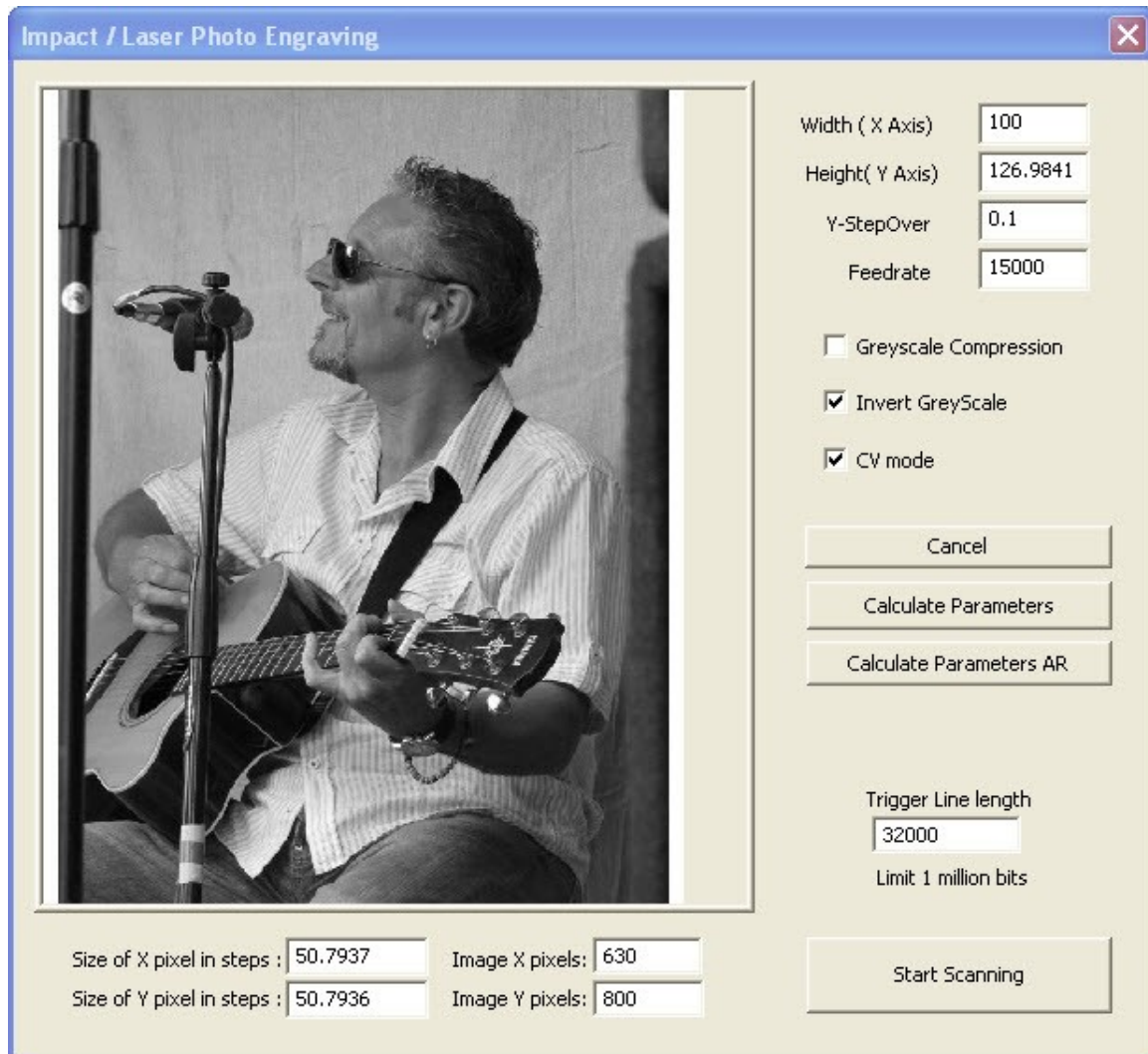


An insight into Art Fenerty's
Impact / Laser Engraver plugin.
By Tweakie.



