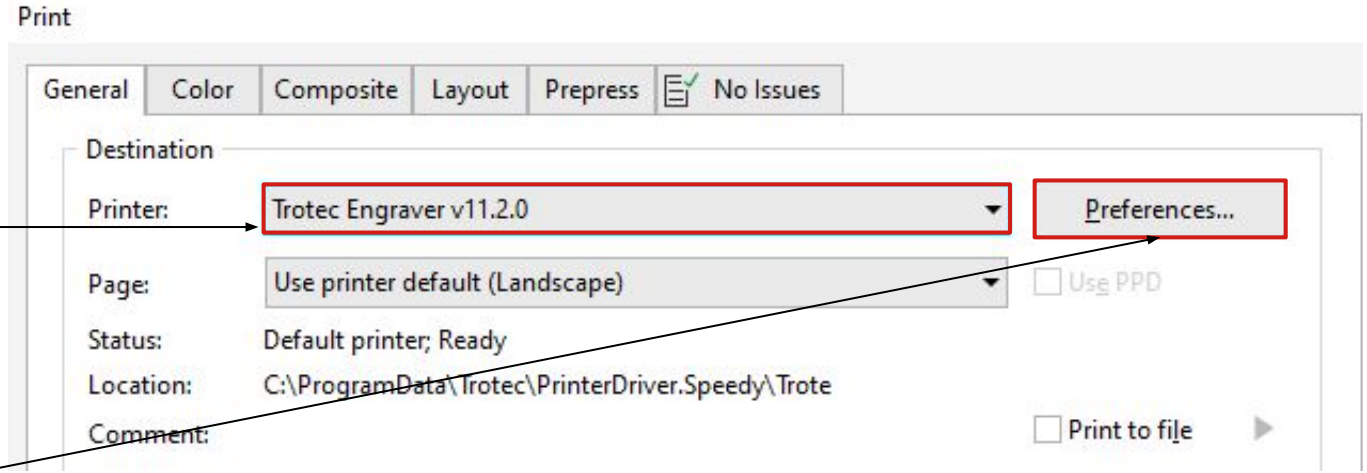
Step 3: Specify the Cut Parameters for the Machine and Material

- In CorelDRAW or Adobe Illustrator the laser cutter appears as a printer.
- To control cut parameter, settings are changed in the print dialog box.
- When finished with file prep, print the file.

Print Dialogue - CorelDRAW

Select Trotec Engraver

Then Click Preferences



- Clicking “Print” opens this dialogue box. Make sure “Trotec Engraver vXX.X.X” is selected as the printer.
- Click the “Preferences” button.

MAKE 102

1 - 2D Vector File
2 - File Prep
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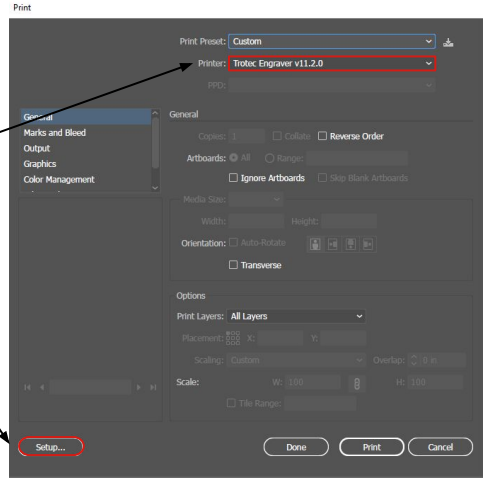
6 - Cleanup

