# Laser Cutting Fret Boards
## By Eddie Ufford

**Description of Activity**

- The purpose of this MLA is to transform one's digital designs and raw materials into a usable custom fret board.
- In this lesson we are going to prepare a pre-designed fret board for laser cutting.
- With this activity one needs their CADD model from the **Designing the Fret Board Shape** MLA. t Otherwise, one may download the following sample: https://www.dropbox.com/s/7hnpcfv749kx3p6/Tenor%20Fret%20Board%20Export%20to%20Laser%20Cutter.dxf?dl=0
- The while this MLA is specifically those shops, labs and classrooms that have a Rabbet Laser USA Cutter/Engraver http://www.rabbitlaserusa.com/ and LaserCut 5.3 control software. One can adapt this lesson to match up with other laser cutters and control software.
- To a lesser extent one can also use this lesson without a laser cutter. That is, being the Demo Version of Laser Cut 5.3, it can be downloaded and installed. This allows one to prep their project in advance. However, to complete this project, one will need to be at the laser cutter. The software's full functionality is limited to the laser-connected PC.
- Students will make vital measurements from the "freshly" lasered fret board and make necessary design changes.
- This lesson is geared towards middle and high school computer aided design & drafting (CADD) students.

**Learning Objectives:**

**(List measurable objectives)**

1. Students will import and export design files from one CAD program to another.
2. Students will use Layers to define the laser's speed and power settings.
3. Students will use precise scaling methods to accurately resize their designs.
4. Students will be able to convert inches to millimeters and vice versa.
5. Students will save designs to a laser cutter/engraver.
6. Students set the origin and focal height for their laser project.
7. Students will identify materials that can and can't be cut with our laser cutter.
8. Students will be able to explain the difference between laser vectors and rasters.

## Standards:

CCSS.Math.Content.HSG.MG.A.1
Use geometric shapes, their measures, and their properties to describe objects.
CCSS.Math.Content.HSG.MG.A.2
Apply concepts of density based on area and volume in modeling situations.
CSS.Math.Content.HSG.MG.A.3
Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost;…)
CCSS.Math.Content.HSN-Q.A.1
Use measurement units as a way to understand problems and to guide the solution of multi-step problems
CCSS.Math.Content.HSN-Q.A.3
Choose a level of accuracy appropriate to limitations on measurement when reporting quantities
CCSS.Math.Content.7.G.B.6
Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.
CCSS.ELA-Literacy.RST.9-10.9
Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.
S7.A.2.2 Select and safely use appropriate tools and describe the information provided by each tool.
S7.A.2.2.1 Describe the safe and appropriate use of instruments and scales to accurately and safely make measurements under a variety of conditions.
S7.A.2.2.2 Apply measurement systems to record and interpret observations under a variety of conditions
S3.4.6.B4 Demonstrate how new technologies are developed based on people's needs, wants, values, and/ or interests.
S3.4.6.E6 Identify key aspects of manufacturing systems that use mechanical processes to change the form of natural materials (e.g., separating, forming, combining, and conditioning).
S3.4.8.E6 Analyze the steps involved in the manufacturing process (e.g., design, development, production, marketing and servicing of products and systems).
3.2.7.B.1 Measure materials using a variety of scales.
CTE.ED.C.C5.2 Know the various object-altering techniques.
CTE.ED.C.C3.1 Know how the various measurement systems are used in engineering drawings.
CTE.ED.C.C5.1 Understand the commands and concepts necessary for editing engineering drawings.
CTE.ED.C.C3.2 Understand the degree of accuracy necessary for engineering design.
CTE.ED.C.C5.3 Know the CADD components and the operational functions of CADD systems.
CTE.ED.C.C5.4 Apply two-dimensional and three-dimensional CADD operations in creating working and pictorial drawings, notes, and notations.

## Materials Required:

- A computer with CAD software such as Rhino, Fusion 360, AutoCAD, Solidworks, etc…
- Digital Calibers
- Laser Cutter/Engraver
- Low cost Wooden Fret Board blank for laser cutter.

## Safety:

- Review safe handling of equipment and tools as needed.
- Review Laser Safety

## References:

- Install LaserCut 5.3 Demo http://wiki.makeitlabs.com/training/laser/lasercut53personal
- Scale Length Explained by STEWMAC https://www.stewmac.com/How-To/Online_Resources/Learn_About_Guitar_and_Instrument_Fretting_and_Fretw/Scale_Length_Explained.html
-

## Activity:

- The students will import their fret board design created in MLAs 1 & 2.
- The students will convert or rescale their CADD design from inches to millimeters if necessary.
- The students will prepare the laser cutter for laser cutting their fret board.
- The students set the job origin from which to start the laser
- The students will set the power and cut speed for the laser cutter.
- The students will use layers to separate different power and speeds setting for desired cut depth.
- The students will use calibers to measure the laser beam kerf width and record this measurement.
- The students will make laser beam kerf compensations to their CADD designed fret board.
- The students will use measurement tools to validate the accuracy of the laser cut fret board and make necessary adjustments.

## Synopsis

This is not meant to be one's first introduction to our CO2 Laser cutters, the Laser Cut 5.3 control software nor the laser cutting/engraving process. By the time my students are ready to design and manufacture a guitar or ukulele fret boards they will have built other projects that require use the laser cutters. One should have a working knowledge to perform basic tasks such as generating simple text with Laser Cut's 5.3 software, making simple edits, manipulating layers, setting the power and speed, transferring the job to the laser cutter, focusing and setting the job origin. In the following MLA step-by-step guide we will be briefly give a refresher on how these basic tasks are done. The end goal is to allow one to quickly transform their digital designs into a real usable parts. For this MLA, the part is a laser cut fret board.

It is vital that laser cutting is strictly limited to only materials known to be safe. At no time is anyone allowed to laser cut polyvinyl chloride (PVC) or anything that that contains chlorine. Polyvinyl chloride (PVC) can be deadly when cut with the laser cutter. The thermal process generates hydro-chloric acid and toxic fumes. It is both highly caustic to the machine parts and deadly for living organisms; e.g., humans and animals. For this reason and to ensure the safety of everyone in the lab, no one is ever allowed to cut PVC. Check with your instructor before laser cutting any material.

Our lasers are capable of two fundaments modes of operations, **Cutting** and **Engraving.** Cutting encompasses the laser focal head following vectors; which are defined here as drawn lines and curves. Engraving scans or sweeps in-between closed-looped vectors and monochrome (2-bit) bitmap images.

Engraving works much like a dot-matrix printer by shooting individual dots row after row to for a matrix. Closed–looped vectors are superior to bitmap images as they can employ both **Cutting** and **Engraving** modes. Whereas bitmap images are limited to engraving only. To get the best of both worlds, one should convert their images to vectors. Freeware programs like Inkscape https://inkscape.org/ or tools inside of paid programs such as Vectric's Aspire and V-Crave software that can accomplish this in only a few clicks. Then export the vectors into a .DXF file format. Raster to vector conversion will be touched on in the future MLA- Custom Fret Board Inlays.

With CO2 lasers one is able to cut or engrave a vast array of approved materials such as: Bamboo, jade, marble, glass, crystal, plastic, garments, paper, leather, rubber, ceramic, hard woods, MDF, plywood, Plexiglas, some plastics, acrylic, and other non-metal materials. However, one can also fake-engrave or fused bond printing onto metals with the use of an additive laser marking material like "Cermark" and "TherMark". The metal is not etched, engraved or removed. But when the dried spray additive is struck with the laser beam, a thermo-chemical reaction occurs, creating a fused bond that results in a colored mark on the metal's surface. Somewhat similar to how laser printers bond the toner particles to paper.

Our Digital Design and Fabrication lab at Hanford High has two Rabbit Laser cutters, model RL-80-1290, from Rabbit Laser USA. Both laser have 80 watt laser tubes and have usable beds of 1200 x 900 mm (47.2 x 35.4 inches). In addition, the newer one has an auto-focus pressure foot, while the older one use manual focusing by raising of lowering the motorized bed.

These C02 laser equipped machines are fundamentally a two-dimensional cutting and engraving tool. An extremely intense focused beam of infrared laser light moves via a computer-controlled X-Y gantry system to trace or "burn" curves and lines onto one's material. The laser beam is automatically switched on and off at the start and end of each curve, dot and/or line by the control software. The CO2 laser tube is housed at the back of the machine. Three specialized mirrors bounce the beam of infrared light into the moving focal head, down through the focus lens and finally onto your material. Anywhere the X-Y gantry can traverse, is a place one can laser cut and engrave. Multiple jobs of the same thickness can be placed on the table at one time; but it is best to do one job at a time.

The term "L.A.S.E.R." stemmed from the acronym "Light Amplification by Stimulated Emission of Radiation". In basic terms, materials struck by the laser beam get "obliterated" e.g., burnt and/or melted. The laser cutting and engraving processes hinges on intensive and pin-pointed heat generated from a reaction of the given material absorbing the redirected light energy. Accordingly, laser cutting is attained by burning lines (vectors) or tiny dots (rasters) onto various materials. Concerning out fret board design activity, only vectors will be used.

## Pre-Laser Cut Actives

- To start, one needs to export their CADD designs from MLA #2 as .DXF. One should rearrange the layers into two groups:
  - 1st Layer is cut all the way through.
  - 2nd Layer is laser marking.