Introduction:

When Art first wrote this plugin, back in 2007, there was little interest in it's use but with the increase in laser ownership it is now starting to come into it's own. More users have resulted in more testing and the inevitable bugs are starting to be discovered and removed.

Art, although busy with his Gearotic Motion software, spent precious time towards the end of November 2010 rewriting some of the code to correct the previously known issues and as a result his latest version is now a real pleasure to use.

He has also made the source code freely available to us all so that we can customize our user interface and if required, make subtle changes to the way in which the code is executed etc.

There have been a number of requests, mainly through the forum, for some documentation on how to use this plugin so I have taken on the task of producing this brief and extremely basic 'walk through' which I will update as I learn more. Although much of the information applies equally to Impact Engraving this document is biased towards and primarily aimed at Laser Engraving.

Please note that all units expressed in this document are metric unless otherwise stated.

Loading and Configuration:

Download the latest version from the Mach support plugins page <http://www.machsupport.com/plugins.php> and run the Engraving.m3p file.

This will automatically load Engraving.dll into the Mach3 / Plugins folder.

Run Mach and under Config / Config Plugins check Enabled the Engraving-Impact-Laser-Version-....

Close Mach and on restart Impact/Laser Engraving v... will appear in the menu bar.

Under Config / Ports and Pins / Output Signals check Enabled the Digit Trig and enter the Port # and Pin Number used to connect the computer to the laser.

Check the Active Low. (Without going into all the details here, the computer LPT printer port can sink more current than it can source therefore it is prudent to use the Active Low mode of operation for driving external devices).

It is important that the output pin # used here must not be enabled elsewhere in your setup or Mach configuration.

Setting up:

It is best to initially start with a basic setup and once everything is working then, if necessary, fine tune the settings for best performance.

Under Config / Ports and Pins select and apply a Kernel Speed of 25000Hz.

Under Config / Motor Tuning for the X Axis check that you have entered the correct Steps per Unit then set and save the highest Velocity and Acceleration your X Axis is comfortable operating at somewhere between 4,000 minimum and 20,000 maximum units per min. Avoid the temptation to set anything faster at this stage, I will try explain later in this document the advantages, disadvantages and limitations of speed.

Connecting to the laser:

Because each installation will be different it is beyond the scope of this document to give exact connexion details but the specified parallel port pin# which has been associated to the Digital Trigger and configured Active Low should be connected to the laser's Active Low trigger input.

It is perhaps worth noting here that the 5Volt TTL standard has, in many instances, now been replaced with 3.3Volt TTL and it is important to check that the computer's LPT port does in fact output the correct voltage level for the laser's TTL trigger input.

Safety:

You and you alone are responsible for your own safety - lasers can be dangerous and in an instant, cause serious harm. Ensure that you fully understand the dangers involved and that you have taken all necessary safety precautions to prevent injury to yourself or others. Always use protective eyewear.

Use:

Line up the job with the starting point, which is in the lower left hand corner and check Z axis dimension for correct focus. Zero all axis DRO's. Select 'Impact/Laser Engraving' in the menu bar then select 'Engrave Photo'. Locate the .bmp / .jpg / .png file you wish to engrave and select 'Open'. The user interface window will now open and display the selected image. You must now enter the desired Width (X Axis) : Height (Y Axis) : Y Step-over and Feed-rate.

Check 'Invert Grey Scale' if required (see Invert Grey Scale).

Click on 'Calculate Parameters' to update the steps per pixel readouts.

The image will be correctly proportioned (aspect ratio) when the Size of X pixel in steps is approx equal to the Size of Y pixel in steps (assuming that the X and Y steps per unit, in motor tuning, are the same value). As an option you can set the Width and click on the 'Calculate Parameters AR' button for an automatic calculation of Height at the correct aspect ratio.

When you are satisfied that everything is correct then select 'Start Scanning' and 'Yes' in the popup window. Scanning will now start when clicking on the 'Cycle Start' button on the main Mach screen and it will continue until the image is completed.