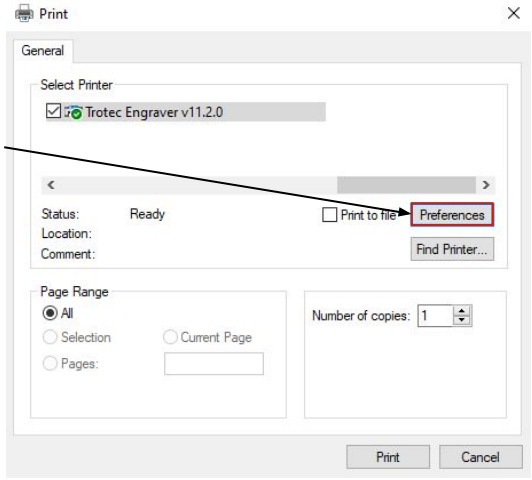
Print Dialogue - Illustrator

1. Select Trotec Engraver

2. Then click Setup



3. Click



- Clicking “Print” opens this dialogue box. Make sure “Trotec Engraver vXX.X.X” is selected as the printer.
- Click the “Setup…” button.
- From the setup dialogue box click the “Preferences” button.

MAKE 102

1 - 2D Vector File
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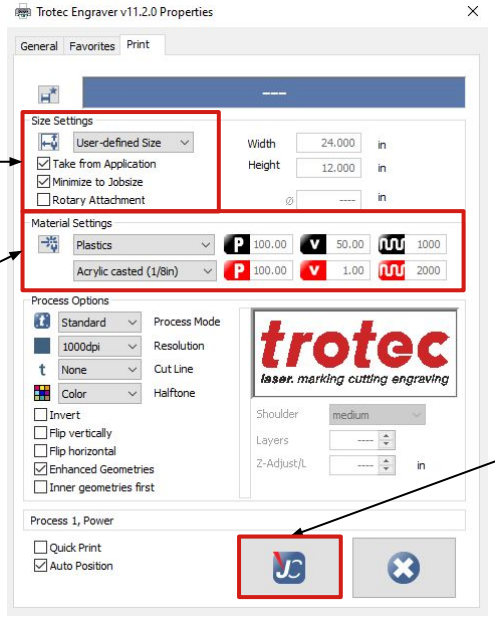
Preferences & Settings

Material type and **cutting/engraving intensity** will be set in this window

Check “Take from Application”
Check “Minimize to Jobsize”
Uncheck “Rotary Attachment”

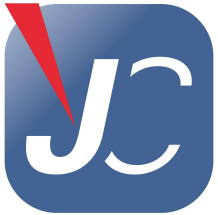
Select the material you are cutting
Keep other default settings as is



When done, click the “JC” icon at the lower right corner.

This will bring you back to the print dialog. Then click “Print”

Job Control



- After clicking **Print**, the computer will automatically open JobControl
- JobControl is the software used to configure, program, and start and stop jobs on the laser.

