Week 1 - Introduction to Lasers

A laser cutter and a laser engraving machine are the same machine, but with different power capacities. In this course we will be learning on the Ortur Laser Master 2 Pro - a popular diode based laser, and the Omni 1390 CO_2 based laser, a more industrial laser with greater power, and a focussed laser.

Both machines have their strengths and weaknesses. In many ways they operate very similarly, and skills developed on one can translate very well to the other.

Similarities:

- Both are CNC (computer numerical control machines)
- Make use of stepper motors and belt drives for movement in X,Y,Z axis
- Have similar maintenance routines in terms of adjusting belt tension and squaring the bed
- Both use Gcode to control the X,Y travel of the laser head (and this code can be streamed from computer)
- Both require focussing in the z plane for optimal cutting/engraving

Differences:

- The laser on the Ortur has a maximum output power of 5 watts, compared to 110 watts on the Omni (be aware that this is a curved power chart, so 110 watts while significantly more is not 20x stronger than the 5 watts)
- The Omni laser requires more complex focussing due to the 3-mirror system used to direct the laser beam, and the use of focussing lenses
- The focus point of the diode laser is rectangular, compared to the round focus point of the CO_2 laser
- Exhaust created on the Omni is generally higher than the Ortur
- The Omni is much bigger and not portable
- The controller on the diode laser is GRBL with trinamic motor controllers. On the OMNI, DSP controllers from Ruida are used
- The CO_2 laser requires constant liquid-based cooling during operation
- The CO_2 laser uses air-assist to extinguish flames that may spring up due to the higher power (the diode laser has built-in smoke detection and deals with flames by stopping the laser)

Comparison:

Omni 1390	**Ortur Laser Master**
110 Watt	5 Watt
CO_2 laser	Diode laser
600 mm/s (36Kmm/min) speed	50 mm/s (3Kmm/min) speed
Blade Worktable	No worktable
.05mm position precision	??

600x900 mm work area	400x430 mm work area
Stepper Drive	Stepper Drive

The practical result of these similarities and differences mean that designing and sending an etch/cut to the machine will look very similar no matter which machine you are working with. The process will be:

1. Come up with your concept
2. Design your concept in 2D
3. Turn your concept into vectors
4. Arrange vectors with layout software
5. Determine the order of operations for the laser
6. Generate the gcode for your operations
7. Position your work material
8. Focus the laser
9. Use a gcode sender to stream the code to the laser

These steps happen in that same order no matter what machine you are using. The OMNI requires more setup, but can move faster at the same precision, and is capable of cutting through a wider variety of materials. Even so, there are materials that it can not be used for, either because a)the material is unsafe, or b)the material is outside of the light wavelength the CO2 laser generates for cutting.

For learning purposes, we combine the lessons on the very accessible diode based lasers, and take turns with the more powerful Omni. In this way, everything about the operation of a laser can be learned with lots of hands-on experience, and time on the industrial laser can be optimized by doing layout and tests in advance.

Exercise: **Learn About the Laser Firmware**

Before we get into etching or cutting, we will take a moment to understand how the machines are set up in order to be able to troubleshoot problems that may occur as we get into heavy operation of the machines.

As gcode (movement information) is sent to the machine, it is interpreted by the control board, which in turn uses motor driver boards to send pulses of electricity to stepper motors - so named because of the “steps” they use to rotate forward and backward.

These motor movements are conveyed to the laser head by drive-gears and belts.

As a result, the precision of the laser and the quality of the work are a result of a variety of factors.

Machine Quality Factors:

- Quality of motors (number of steps they can do in a full rotation - higher is better)
- Quality of motor driver boards - the frequency they operate at
- The bit-depth of the control board, processing speed
- Quality of belts, number of teeth and belt tension
- Number of teeth on drive gears
- Rigidity of rails
- Weight of laser unit
- Quality of optic parts (lenses, the laser itself)
- Consistency of cooling and air displacement (CO2 laser)
- Quality of firmware

The last point, regarding firmware, is a good place to begin working with the laser, and for this lesson we'll be working with the Ortur diode-based laser.

Connect the computer to the laser controller via USB.

Note that not all CNC machines are controlled via USB - that is actually a relatively recent phenomenon. Many machines are controlled via proprietary cables (like our OMNI CNC milling machine, which uses a 50 pin cable).

This change to USB control was made possible by boards created for the hobby market, and over time has become a standard for laser cnc control in increasingly capable machines.