To abort the operation press the keyboard spacebar or click on the 'Feed Hold' button and when the scanning stops click on the 'Reset' button to exit the routine. Obviously it will be necessary to click on the now flashing 'Reset' button one more time before proceeding. If you don't do it this way then a 'Previous SEQ not yet complete' error is triggered.

Plugin Operation:

The loaded image is converted to 8 bit greyscale which allows each pixel to have a value of between 0 and 255. The plugin then scans the image, line by line, starting at the lower left hand corner and converts the value of each pixel it encounters into a series of output pulses on the Digital Trigger pin. The exact timing of these output pulses is dependant on a number of factors including the pixel value, axis speed, axis steps per pixel and the kernel speed. Art has explained it to me twice now but I still don't fully understand exactly how the pulses are calculated but understanding is perhaps unimportant because it works and that is all that really matters.

The scan commences by the X Axis accelerating from zero to the specified speed which is maintained for the whole of the line and then decelerating to zero again at the end of the line. During these periods of acceleration / deceleration the output pulse rate is reduced pro-rata with speed to prevent excessive burn or cut depth at the edges (see Edges).

Invert Grey Scale:

Under normal circumstances the laser will be turned on for the white parts of the image and turned off for the black parts. If engraving onto the surface of a light coloured piece of wood the image produced will be a negative (the white areas will be black and the black areas white) so Invert Image is selected to turn the laser on for the black parts and off for the white parts and thus produce the correct image as shown here on this engraving laminate.



Different materials, of course, produce different results and as just mentioned a laser pulse will darken a piece of wood but it will lighten a piece of slate, stone or glass therefore the material being worked on will determine if the image needs to be inverted or not. A little bit of trial and error is all that is needed here to become an expert.

Edges:

As already mentioned, the frequency of the output pulses are reduced as axis speed is reduced at the start and finish of each line and this can sometimes result in the outside vertical edges of the work becoming visually ragged in appearance. One of the easiest ways I have found to prevent this, is to create side borders or dead bands as part of the original artwork which are just wide enough to allow for the acceleration / deceleration of the X axis and 5mm each side is usually more than enough. The shade of these bands (black or white) is chosen so there will be no output pulses from the plugin at any time when the axis is not moving at it's full velocity. The image in the illustration on page 1 shows these side bands which are white and because Invert Grey Scale is checked the laser will not fire in these areas.

CV mode:

Another item for consideration is that of Constant Velocity vs. Exact Stop mode. With CV mode checked the linefeeds will occur during the last couple of mm of the horizontal line scans and this can produce visually poor quality edges as can be seen in the following example. Although this effect is, to a large extent, dependant on the step-over size and the velocity / acceleration settings of the Y Axis it can really spoil an otherwise excellent engraving.



The default mode of operation for the plugin is Exact Stop and this forces the linefeeds to occur only after each successive line scan has ended resulting in a much neater and cleaner edge as can be seen in this, the next, example.



As always there is a price to pay and that is one of speed, the whole process unfortunately can take just that little bit longer to complete when operating in Exact Stop mode. If speed is to be optimized then checking CV mode is just fine for images where the detail does not extend to the sides of the canvas (such as the Aztec Queen on page 8) or for images where side borders or dead bands have previously been added – In other words use CV mode when there will be no

