Shapeoko CNC A to Z

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Belts upgrade

This is probably the cheapest upgrade: replacing the original GT2 belts with reinforced ones. The two most popular are **steel-core** belts, and **kevlar** belts.

Here's a section view of steel-core belts showing the embedded steel wires:
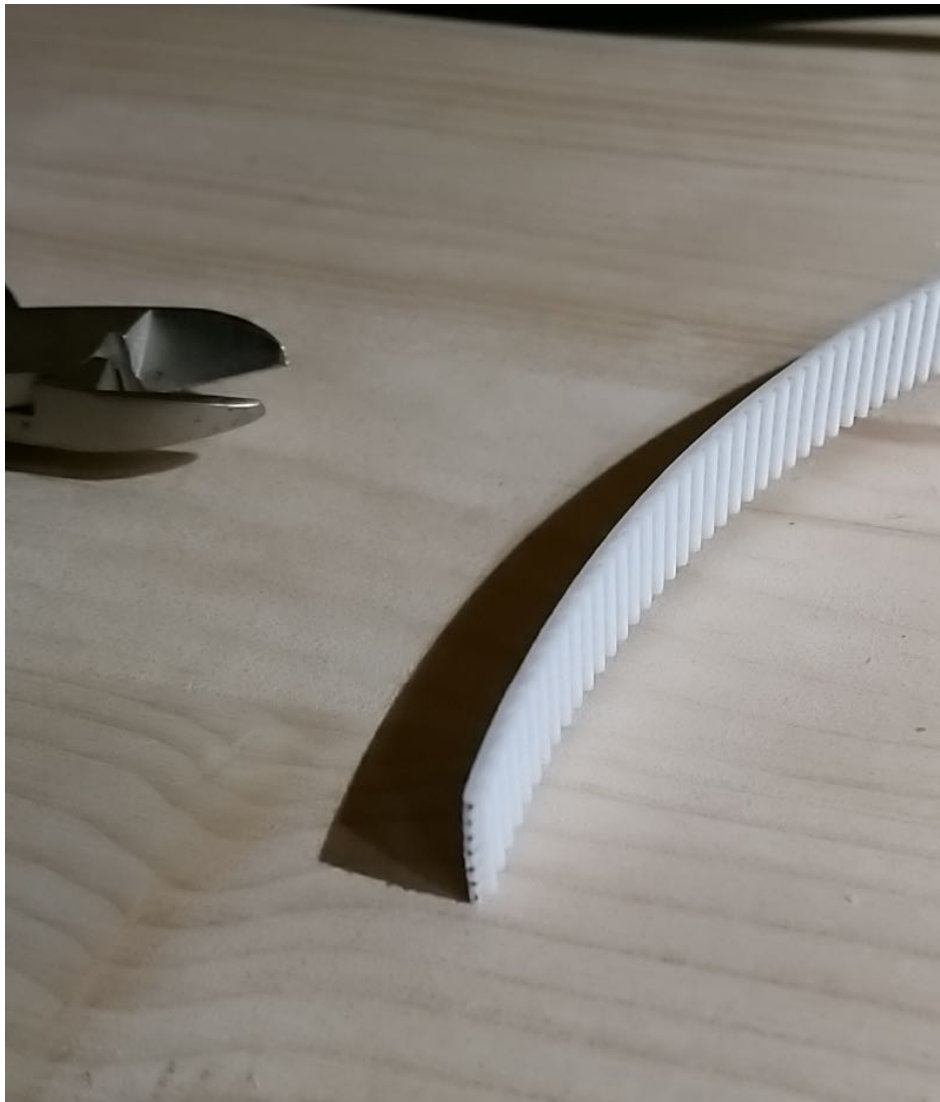
Buying several meters of steel-core belts is cheap, will serve as a provision in case the original belts snap, and replacing the belts is very easy (since it does not involve disassembling anything else other than the belt tensioners) so that upgrade is a no brainer if you feel you can benefit from the increased robustness, and possibly from the ability to push the max speed and acceleration beyond the default settings:

It has been reported that the belt stretch factor for those steel-core belts is about half as much as with regular belts, so they may also bring some benefits for precision work.

> ⓘ The tight bends around the pulleys is more than what steel belts are rated for, but no one in the community has reported any actual issue so far.

Automatic (router) RPM control

Having to manually set RPMs on the router knob at the beginning of each job can get old, and is also error prone. Luckily the Shapeoko controller board happens to have a "PWM" output that GRBL modulates as a function of the RPM values found in the G-code. So it is possible to feed this signal into a dedicated power controller, that will adjust the voltage applied on the router power leads accordingly, resulting in a specific RPM value.