The firmware is the set of instructions stored in memory on the control board of the laser. Those instructions determine the way gcode will be interpreted by the machine into movement. To determine the movement, the firmware must be programmed with several important bits of information, including:

- The number of steps/minute the motors are capable of
- The mm/step the belts/gears are capable of
- The power range of the laser

The firmware of the Ortur is GRBL 1.1. The manufacturer of the machine programs this firmware into the control board, and provides the necessary information. However, every machine is slightly different, and there will always be small variations in the actual physical properties of the unit. With lasers, small variations can have a noticeable effect on the quality of the work done.

For this reason, it is good to be able to read the factory settings from the firmware, and make adjustments if necessary.

Reading the firmware settings:
Type $$ into a gcode sender - the machine sends the current settings back.

It is possible to overwrite these settings. But for now, lets just check to see how accurate the current machine settings are by sending our first gcode to the machine, and measuring the result.

1. Position a ruler along the x-axis of the machine.
2. Send the gcode to enable the laser at .1 power (visible, no cutting)
3. Send the gcode for an x-position change of 50mm
4. Measure the actual travel of the laser

You can perform this test several times, and perform it in the Y-axis as well. If the movement is off, this can be a strong indication that the belts require tensioning (this is common after extensive operations)

From this, we can see that the physical and mechanical properties of the machine make a significant difference to the performance, and we should get in the habit of performing a set of visual checks at the start of each session.

Things To Check:

- Are the belts properly tensioned
- Are the rails free of dust and debris
- Feet should be securely positioned on an unmoving surface
- Nothing protruding upwards in the work area
- Are the rails squared such that the laser travels in lines parallel to the rails? They may need adjustment from time to time

Performing such a quick check is important in a makerspace environment, where a wide variety of people with different experience levels and project goals will use the machines in a diverse set of ways.

As we continue, you'll get to know other aspects of backing up your settings, creating libraries, and other aspects of ensuring you get good quality work in the makerspace. We are ready to jump into the primary software we will be using through the course - Lightburn.

Software We Will Use:

- Lightburn - layout and light design tools, gcode sending and monitoring (both diode and CO2 laser)
- FreeCAD - constructing 3D objects from 2D shapes, integrating with Lightburn
- Inkscape - more extensive design features, integrating design tools with Lightburn

Projects and Lessons

Our initial projects are all chosen for the purpose of increasing your knowledge of working with a laser, and build upon each other to reinforce concepts that will allow you to quickly start getting high quality work.

- Perform your first simple etch and cut understanding origin/framing
- Create a template to understand absolute and relative work position
- Array and alignment options for layout
- Use your template with a power grid to understand feed/power
- Test a variety of materials to understand creating your own personal cut library
- Backing up your settings, restoring/continuing a project

You'll get a chance to perform all of these lessons on both the Ortur and the OMNI. At this point you'll have some helpful files, a library of settings you can use and refine, and have a good idea of how the hardware of both machines works.

From there you can progress into the design process involved in working with lasers. Lasers provide some very unique features not easily achieved with other tools - these will be stressed in the lessons. Lasers work very well with vector graphics, so the majority of lessons will focus on this form, though raster images will be lightly touched on.

- Understanding vectors and raster images
- Boolean operations (combining and subtracting vectors)
- Node editing and drawing
- Use of text
- Working with external vector tools (like Inkscape)
- Creating an art library

With a solid understanding of vectors, positioning, feed rates and power settings you'll be able to design and create good-looking artwork with a laser, and you'll be ready to move to the next step - creating and constructing 3D objects with 2D patterns. For this we will move into a CAD program to show basic sketching and a huge time-saver called "parametric modelling"

- Sketching in CAD
- Understanding accuracy and constraints
- Designing constructions with connectors like tabs, slots, rails etc.
- Parametric modeling - the advantages and how to do it
- Exporting vectors for layout, importing to Lightburn for processing

With no further ado, lets begin with creating our first etch and cut.