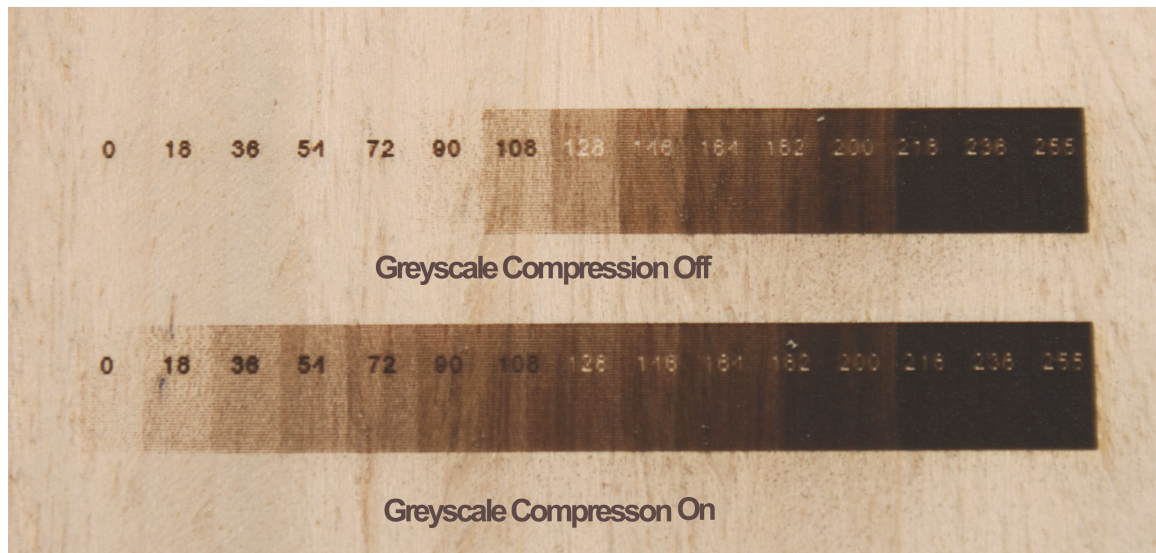
output pulses from the plugin within a few millimetres of the vertical edges of the finished work. In all other situations it would be wise to accept the small speed reduction, go for quality and use the default Exact Stop mode.

Calculate Parameters AR:

For those occasions where the aspect ratio of the original image is to be preserved this button should be used to update the set parameters. It's function is extremely basic and it uses the entered Width (X Axis) data to calculate the Height (Y Axis) data and then update the respective readouts.

Greyscale Compression:

The effect of this function is probably best demonstrated by reference to the following illustration where both images have been created at exactly the same laser output power setting and axis speed.



As mentioned earlier, an 8bit image has 256 variants of greyscale (including black and white) and in order to reproduce the lighter shades (below a pixel value of say 85) laser output power has to be set so high that the darker shades (above a pixel value of say 200) are burnt too deeply into the work and any detail in these darker areas of the image is lost entirely.

The Greyscale Compression function essentially alters the ratio of output pulses in relation to pixel value so that a different balance is achieved over the total range of values with the density of the low value pixels increased thus allowing laser output power to be reduced and create improved detail within the high value pixel areas of the work.

This function is probably best suited to burning photographic type images into wood and it may not be suitable for all applications and / or materials used so it has been added as an option which can be selected if required.

Image quality:

It is best to use original images that exhibit a high level of contrast as these will produce better results from the physical laser engraving process.

Experimentation will reveal the types of images or compositions that are good and those that are bad and it does not take long to learn the difference.

Many of the photo manipulation software's (mentioning no names) have image processing plugins which can produce some quite stunning effects and of course, there are a couple of stand alone, halftone or dot-dithering, software's intended solely for laser image use. These software's produce an image which has, what appears to be, a random dot pattern but like this Mach plugin the dots are not placed at random, they are mathematically calculated and if you dare to change the scale or aspect ratio of a processed image the dot patterns can start to show and pattern 'banding' may well occur.

There are a number of pre-processed images, available for download, on the various USA and UK laser supplier's websites and the Aztec Queen below is one such image. This has been engraved onto Obechi, again with Invert Greyscale checked so the laser burns the black areas of the original image.

Unlike the purpose built laser machines which have a requirement for multiples of either 250dpi or 300dpi images (depending on their axis steps per unit) the Mach plugin is really not that fussy. Obviously I have not tried every possible combination of image size / pixel density / step-over etc but so far it has handled everything I have thrown at it without complaint. I have no idea what the dpi of this image was nor do I need to care as the results speak for themselves. It is perhaps worth mentioning here that the final colour of the image has a strong relationship to the type of wood used, some woods engrave to a really black image and others just a light brown. Increasing the power density usually does the trick, but not always.