- It is also recommended that one prints out a dimensioned drawing of your fret board. You will need to make vital measurements after your fret board is lasered out. One will check the accuracy, in addition to making laser beam kerf compensations if needed.
- The width of the fret board starts off as a blank rectangle but is then transformed into a **double-tapered trapezoidal shape** with lines to indicate where the fret wires are placed. Record the following from you CAD file

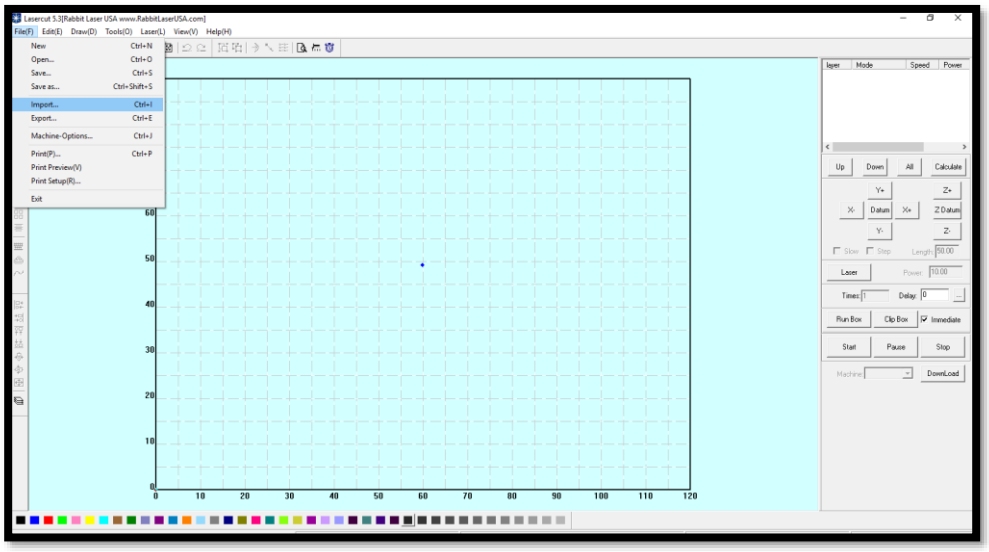
  - Overall Length _____ and width_____
  - Overall Width a fret zero/nut _____,
  - Width at 12th fret_____
  - Width at last fret_____
  - *Optional – laser beam kerf width_____

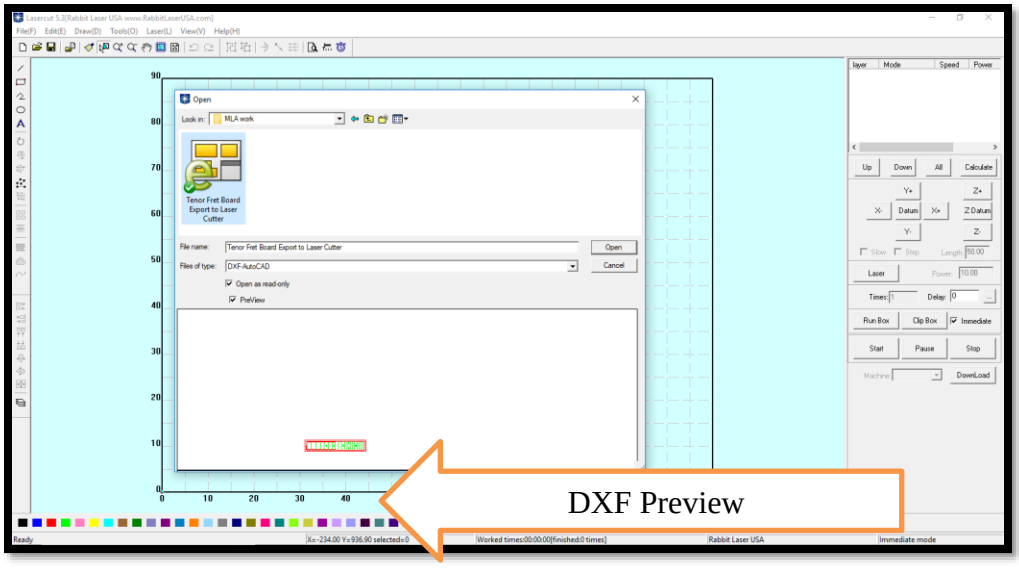
## Laser Setup Activities

1. Launch Laser Cut 5.3

2. Import your .DXF fret board design

- An exported CAD file with the .DXF file extension is a universal file format developed by Autodesk, the makers of AutoCAD. It is meant to be standardized way to exchange graphic files between various CAD software.
- With Laser Cut 5.3 the .DXF is the universal format for storing CAD models that requires one to use the Import command vs. Open.
- If this is the first time working on with your CAD file with Laser Cut 5.3, then you need to use the Import command. After you have saved your progress from Laser Cut 5.3 in the .ECP file format, then you will use the Open command.
- Click on File drop down menu, followed by Import and navigate to your .DXF location.

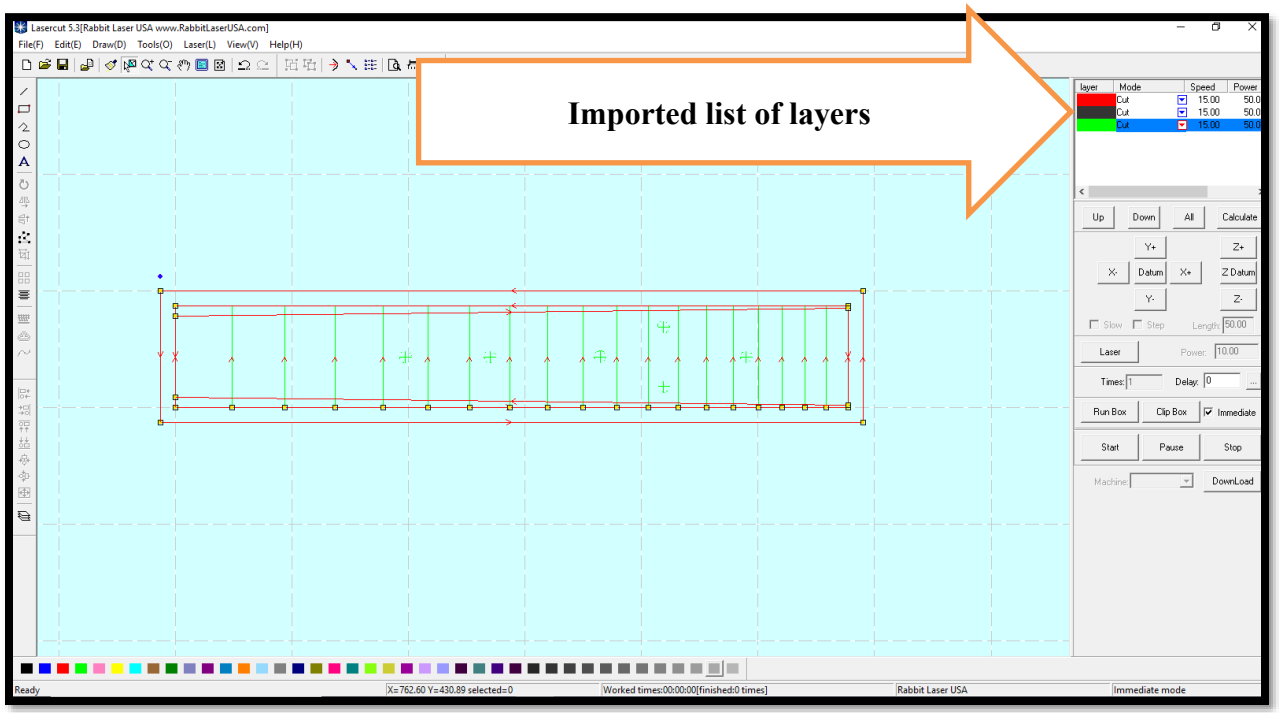




- Select your .DXF file and you should see a small preview of it in the preview window

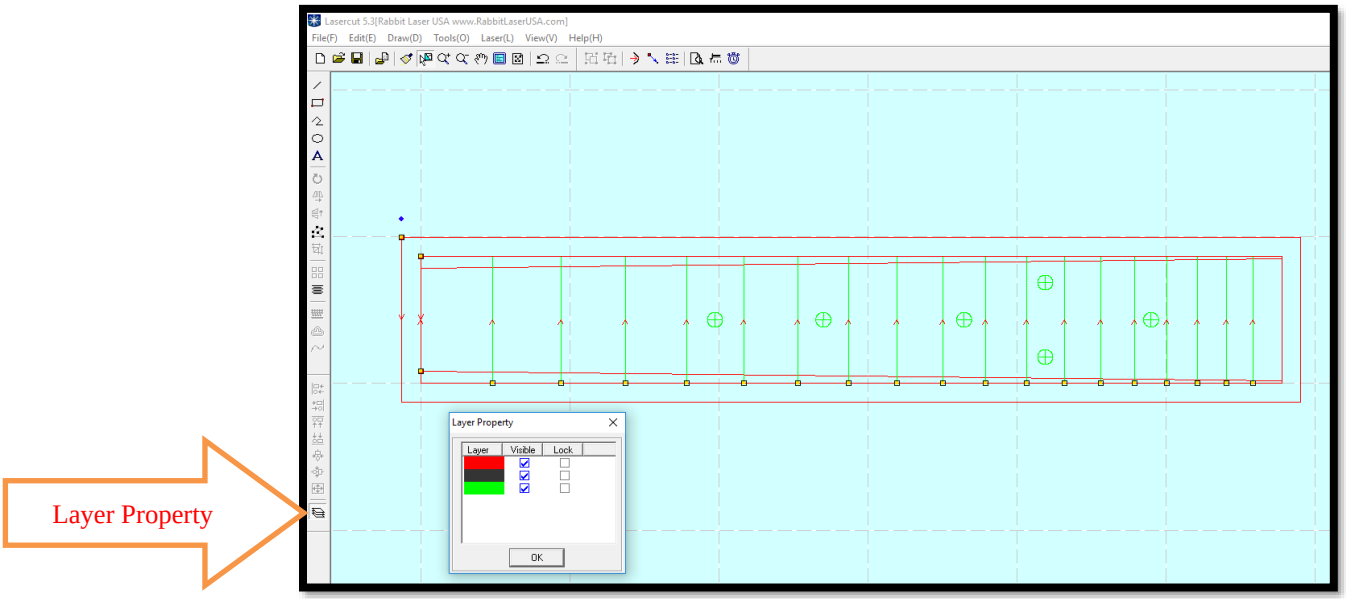
3. Re-Scale -- if needed
   - When importing .DXF files from other programs that where drawn in inches, one may need to convert the measurements to millimeters.
   - Select all the vectors that were imported, then use the Size feature and multiple the X and Y values by 25.4. This will convert the inch units into millimeters and correctly resize your work.
   - For reference, each grid space display in Laser Cut 5.3 is 50mm or approximately 2". Thus, if you know your fret board is 12" in length, one will be able to count over 6 grid spaces.

4. When your fret board is imported notice on the upper right hand corner of the screen that it found three layers. But when we exported it we only had two.
   - The Red layer was designated to be the cut through layer.
   - The Green layer was designated for laser marking layer.
   - The Black Layer, but there should be anything on this layer. It appears a very small vector, dot or line fragment was exported into our .DXF file. We will need to resolve this issue before we continue. If not, then it may cause unwanted laser marks or cut on our fret board. Plus, it also could through off the start point for the laser cut job.