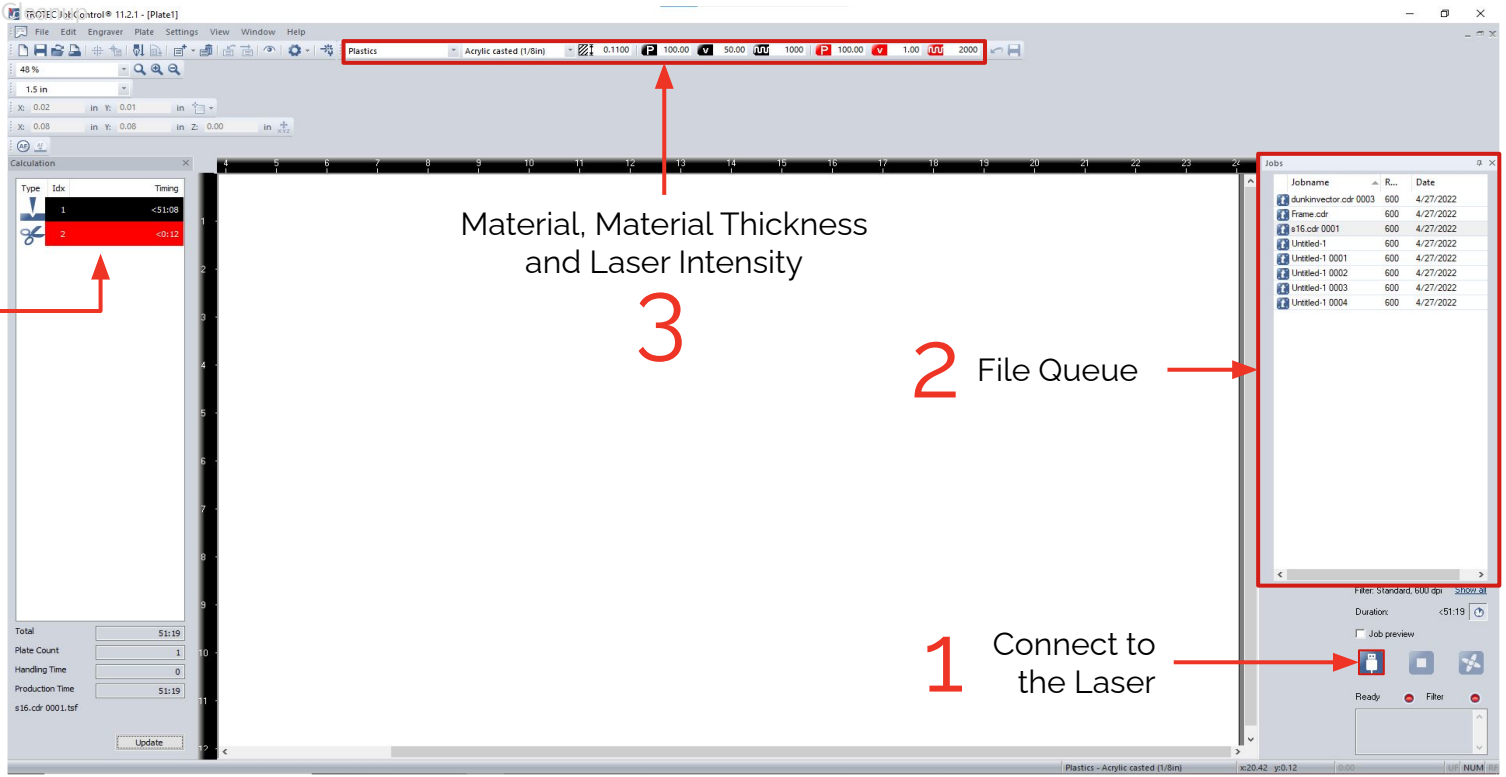
Then next step is to make sure the laser is configured correctly and that the material you intend to cut is appropriate.

Verify lens, laser type, and material compatibility.

MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - [illegible]

Job Control



MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
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5 - Cut
6 - Cleanup

Job Control

1 Connect to Laser

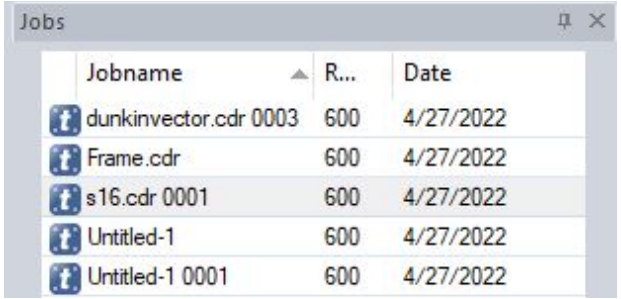
(Will alarm if not connected)

Not Connected

Connected

2 Job Queue

1. Select job from this list
2. Drag job into workspace



3 Check and adjust **material** and **material thickness**

MAKE 102

1 - 2D Vector File
2 - File Prep
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6 - Cleanup

Laser Cutter Orientation (Speedy 100)

Power Switch
(Turn off when finished)

Interlocked process chamber door
(Will abort if opened during run)