Digressing a bit, but something else that is perhaps worth mentioning here is the phenomena of horizontal banding. As well as the pattern banding, mentioned earlier, there are other types of banding which seriously affect the quality of the finished work. This problem is generally always as the result of power density fluctuations within the laser tube itself and in my case was quite a big concern in the early days. Almost all of my initial image work suffered with one sort of banding or another and it took some time to realize the cause and just how sensitive to incoming mains power fluctuations my laser PSU really was. The culprit was finally traced - the thermostatically controlled electric workshop heater, which has now been wired on a different circuit to the laser. Magically my problem was resolved and hopefully banding is now an issue that remains in the past.



Some things that just don't work:

There are infinite combinations of settings within Mach and obviously I have not been able to try them all but these points have been found so far.

1) The plugin has been written for use with the computers parallel port and it will not work with external motion controllers such as the Galil, SS etc.

2) Satisfactory results cannot be obtained if Sherline 1/2 Pulse mode has been selected. This results in a ghost image.

3) I have been unable to get reliable results when using the spindle speed control output of a PWM signal (controlling laser maximum current) at the same time as running the plugin. This does not mean to say that it will not work just that I have not succeeded.

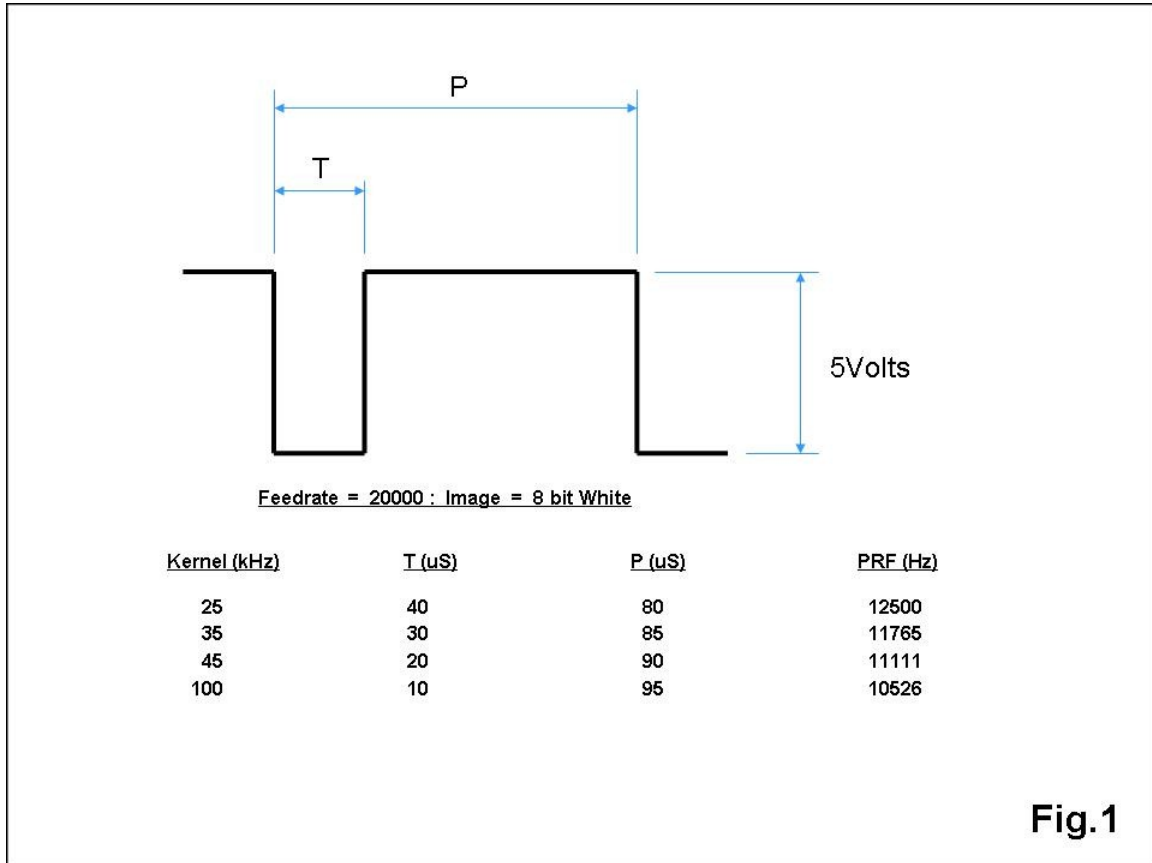
A stand alone PWM source or analogue dc control for laser maximum current works beautifully.