This requires buying such a power control module, the most popular one is the **SuperPID**. You need to know what you are doing since installing it requires wiring mains.
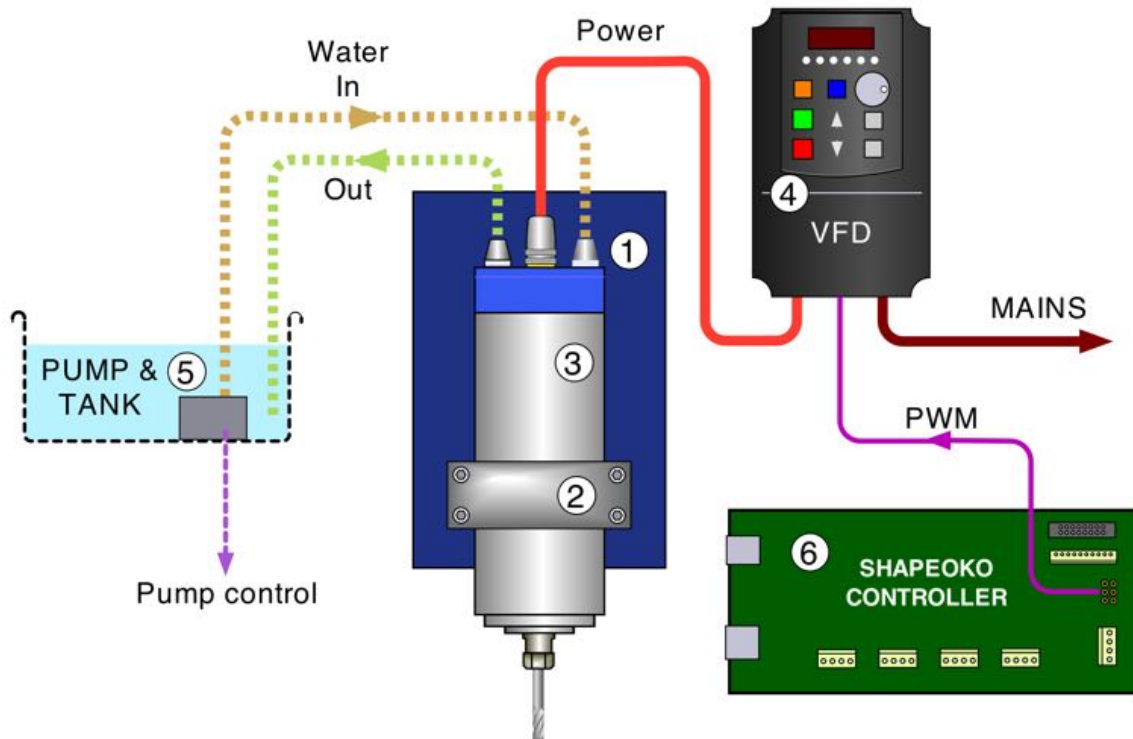
Beyond the automatic RPM control, the added benefit is that this allows the router to operate at a lower RPM value than the minimal knob setting, *e.g.* to run at 5000 RPM on a Makita that normally mins out at 10,000RPM.

Spindle upgrade

The Shapeoko uses a trim router by default for cost/convenience reasons, but most higher-end CNCs use a spindle instead. Some of the main benefits are:

- a spindle can run at lower RPMs than a router (some models can run at much *higher* max RPMs too), and usually has higher torque. Since a spindle needs a dedicated controller to run anyway, the automatic RPM control described above is a given.
- the runout is smaller.
- it is WAY quieter than a router, especially when using a water-cooled version.
- there is no need to change bushing, so basically no maintenance.
- it usually supports "ER" collets, which come in much more varied sizes than trim router collets.

Here's an overview of the key points to consider for the upgrade:

Diagram labels: Water In, Out, Power, VFD, MAINS, PWM, PUMP & TANK, Pump control, SHAPEOKO CONTROLLER

Numbered callouts: ① ② ③ ④ ⑤ ⑥

1) The Z axis capability. Spindles can be HEAVY, especially 2.2kW ones. The stock Z axis will not be able to cope with the heavier models, but should be fine for the lighter (800W) ones. The HDZ and Z-plus axis, with their ballscrew design, will handle all models.