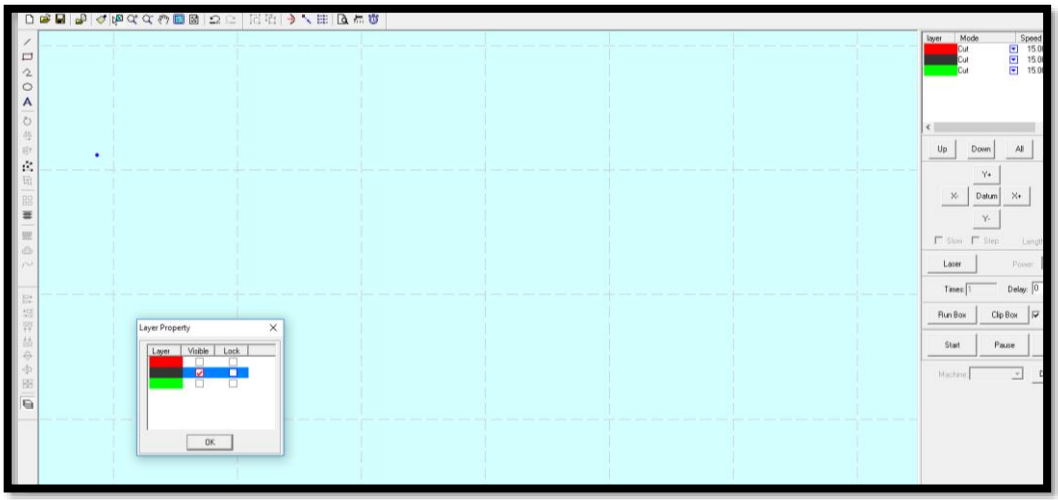


5. Click on Layer Property

- Layer Property is located on the left-hand side near the bottom of the quick pick tools.
- Click on the Layer Property button in the lower right-hand corner and one will see all available layers with vectors or data on them.
- We are going to turn off the Red and Green layers to isolate the black layer.

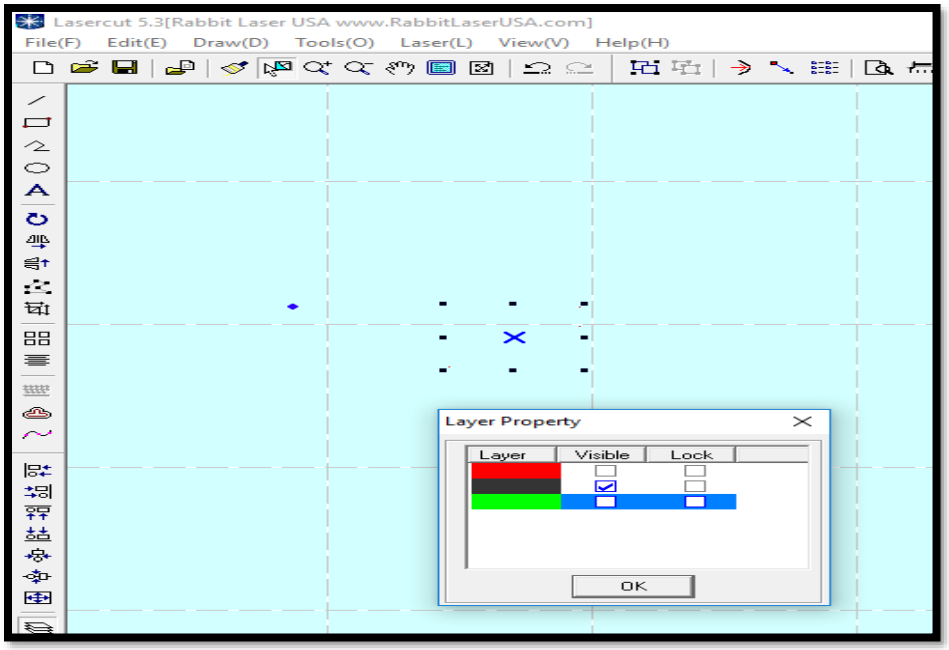



- In Layer Property uncheck the needed “Visible” boxes in to isolate the black layer. See below.
- Notice it looks as if that all vectors have disappeared. But there remains a tiny black dot or vector.

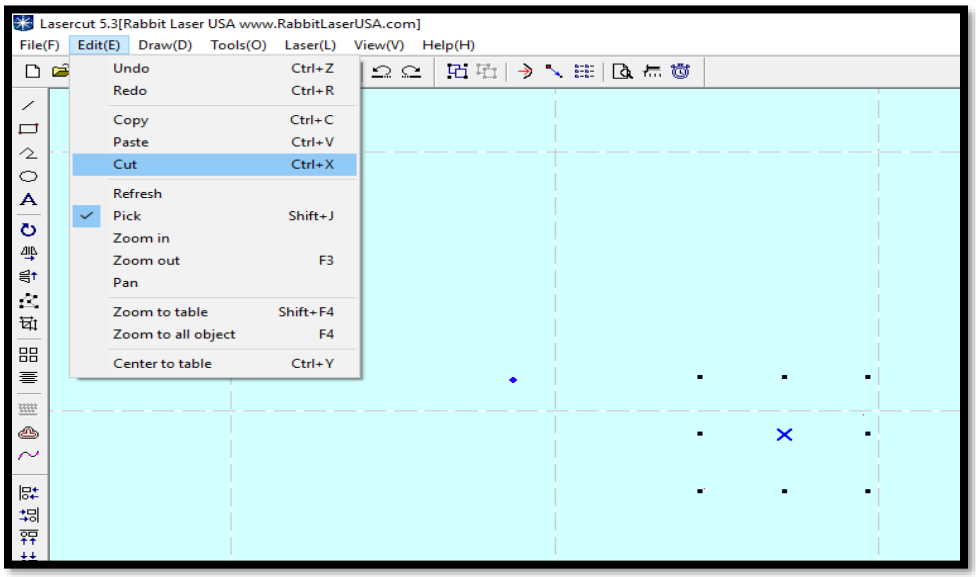


## 6. Remove the Lone Vector

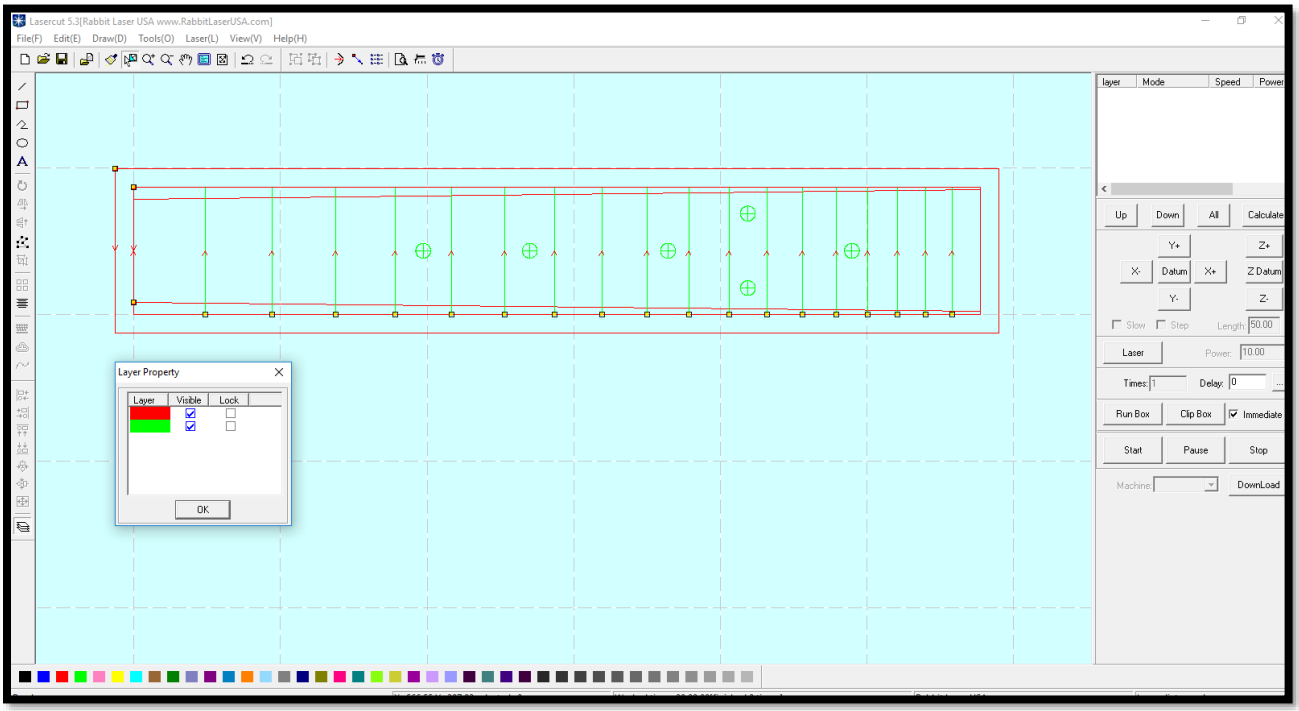
- To remove the lone vector one can find and select it by one of two methods:
- The 1st use the Pick Tool and dragging a large window around the screen.
- If the Pick tool finds anything, it will show up with a blue X and eight tiny dots around the mysterious vector. To remove it, press delete key on the keyboard



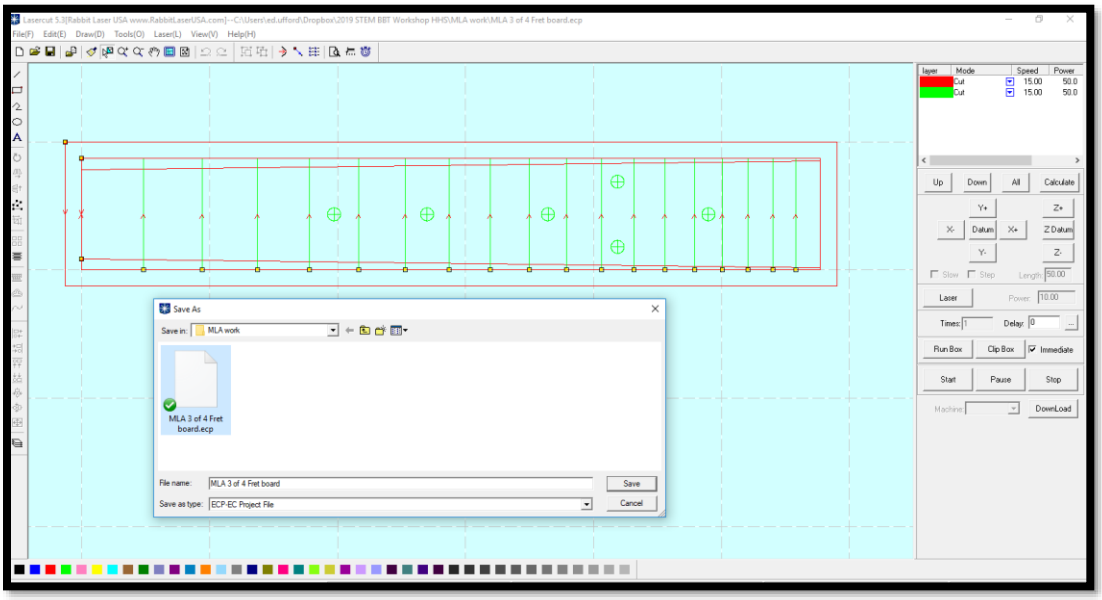

- The 2nd method is to use the Edit pull down menu, and Cut, followed by pressing the Enter key on the keyboard.