4) The X Axis scale DRO should not be used. If set to anything other than 1.0000 it will create multiple images (This could perhaps be used to good effect but it may need some experimentation).

Fine Tuning:

Obviously we all want our machines to operate at the fastest possible speed and jobs to be completed in the minimum amount of time but there are many constraints and fastest is not always best. Maximum Axis speed is related to Steps per Unit and Kernel Speed but as Kernel Speed is increased then the width of the plugin's output pulse decreases and a gain in one direction can be offset by a loss in another.

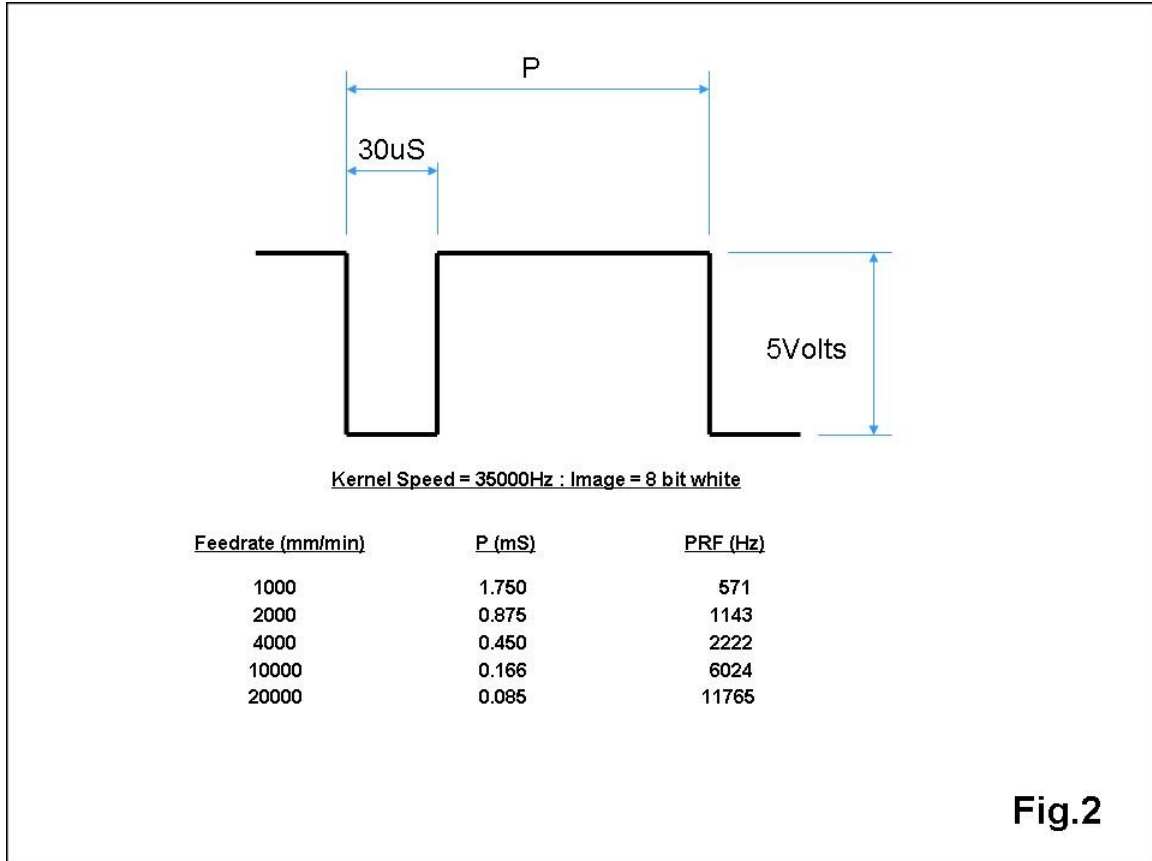
Fig.1 illustrates the relationship between the pulse width (T) and the Kernel Speed setting.