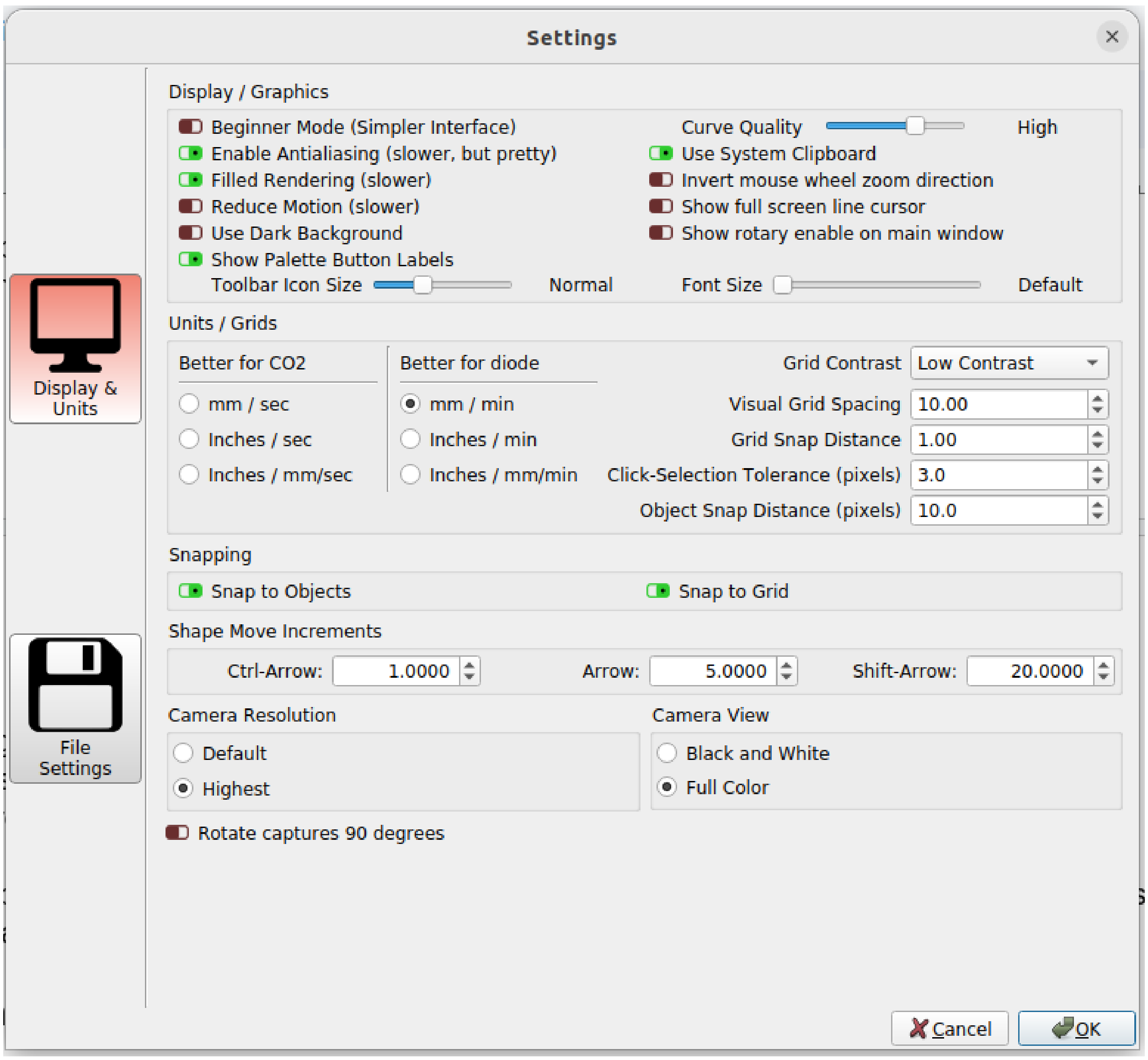
Introduction to Lightburn

Lightburn is a relatively new software custom made for working with lasers. Prior to lightburn it was necessary to string together a variety of software to create graphics, align your page, configure the laser and send gcode to it. Lightburn combines these features into one software that is straightforward to use, and does not limit us from integrating other software as we wish (as we will see when we get to FreeCAD and Inkscape).

Lightburn is primarily layout software, allowing us to create, import, and combine vector images and raster images, then plan how these will be sent to the laser.

Configuring Settings:

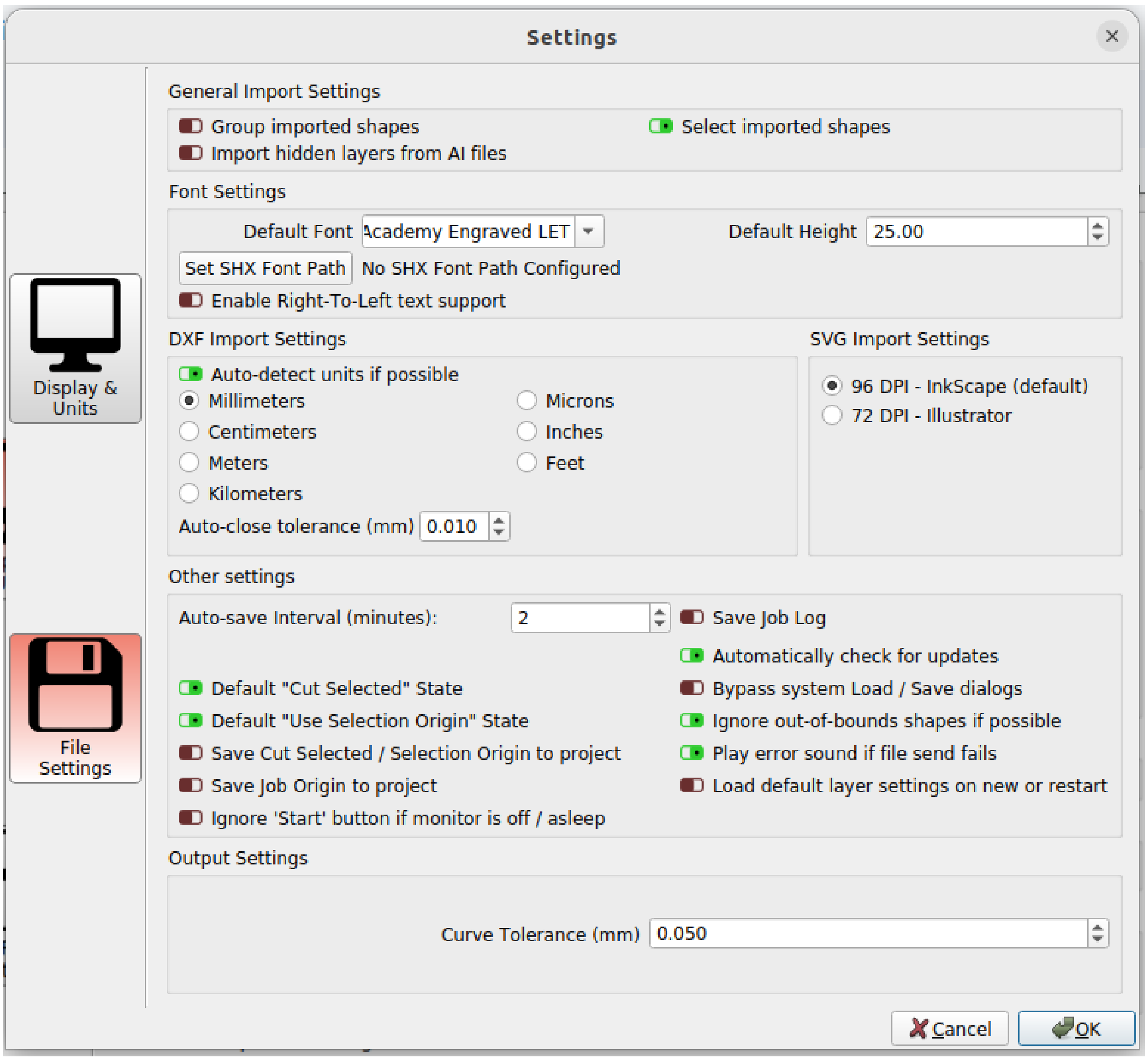
Lightburn does a good job of connecting to most lasers and determining things from the firmware, such as the size of the bed and the home position it uses. But there are settings we need to configure by selecting the gear icon from the menu bar.



On the diode-based laser like the Ortur, under Units select mm/min. For the CO2 machines, select mm/min.

Under Display/Graphics, you should enable rendered fills so you can easily distinguish them from “line” layers in the viewport.

From here you can also enable or disable snapping, and tune how responsive snapping should be as you use the design grid.



Under “File Settings”, probably the most important option comes under the import settings for DXF and SVG. Most notably, the DPI for imported SVG files should be set to 72 dpi if using Illustrator, or 96 DPI for any other vector drawing tool.

Exercise: **First Cut and Etch Operation**

For our first exercise, we will be practicing with cardboard sheets in order to understand the following principles:

- Positioning and work area
- Origin point
- Moving the laser, checking alignment
- Focussing the beam
- Feed rates and power

Have students cut out a 300mm x 300mm corrugated cardboard sheet. Have them position it in the lower left corner of the Ortur. Get them to draw out two boxes on the screen. Set one to “line” and the other to “fill”.
Explain about positioning - absolute and relative.
Explain about “framing”
Show how to activate the laser at .01 power
Explain the power scale used in GRBL (1 to 1000)

Prepare them for the idea that different materials at a variety of thicknesses may have very different properties, and that we will be creating a library of cut/engrave settings they can customize and keep for use any time they are in the makerspace.

Outcomes:
At the end of week one, you’ll have come to understand the fundamental aspects of how laser hardware works, and the differences between hobby machines and industrial lasers. You’ll have gotten familiar with the software used, and basic troubleshooting techniques and best-practices for ensuring the machine is operating properly.

In Lightburn, you’ll understand where to set feed rates and power settings. You’ll be able to explain the difference between cutting and etching settings. You’ll know how to position the laser, preview the framing of your work, and will have practiced your first operations.

Additional/Optional:
- Setting up exhaust clearing
- Recovery from smoke detection