For reference, here's the relative size of a 2.2kW spindle, next to the Makita trim router:
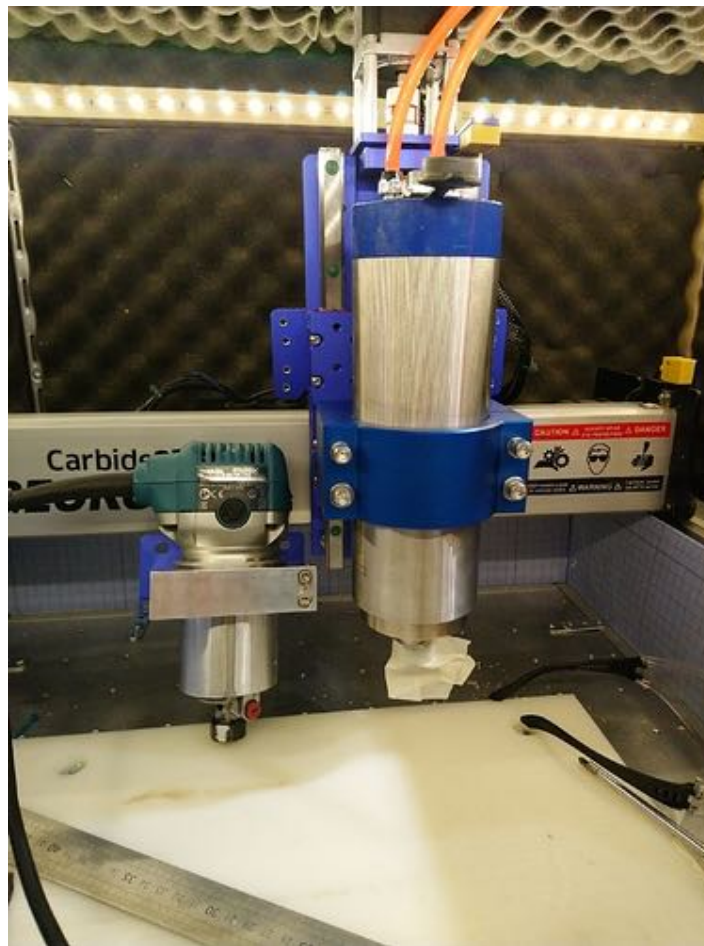
2) The router mount diameter: chances are, the stock router mount diameter will not match the diameter of the selected spindle. Spindle kits often include a mount, but it's usually very bad quality and not easily adaptable to the Shapeoko's Z axis. You are probably better off buying a spindle mount from Carbide3D's store. Here's a view of a 80mm one for reference:
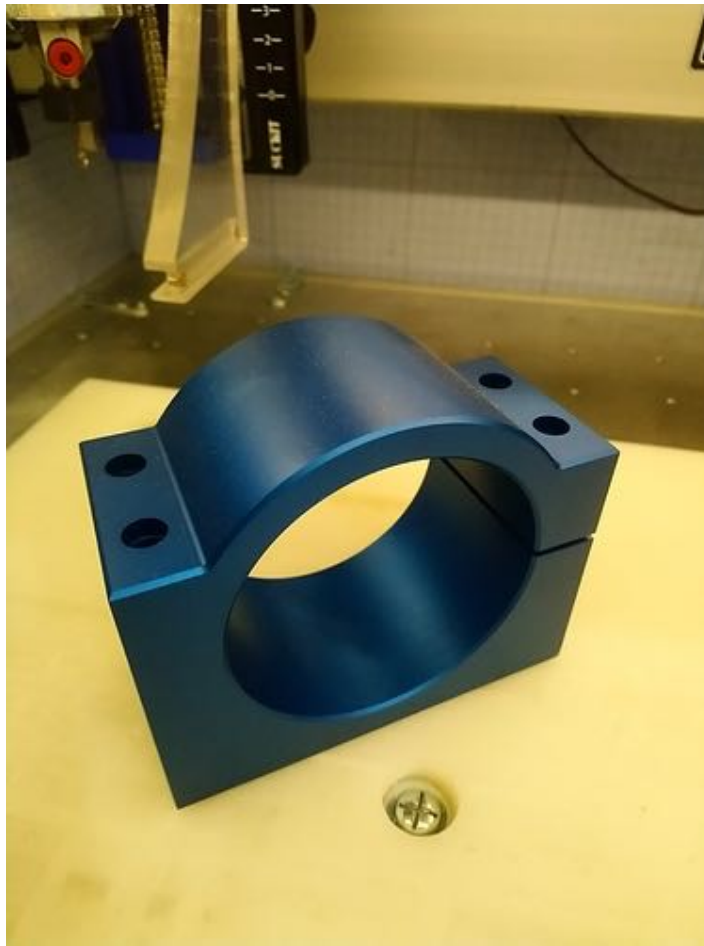
3) Then there is the choice of the spindle itself. They come in two types: **air-cooled** and **water-cooled.** The former is easier to install, but noisier. The latter is extremely quiet, but requires one to install an external water-cooling system.