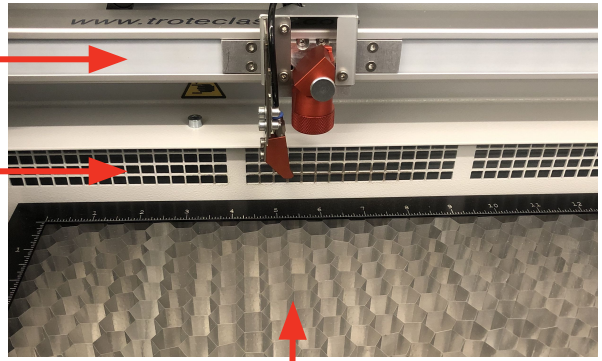
Emergency Stop

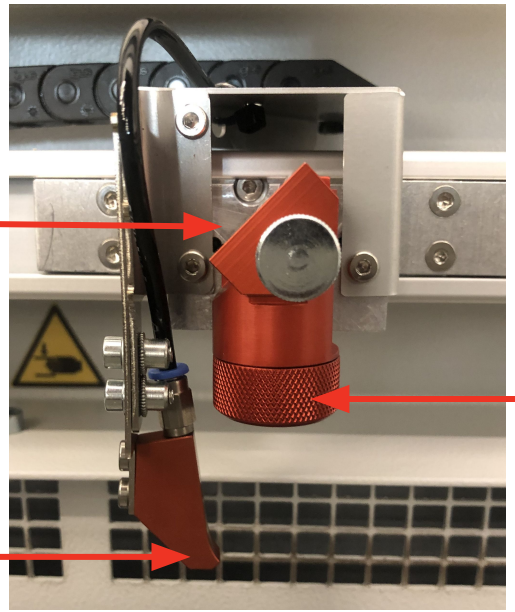
Movement Controls
Start/Stop Controls
Standby Control
(Put unit in standby when not cutting)

MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanupv

Speedy 100 - Inside Process Chamber



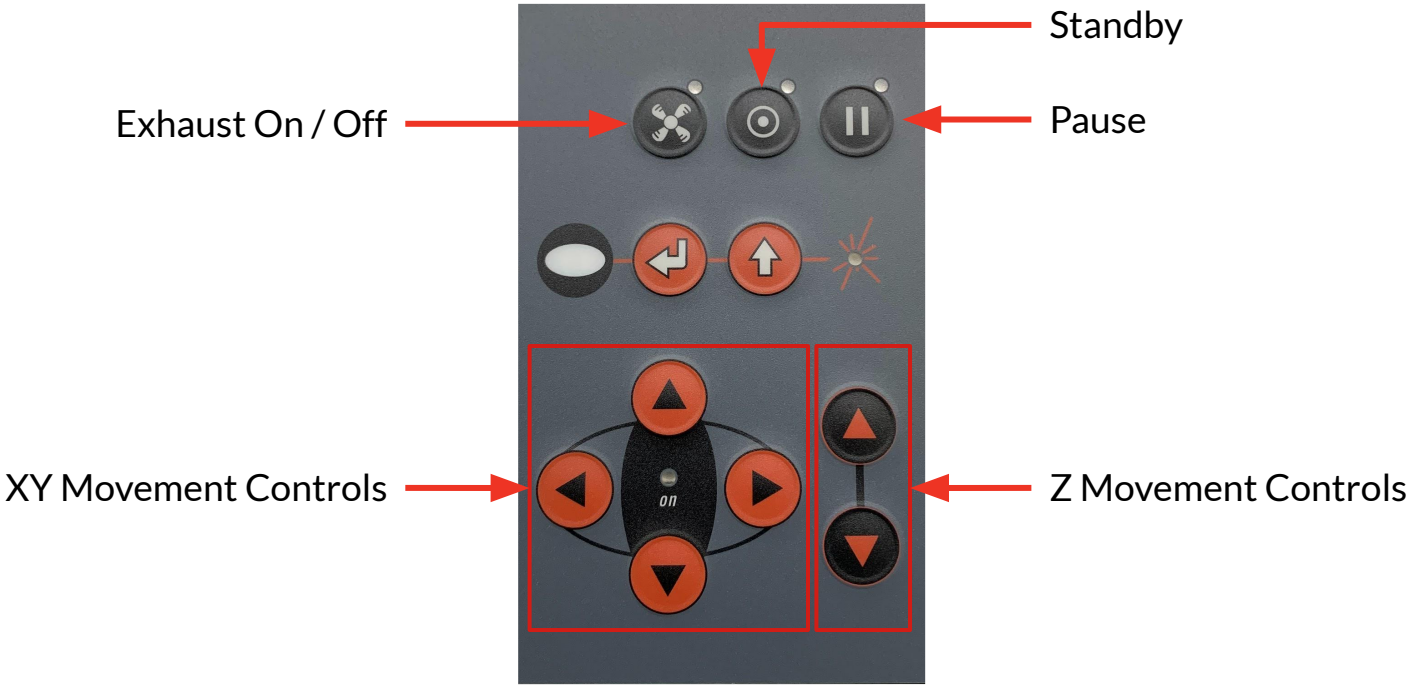


DO NOT TOUCH LENS!

MAKE 102

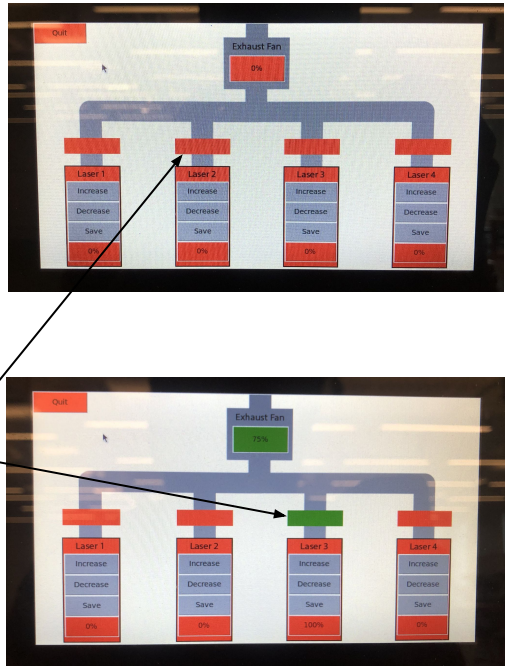
1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

Speedy 100 - Controls



Exhaust Controller

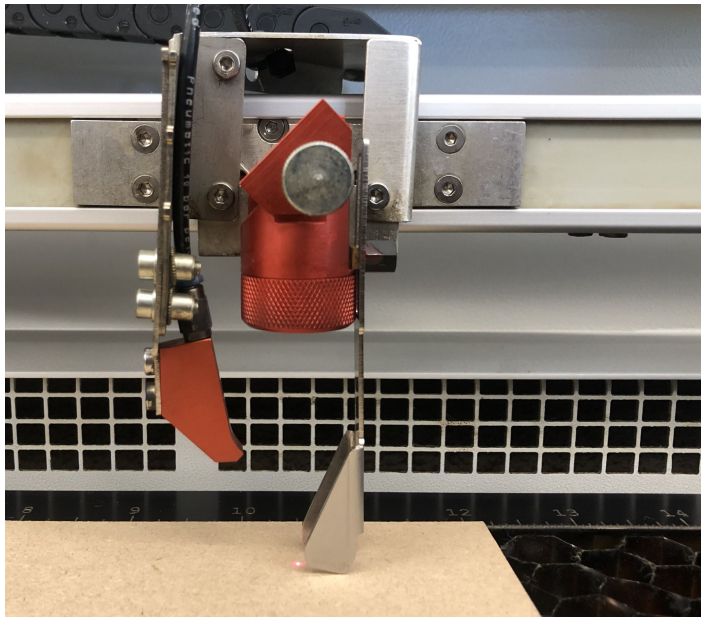
- Each laser has its own exhaust line
- A central controller monitors the laser state and turns the exhaust on when the laser requests it.
- The exhaust system should turn on **automatically,** but it is the **users responsibility** to verify that the exhaust is functioning **properly.**
- The bar is RED when the line is off and GREEN when the line is on.
- **Listen and observe**. You should see smoke actively being pulled out of the process chamber while cutting.



MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

Setting Focal Distance

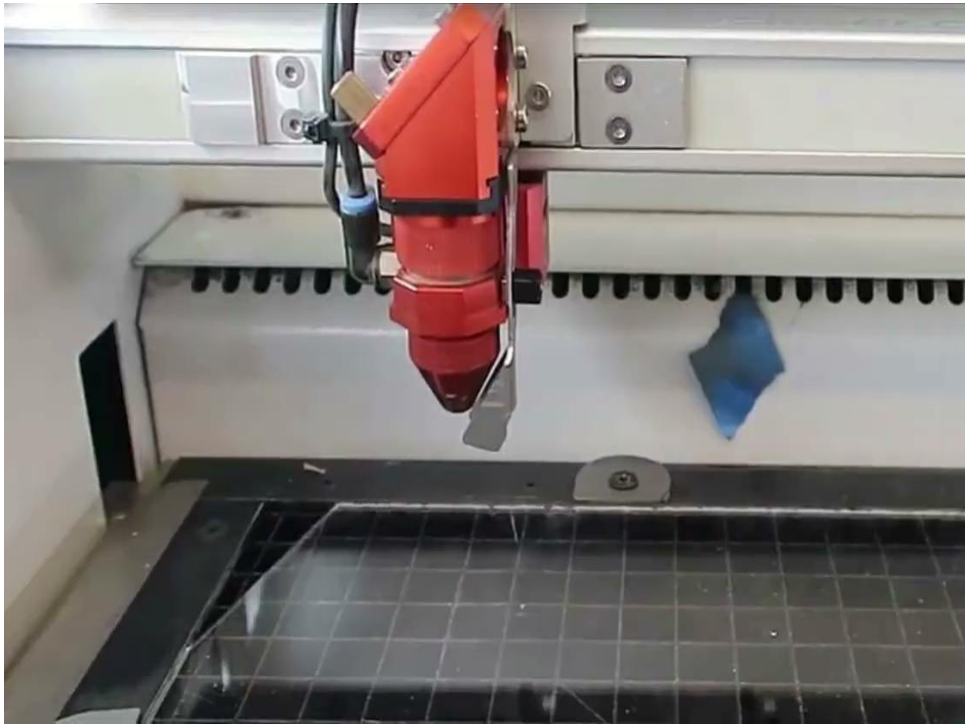


- The “focus tool” is used to set the focal distance from the lens to the workpiece and must be done for **every cut/engrave.**
- Tool is stored in the compartment on the right top of the laser
- To focus:
  - Place workpiece on the table
  - Lower table
  - Place focus tool on cutting head
  - Slowly raise table until focus tool gently falls off

MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

Setting Focal Distance

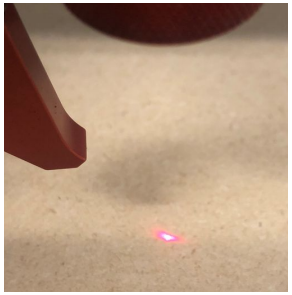


MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

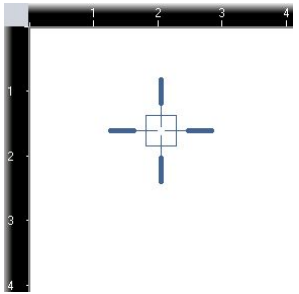
Positioning Job on Workpiece

4 Position the laser



- Use the XY move buttony to position the laser (the small red dot) where the cut or engrave should start from.

- Once JobControl is connected the a cross hairs will appear. The cross hairs are a digital representation of where laser / red dot is located in the process chamber.