7. Reset the Red and Green Layers to visible. Go to Layer Property and check the visible boxes.

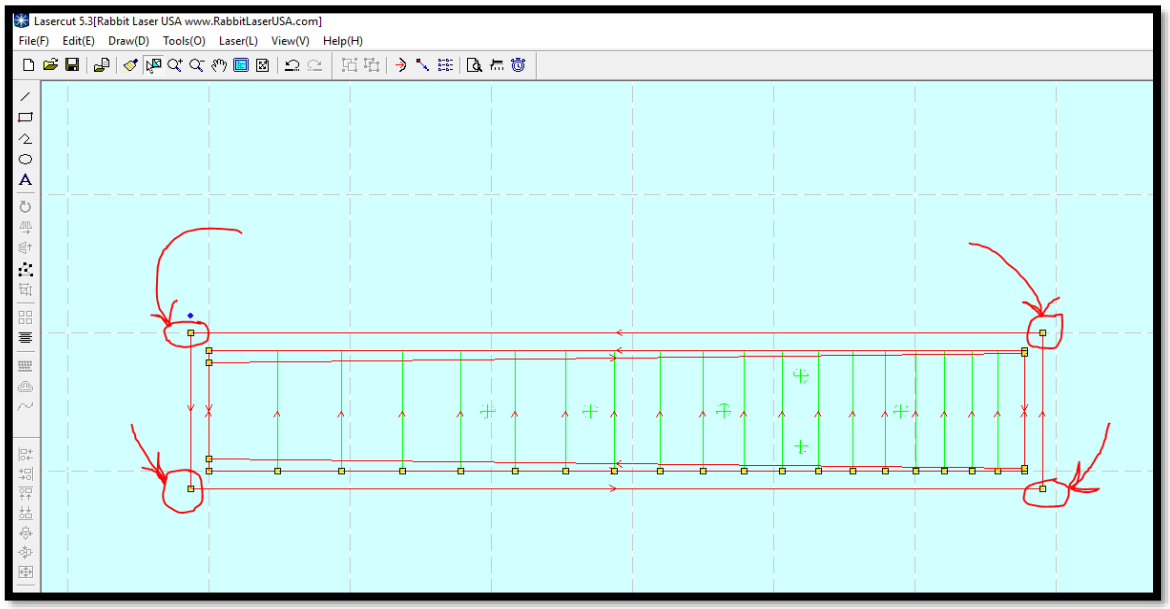



8. Now would be a good time to **Save** your work. Click on the **File** drop down menu and then **Save As**, give it a proper name and select a proper place to save it.

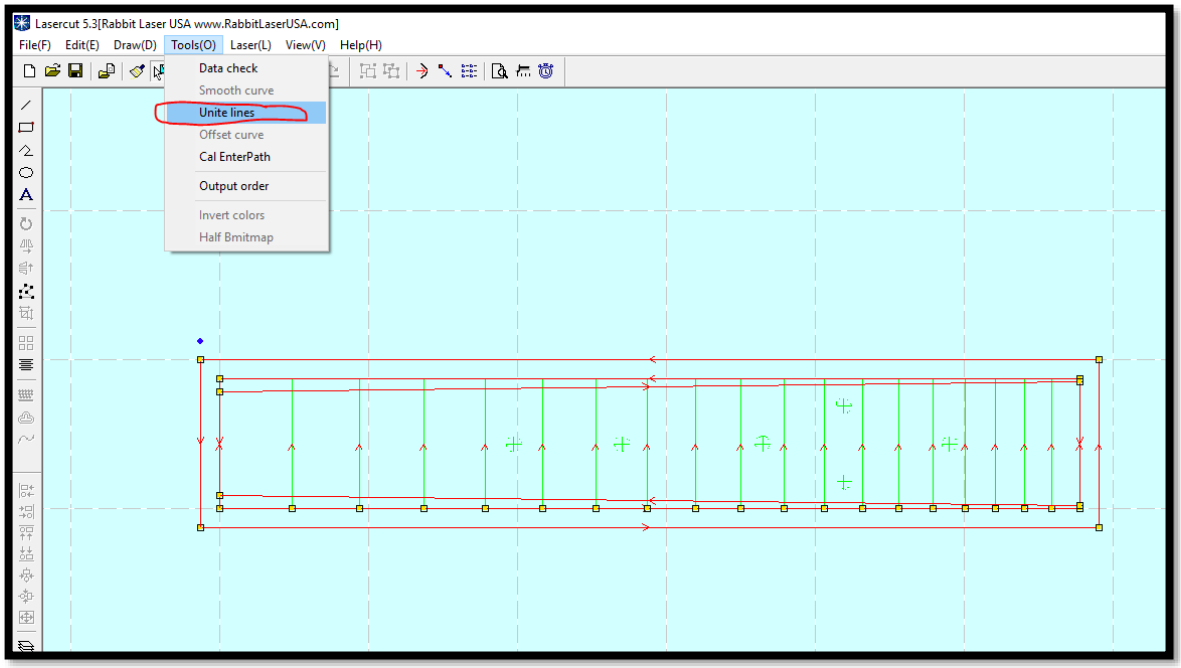


## 9. Another issue we need to correct is rejoining all the necessary lines.

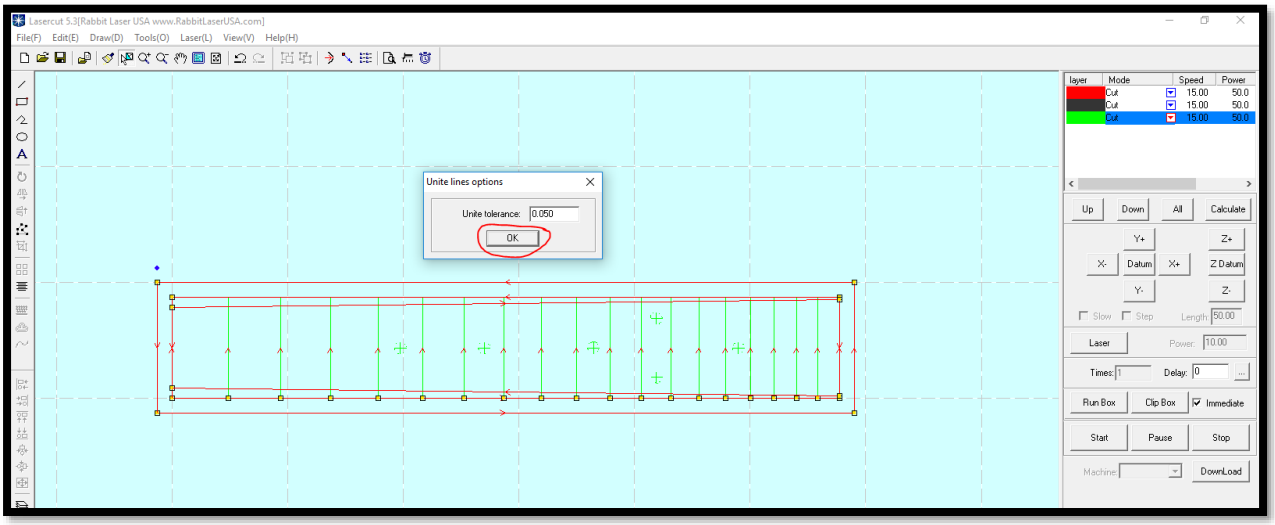
- Notice the on the red rectangles below have multiple yellow corner dots. These for rectangle that represents four single lines instead of one joined rectangle.
- It also means the laser must start and stop four different times instead of making one start and stop.
- Rejoining the lines will yield a more efficient laser cutting and engraving job.
- If this is a properly joined rectangle there should only be one yellow corner dot. During the import process the joined line segments became fractured. See image below:



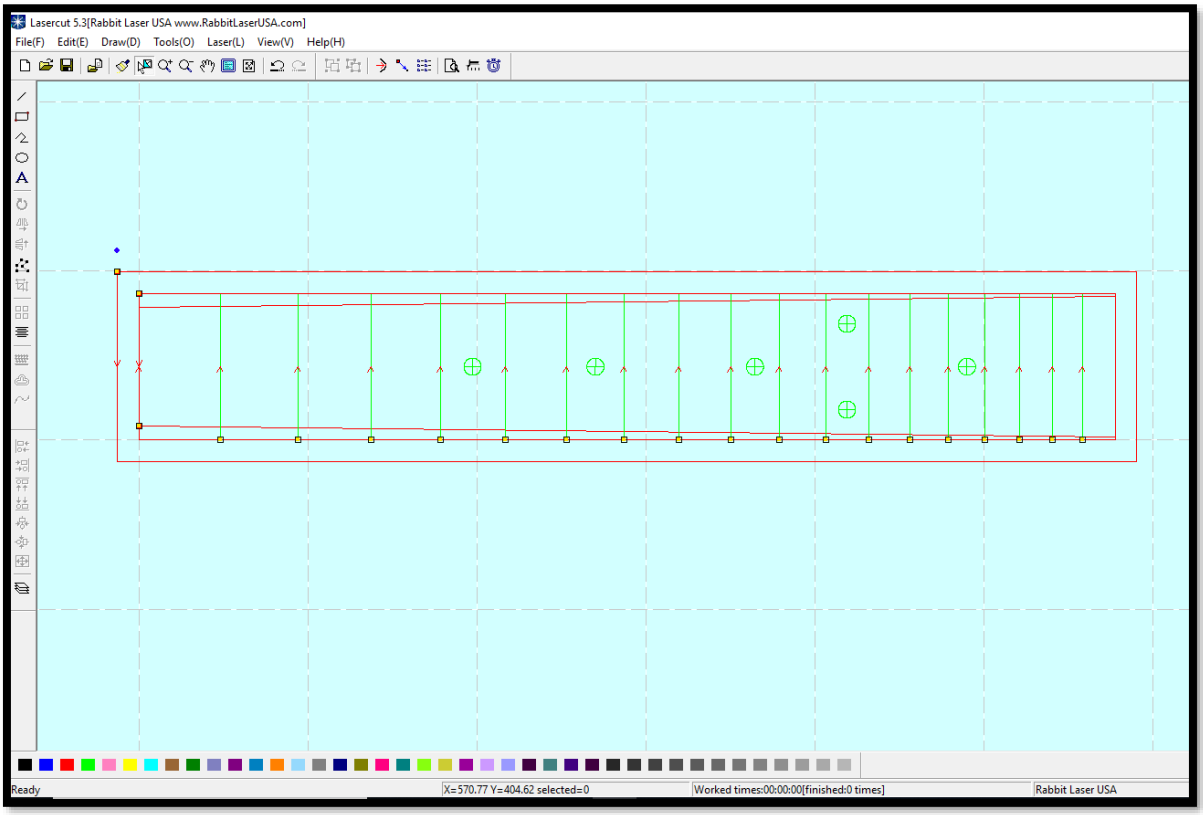

- To correct this issue click on the Tools pull-down menu and select Unite Lines.



- The Unite lines options will appear and ask for the Unite Tolerance setting. Leave it at the default setting and click OK.

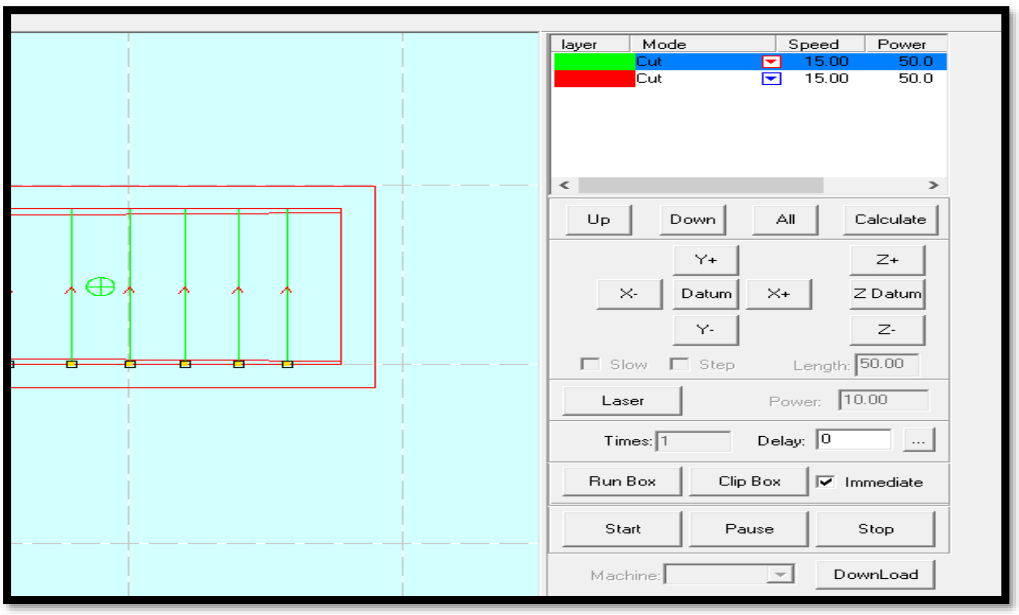



- This will rejoin all fractured lines.
- Notice there is only one yellow dot for each of the red rectangles in the image below.
- The rectangles are now considered a **closed-loop** and **water-tight**.
- Closed-loop and water-tight vectors can be both laser-cut and laser engraved.
- For future reference, all vectors must be closed-loop and water-tight for inlay work.

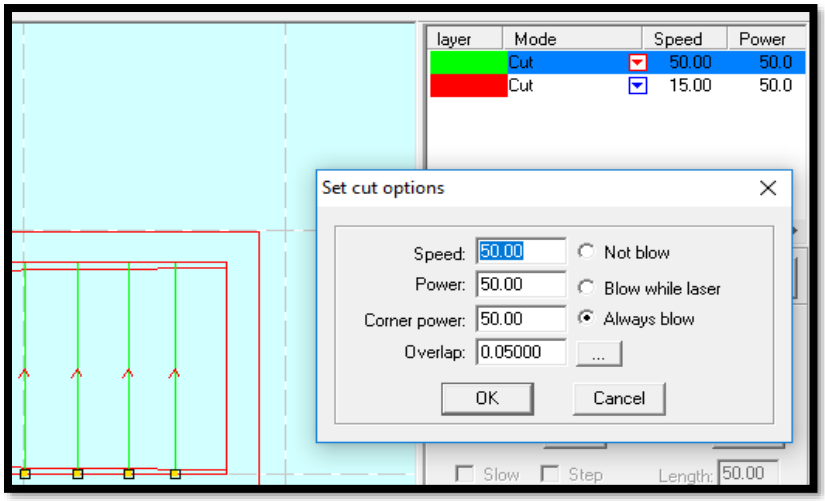


## 10. We are ready to set the laser's mode of operation which includes Speed and Power

- Notice in the upper right-hand corner. This is where one can access and change the laser cutter modes of operation, the speed and power for each layer.
- Currently both the Green and Red layers are set to the same speed and power.
- For or design we originally designated the Green layer for laser marking. Laser marking requires a higher speed and lower power. Remember it is not our goal to have the laser cut completely through the material; but halfway would be fine for the fret wire lines.
- For laser marking in **Cut Mode**, one needs to set a high Speed and low Power.
- In cut mode the maximum **speed** and **power** settings are 100.

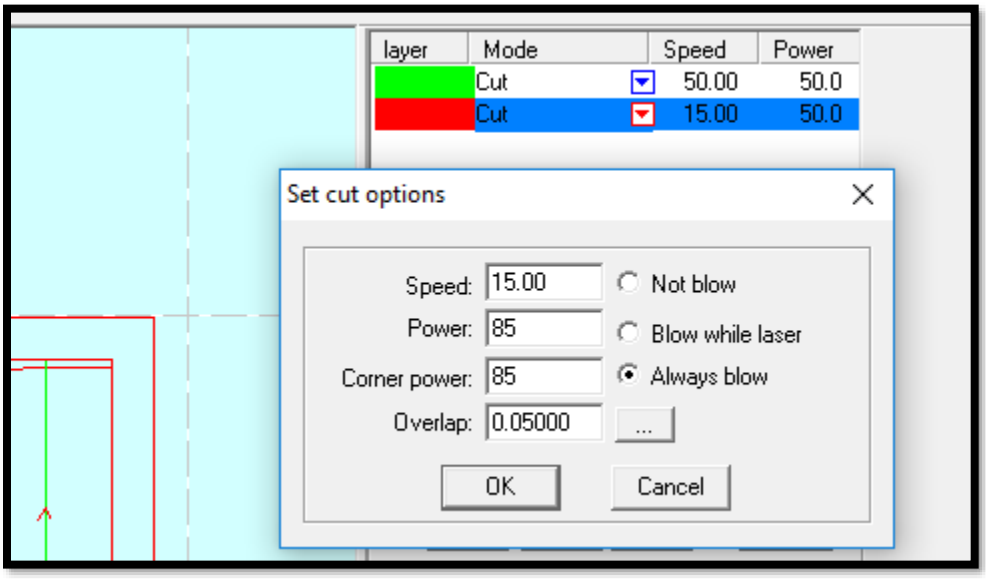



- By double clicking on the specific layer's speed, the software will pop up with the Set Cut Options dialog box. From there reset the Speed 50 and Power 50. See screen shot below.



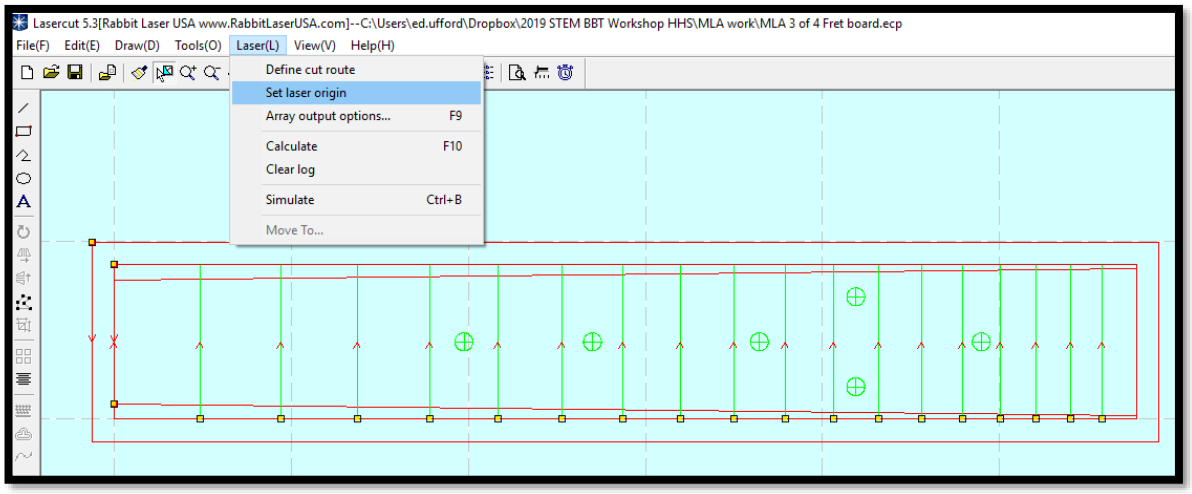
## 11. Set the Laser's speed and power for the Red (cut all the way through) layer.

- For cutting all the way through with the Red layer, one needs a low speed and higher power.
- In this example Speed will be set to 15 and Power will be reset to 85. See example below. Click OK when done.