Ideally the plugin should be operated at the kernel speed of 25kHz but depending of your machines Steps Per Unit and rated laser power a sufficiently fast enough axis speed may not be achievable. This is where compromise comes into effect and a happy medium has to be found remembering that the quality of the finished work should take priority over everything else.

At a kernel speed of 35kHz each pulse will be 30uS wide and the maximum density of pulses (pulse repetition frequency) that can be achieved will still be dependant on feedrate which is in turn dependant on steps per unit. This is quite a balancing act really with every parameter being tightly linked to each other. Increasing the kernel speed to obtain a higher feedrate may be inevitable in some circumstances but this may not always be an advantageous move.

Fig.2 shows the relationship between feedrate and pulse repetition frequency.



There will be upper frequency limitations on the TTL input to the laser but this may vary from one type of PSU to another and the Chinese manufacturers of the DC units are very guarded at giving out any details although a maximum pulse repetition frequency (PRF) of 20kHz is assumed for the PWM input of most power supply units.

The controller for my RF laser is, for example, currently operating at a PRF of 5kHz (which is the manufacturers recommendations) and although I can increase this in 5kHz steps up to 20kHz that in turn causes other limitations on the available range of PWM that can be used without overdriving the tube and shortening it's life expectancy.

Obviously some individual experimentation is necessary because the setup that works well with one machine is unlikely to work well with every other machine.

Looking at my setup:

The steps per unit are 320 and the maximum, comfortable, velocity for the X Axis is 4500 so if a kernel speed of 25kHz is used then selecting a plugin feed-rate of 1500 will give a trigger pulse width of 40uS with a maximum pulse repetition frequency of 8.2kHz which would result in a maximum laser pulse density of 30%. (This approximates to the maximum density output from the plugin using just 30% of the laser's maximum available output power).

Doubling the feedrate to 3000 would still give a 40uS trigger pulse width but it would increase the pulse repetition frequency and thereby increase the maximum laser pulse density to 50%. Continuing to increase the feedrate we will eventually arrive at the maximum possible, for this setup, of a 67% pulse density and a feedrate of 4687 but is this necessary?