MAKE 102

1 - 2D Vector File
2 - File Prep
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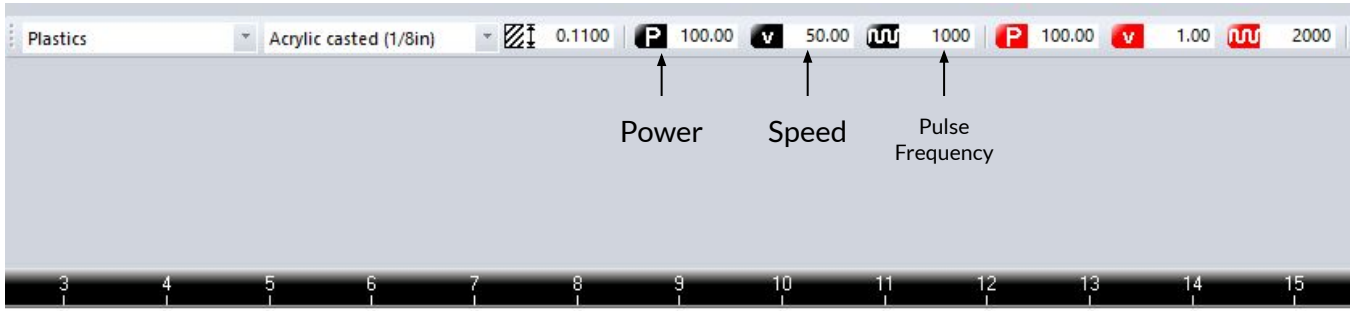
5 - Cut
6 - Cleanup

Positioning Job on Workpiece

5 Positioning File using Crosshairs

Drag your file and snap it to the laser cross hairs. Can be positioned in 5 different positions - each corner of the file to each quadrant and center to center.

Power & Speed



6

- Start with a material preset, **then** experiment with the intensity settings **as needed**
  - Increasing power or decreasing speed → cut strength **increases**
  - Increasing speed or decreasing power→ cut strength **decreases**

MAKE 102

1 - 2D Vector File
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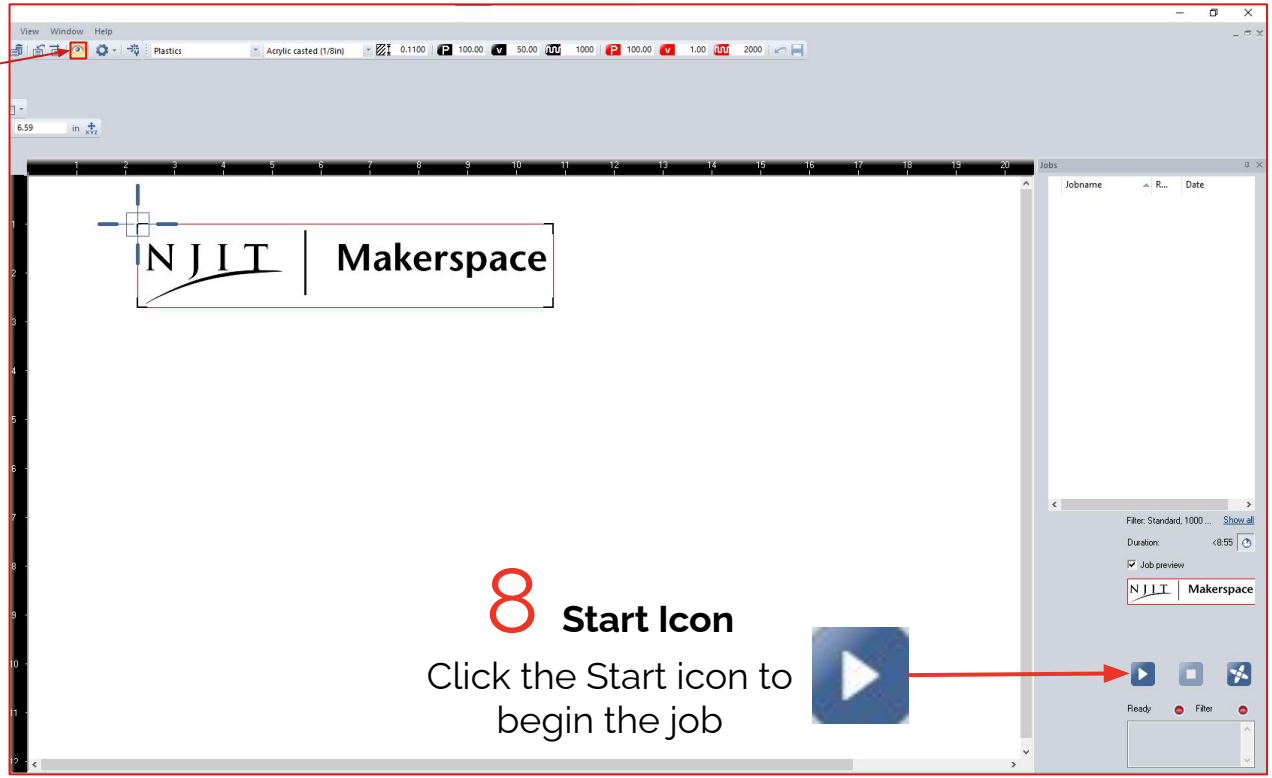
Starting Job