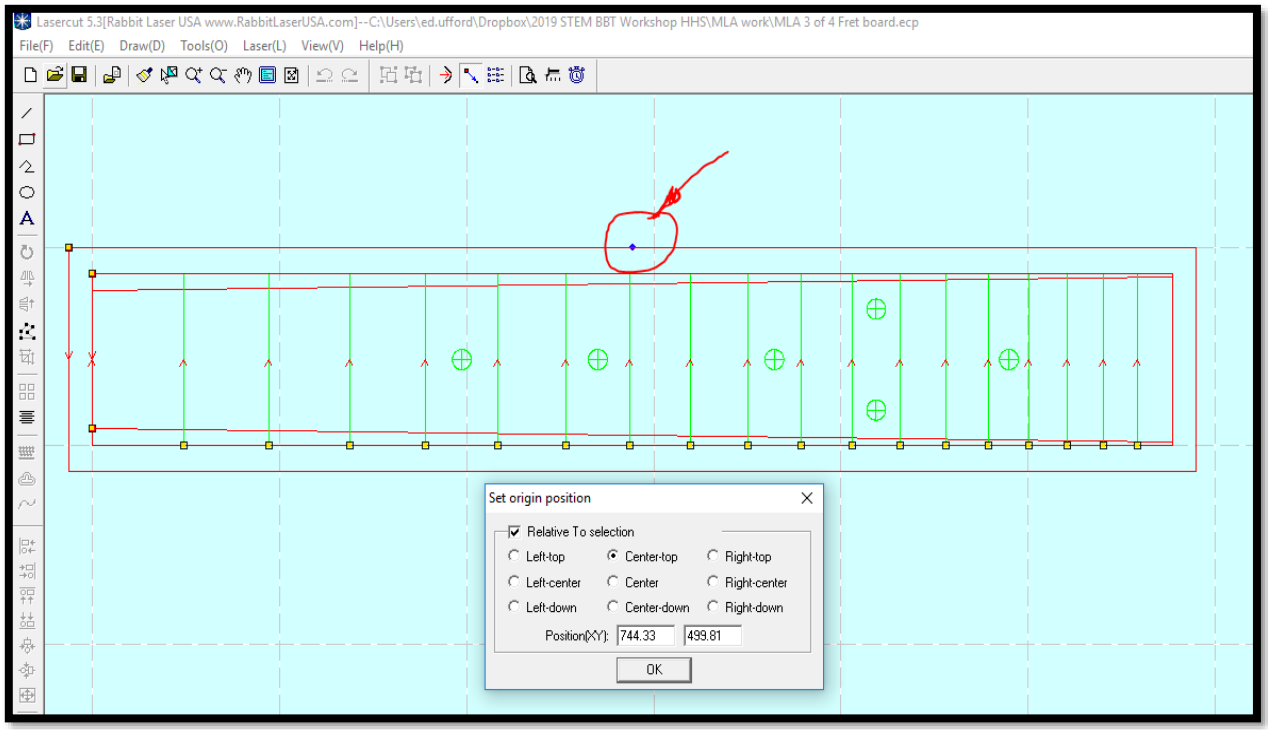
## 12. Set the Laser Origin

- Next we need to tell the laser where to set itself in relationship to the job.
- Click on the Laser pull down menu




- We have nine different spots to select from:
  - Left Top Center Top Right Top
  - Left Center Center Right Center
  - Left Down Center Down Right Down

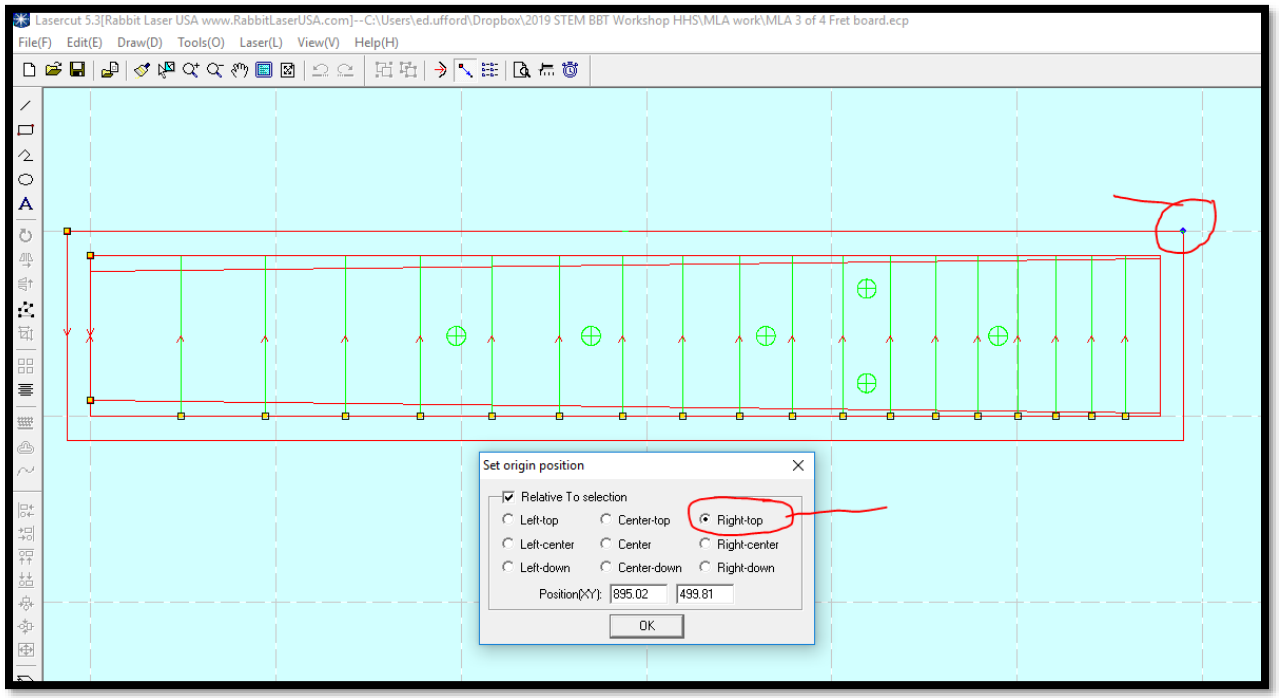
- Notice the tiny blue dot at the top center. Currently, this defines where the laser has set to be as its origin. See the image below.



13. Manually set the XY origin.

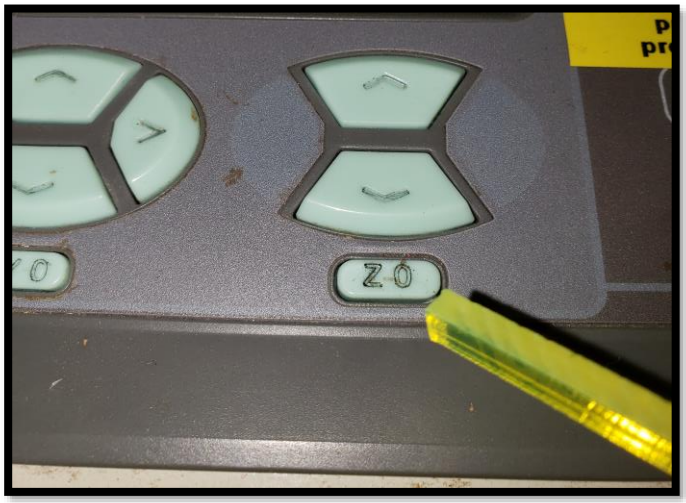
In this screen shot notice how we moved the XY origin to the upper right-hand corner.

- Again, notice where the blue origin dot has moved to.
- Manually move your material to align it to the new XY origin.
- It is vital that one reposition the laser's focal head over this point.

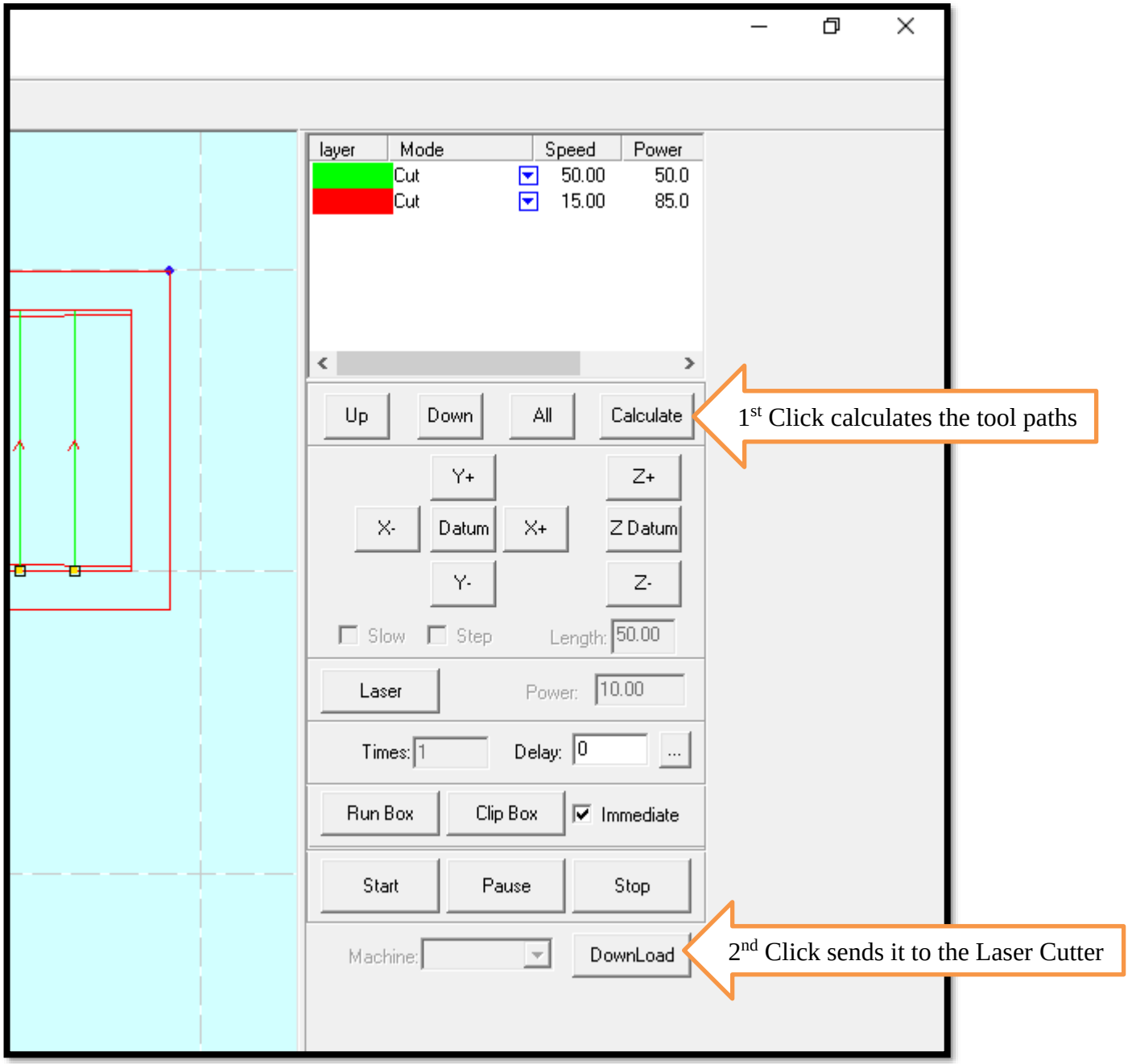



## 14. Set the Z focus height.

- With the X Y origin set in the previous step, set the Z origin or focus height.
- Ensure the focal foot is over the material and press Z0 on the laser's control panel.
- This will run an auto focus program.