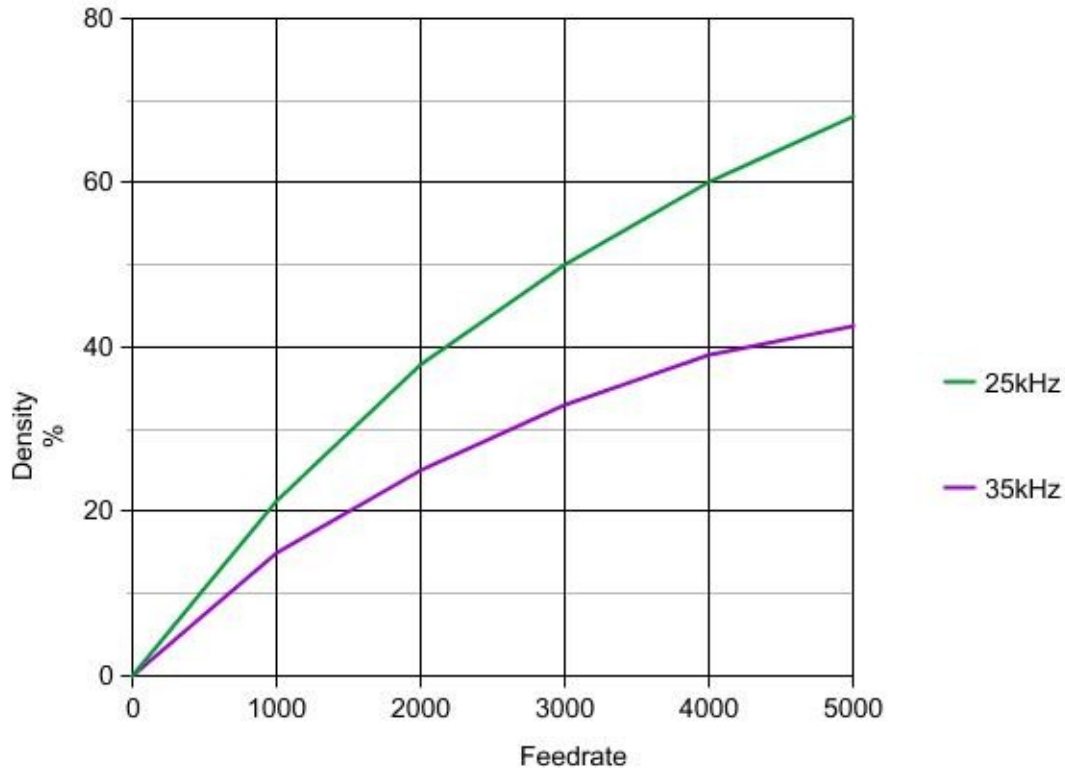


Fig.3. Relationship between Feedrate, maximum Pulse Density and Kernel Speed

It is a trait of lasers that (to a large extent) the results achieved using a high laser power at a high feedrate are similar to the results achieved using a low laser power at a low feedrate but, because the relationship is not completely linear this can become bit of a conundrum.

Somewhere in between the minimum and the maximum feedrate there is an optimum position where the best results can be obtained for any one particular setup with 'trial and error' almost certainly being the order of the day.

Speed is not my goal and so far, my best results have been obtained at a feedrate of between 3500 and 4000 (maximum pulse density of 55% to 60%) and any deviation outside these figures results in a noticeable reduction in the visual quality of the finished work. It is perhaps still early days yet and I have a lot more experimentation to carry out before I am finally satisfied that I have truly achieved the best possible results the plugin can provide.

Some other considerations and ramblings;

To produce a good quality engraving, a 40Watt tube may need to use 60% of it's available power whereas an 80Watt tube may only need to use 30% of it's available power to achieve similar results. This being the case then referring to Fig.3 an 80Watt system could easily be operated at 35kHz whereas a 40Watt system would struggle. This example is only hypothetical but it serves to illustrate the differences and just why one setup will not apply to all machines.

There is no magic solution or easy way to find the best settings for using this plugin, at least I have not yet found one, and you will have to start at the beginning, then experiment to find what works best and what doesn't. Please don't just start with 100kHz kernel Speed then wonder why it doesn't work.

The relationship between the plugin's digital trigger output signal to the actual laser output power is unlikely to be exactly linear but for the purposes of this document you should assume that it is linear and that a 50% PRF (see Appendix.1) will produce a 50% laser output power and pro rata (I have used heuristic forecast and solution for many years now and I can confirm that without assumption the way forward can be painfully slow).

There is no guarantee that any two laser tube / power supply combinations will offer the same output power for any given PRF input or indeed even follow exactly the same power curve so two identical machines may still perform differently and the best setup for each may therefore not be the same.

The data necessary to compile the graph shown in Fig.3 took me some while to obtain so it is limited in it's extent but I think it would be most interesting to extend the parameters and see the full picture. Do the curves peak and then cross as they diminish and if so at what values?. What happens at a Kernel Speed of 100kHz? I have added this to my 'to do' list.

There may be some advantage in increasing the digital trigger's pulse width (output from the plugin) although this has yet to be confirmed. My first thoughts are to electronically 'pulse stretch' as this can be easily achieved and adjusted 'on the fly' to suit any Kernel Speed or laser output setting. Again this has been added to my list.

Appendix.1

As I have referred to Pulse Width Modulation (PWM) and Pulse Repetition Frequency (PRF) a number of times in this document, this is a very simplified, graphical, comparison of the two techniques.