7 Eye Icon (WYSIWYG)

Click on the eye icon to make the file pattern visible.
(What You See Is What You Get)



8 Start Icon

Click the Start icon to begin the job

MAKE 102

1 - 2D Vector File
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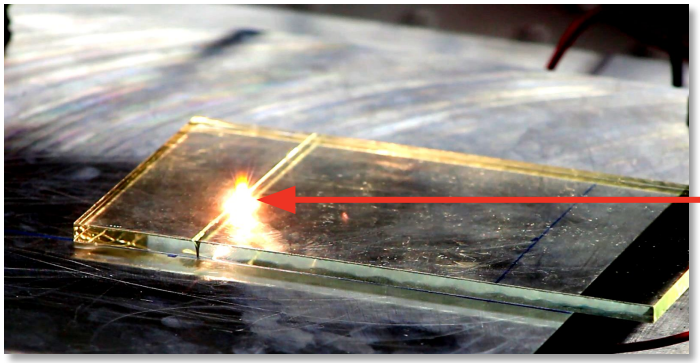
6 - Cleanup

Small Fires When Cutting



Small fire that follows the laser

- You may notice small fires or flashes on the workpiece as the laser cuts or engraves.
- This is ok as long as the fire is small and is following the laser.
- If you notice a large and consistent fire while cutting, immediately stop the job using the stop button on the laser and extinguish the fire with the water bottle (fire extinguisher if water bottle does not work).
- Check to make sure you are using an approved material and proper settings.

Smoke

- When cutting, you should be able to observe the exhaust system pulling smoke and fumes out of the laser enclosure
  - If this is not happening, **stop the laser immediately**
  - Smoke particles can cause irreparable damage to the laser lens if they deposit onto the lens while the laser is running
  - Smoke is hazardous to your health

Do Not Leave the Machine When Cutting a Job!

Even if your job is a long cut, pull up a chair and wait with the machine.

MAKE 102

1 - 2D Vector File
2 - File Prep
3 - Cut Parameters
4 - Machine Setup
5 - Cut
6 - Cleanup

Cleanup

We hope you enjoyed using the laser cutter, and ask that you leave it in a condition that lets others do the same

- You are responsible for the waste you produce
- Large sheets can be broken or laser-cut into smaller pieces for disposal or to save unused portions

MAKE
102

We look forward
to seeing your
creations!
Have Fun Making!
NJIT | Makerspace
EST. 10.24.2016