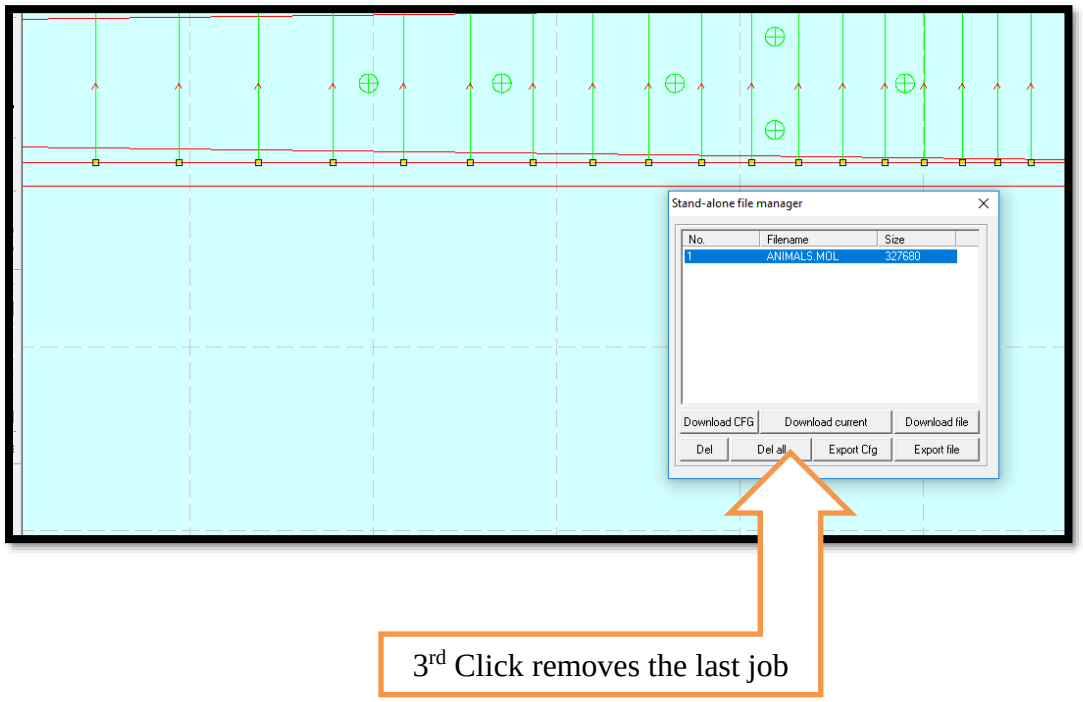


15. **Time to calculate the tool paths and send that information to the laser. See Below.**



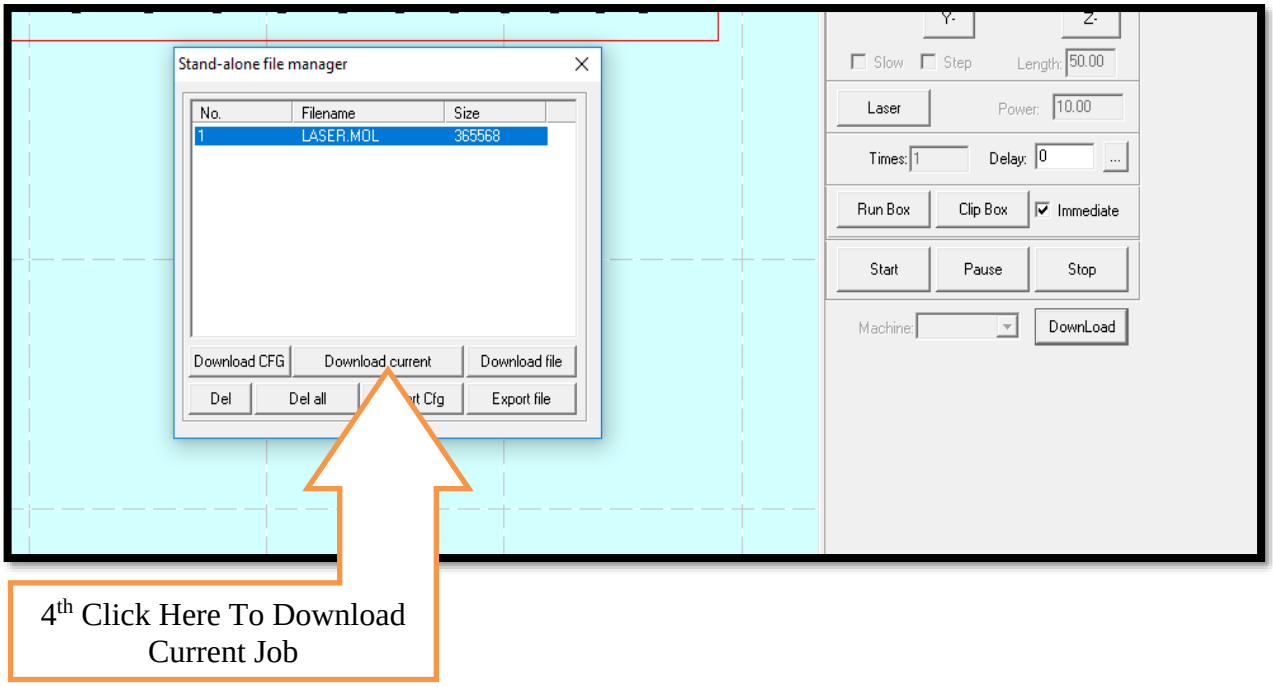
## 16. Delete the Old Job and Replace with the new.

- Click Del All to remove the last Laser job.

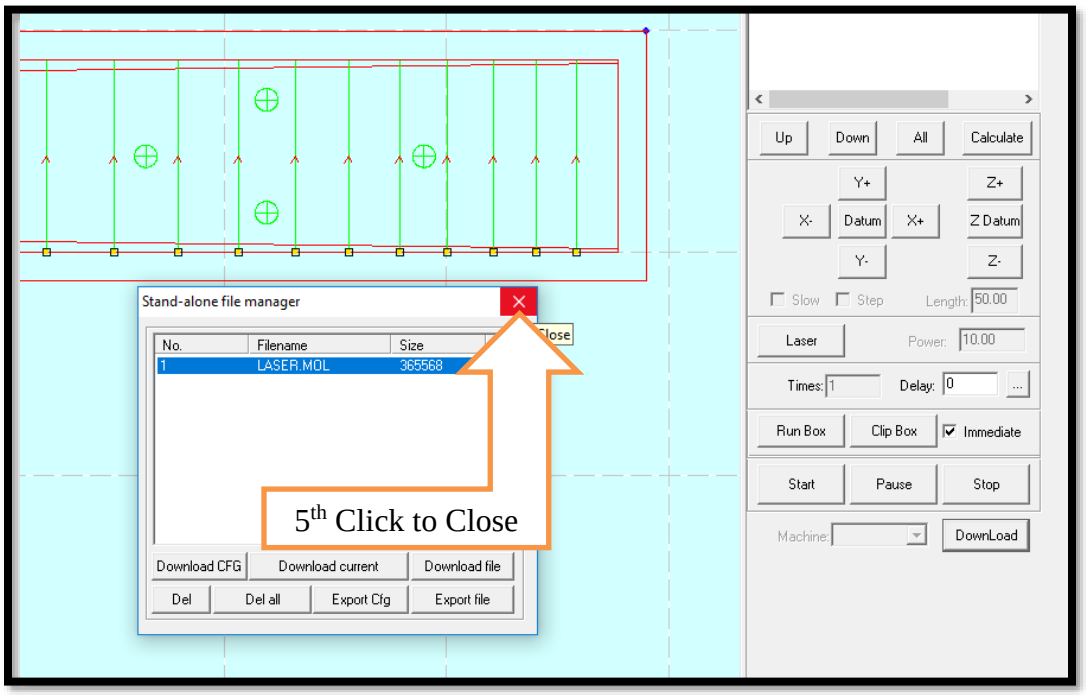



## 17. Download your current Fret Board job

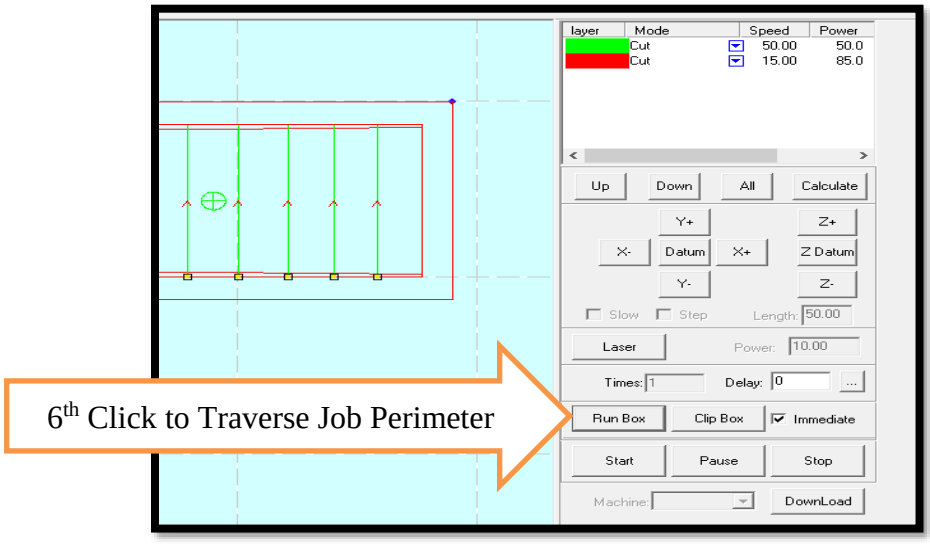
- Click on Download Current



18. Close down the Stand-alone file manger
    - ☛ Click the X to close down the stand alone-file manager.

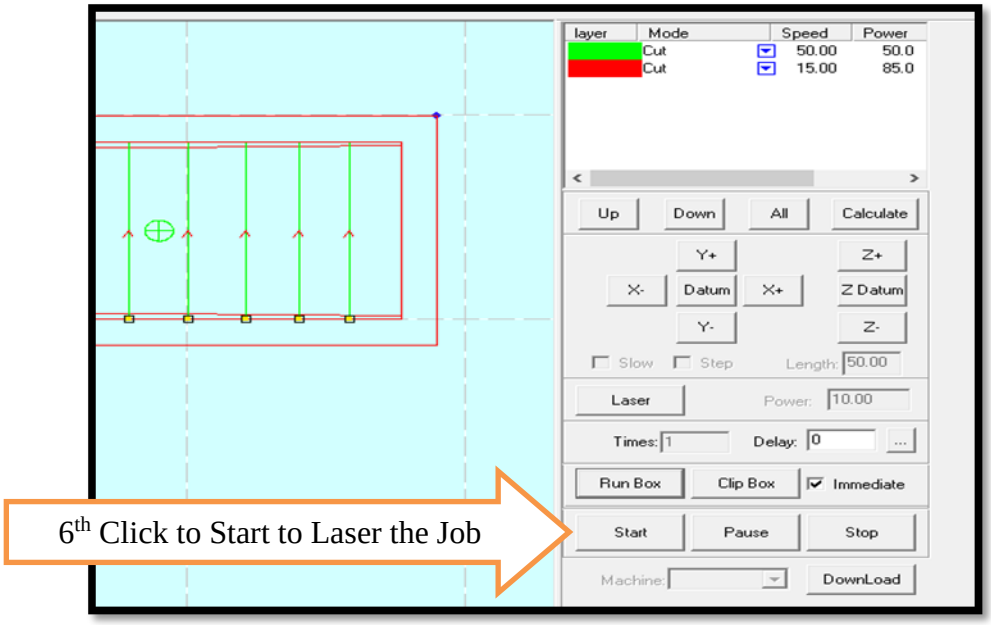



19. Click on Run-Box to see the perimeter of the laser job
    - ☛ The laser cut will traverse the perimeter of the current job by clicking on Run Box.
    - ☛ Reposition the laser according to your material and current laser job needs.



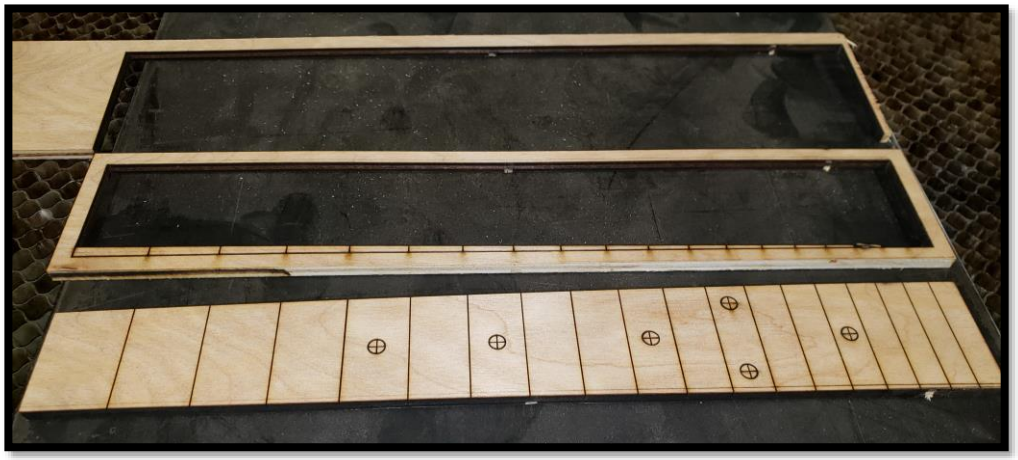
20. Laser Time

- ☛ If the RUNBOX is successful, then click Start.



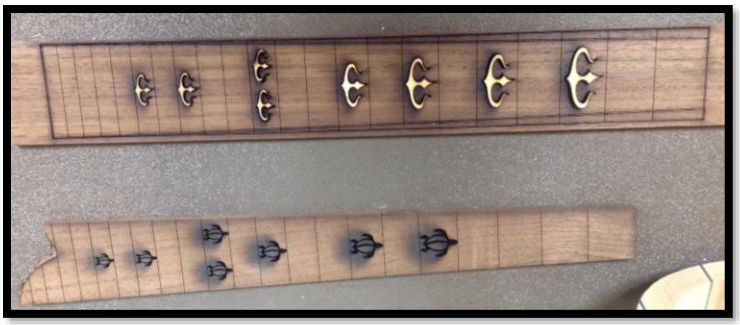

21. Laser Time

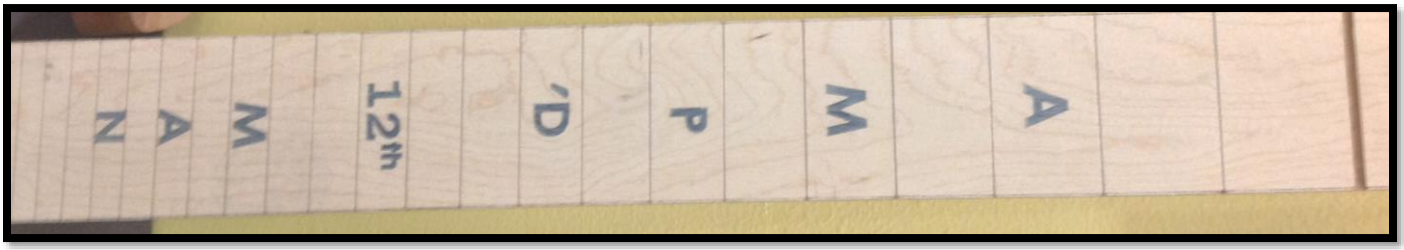
- ☛ Examine your results and then make critical measurements.
- ☛ If the measurements are within the needed tolerance, then you may proceed to post processing your laser fret board
- ☛ If you measurements are off, then go back and make the needed changes.



22. Next Up

- In a follow up MLA we will replace the standard .25” dot makers with custom inlay work.
- For inlay work one will need to convert your rastered bitmap images into vectors.





**Quiz:**

**Circle the Best Answer**

1. What does the acronym LASER stem from?
   - Light Action Saber Equipment Rebel
   - Luke Aaron Skywalker Ewok Repealer
   - Light Amplification by Stimulated Emission of Radiation
   - Light Application by Stimulated Embankments of Radiation

2. What file type does our laser cutter need export from your CADD designs?
   - .DWG
   - .RHL
   - .DXF
   - .STL

3. What best describes Vectors?
   - Dots
   - Lines
   - Curves
   - All the above.

4. What best describes raster images?
   - Made from hundreds to thousands of tiny individual dots
   - Closed-Loop Vectors
   - Open-Ended Vectors
   - None of the above.

5. What is PVC?
   - Polyvinyl chloride
   - Plastic Volume Container.
   - Plastic Vinyl Cup
   - None of the above

6. Products like CenMark and TherMark allows one to engrave or etch metal with a CO2 laser?
   - Yes
   - No

7. CO2 Lasers bonce their infrared beams off of:
   - X-Y Gantry systems
   - Specialized Mirrors
   - Focal lens
   - Your eyes

8. The X – Y Gantry system is responsible for:
    - The two frets farthest apart
    - Moving the laser's focal head to various locations around the worktable or laser's bed
    - Keeping the laser's mirrors in a static location
    - Absorbing the energy of the laser beam

9. Closed–looped vectors are superior as they can employ both _____ **&** _____ mode**.**
    - Skip Dotting
    - Cutting
    - Engraving
    - Z-Perforations

10. What type of images are needed for laser engraving?
    - 2-bit bitmaps .BMP
    - 16-bit bitmaps. .BMP
    - 24-bitmaps .BMP
    - 16 Million Color bitmaps .BMP

## Answer Key

1. What does the acronym LASER stem from?
    - Light Action Saber Equipment Rebel
    - Luke Aaron Skywalker Ewok Repealer
    - Light Amplification by Stimulated Emission of Radiation
    - Light Application by Stimulated Embankments of Radiation

2. What file type does our laser cutter need export from your CADD designs?
    - .DWG
    - .RHL
    - .DXF
    - .STL

3. What best describes Vectors?
    - Dots
    - Lines
    - Curves
    - All the above.

4. What best describes raster images?
    - Made from a matrix of hundreds to thousands of tiny individual dots
    - Closed-Loop Vectors
    - Open-Ended Vectors
    - None of the above.



5. What is PVC material?
   - Polyvinyl chloride
   - Plastic Volume Container.
   - Plastic Vinyl Cup
   - None of the above

6. Products like CenMark and TherMark allows one to engrave or etch metal with a CO2 laser?
   - Yes
   - No ---These produce allow for thermo-fused printing. No metal is remove.

7. CO2 Lasers bonce their infrared beams off of:
   - X-Y Gantry systems
   - Specialized Mirrors
   - Focal lens
   - Your eyes

8. The X – Y Gantry system is responsible for:
   - The two frets farthest apart
   - Moving the laser's focal head to various locations around the worktable or laser's bed
   - Keeping the laser's mirrors in a static location
   - Absorbing the energy of the laser beam

9. Closed–looped vectors are superior as they can employ both _____ **&** _____ mode**.**
   - Skip Dotting
   - Cutting
   - Engraving
   - Z-Perforations

11. What type of images are needed for laser engraving?
   - 2-bit bitmaps .BMP
   - 16-bit bitmaps. .BMP
   - 24-bitmaps .BMP
   - 16 Million Color bitmaps .BMP

**Reviewing Faculty Cohort Members:**

Allen Androkites
Alex Moll
Matt Peitzman