4) A "Variable Frequency Drive" (**VFD**) is required to power the spindle and control its speed. The wiring of the VFD depends on the model (spoiler alert: chances are you will buy your spindle kit from China, documentation will be sub-par, but the community is here to sort it out). In the example pic below, the green wire is the PWM signal from the Shapeoko, the black wire is the Ground signal, and the purple wire is just telling to VFD to force the rotation direction:

Beyond that it's just a matter of connecting mains, and the four wires to the spindle (1,2,3 and Earth, also called U,V,W and Earth):
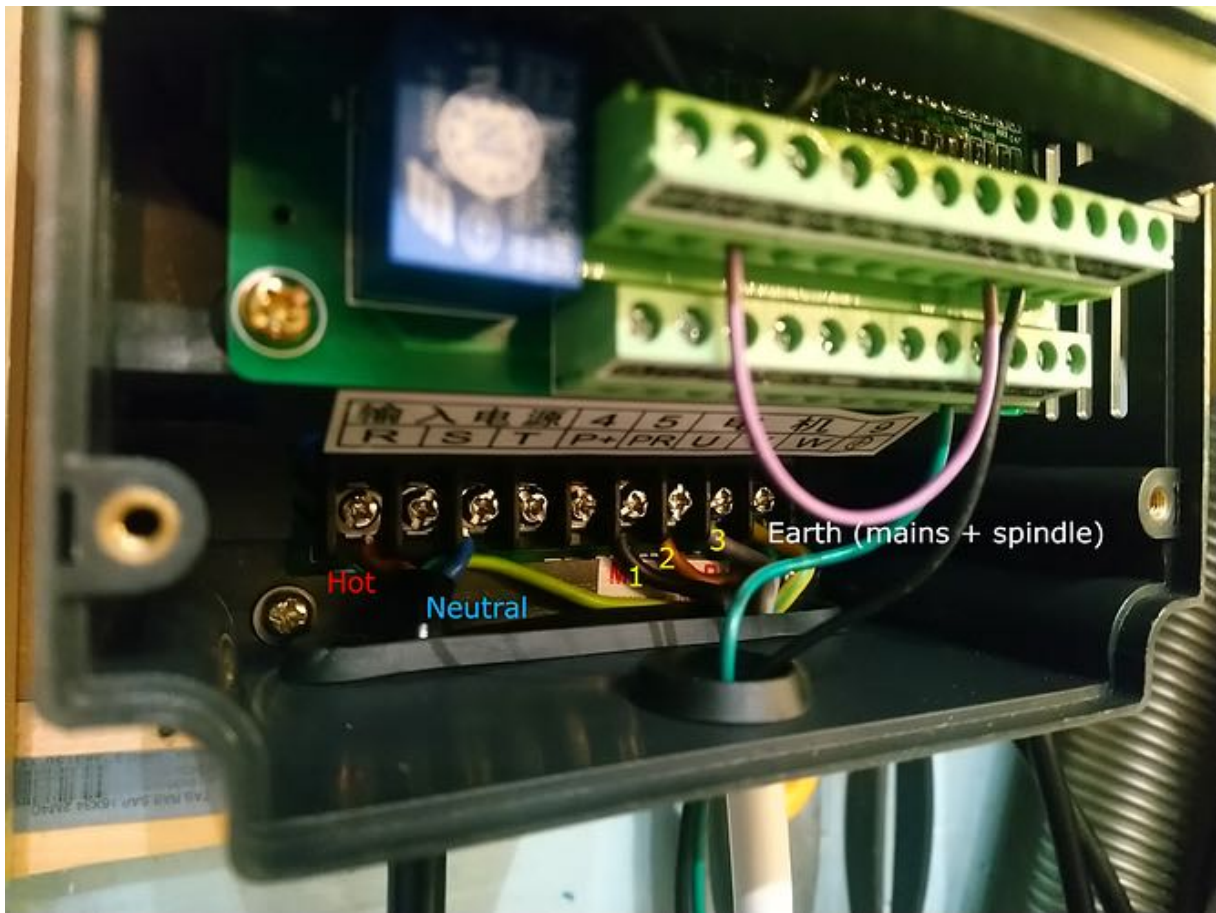
Make sure the spindle's **ground/earth pin** is actually connected inside the spindle to the body:

Sometimes it is left unconnected and then you are bound to get static build-up and possibly EMI issues

Finally one must configure the (many) parameters on the VFD, they are usually called "PDxxx" parameters, and depend on the VFD type/brand, so you will have to refer to your documentation.

> (i) Huanyang VFD owners may find this discussion helpful :
> https://community.carbide3d.com/t/vfd-parameters-huanyang-model/15459/7

5) For water-cooled spindles, one then needs to decide what type of cooling system to use. There are basically two popular approaches:

- one can use a large container as a tank, and install a **submersible pump** in it:
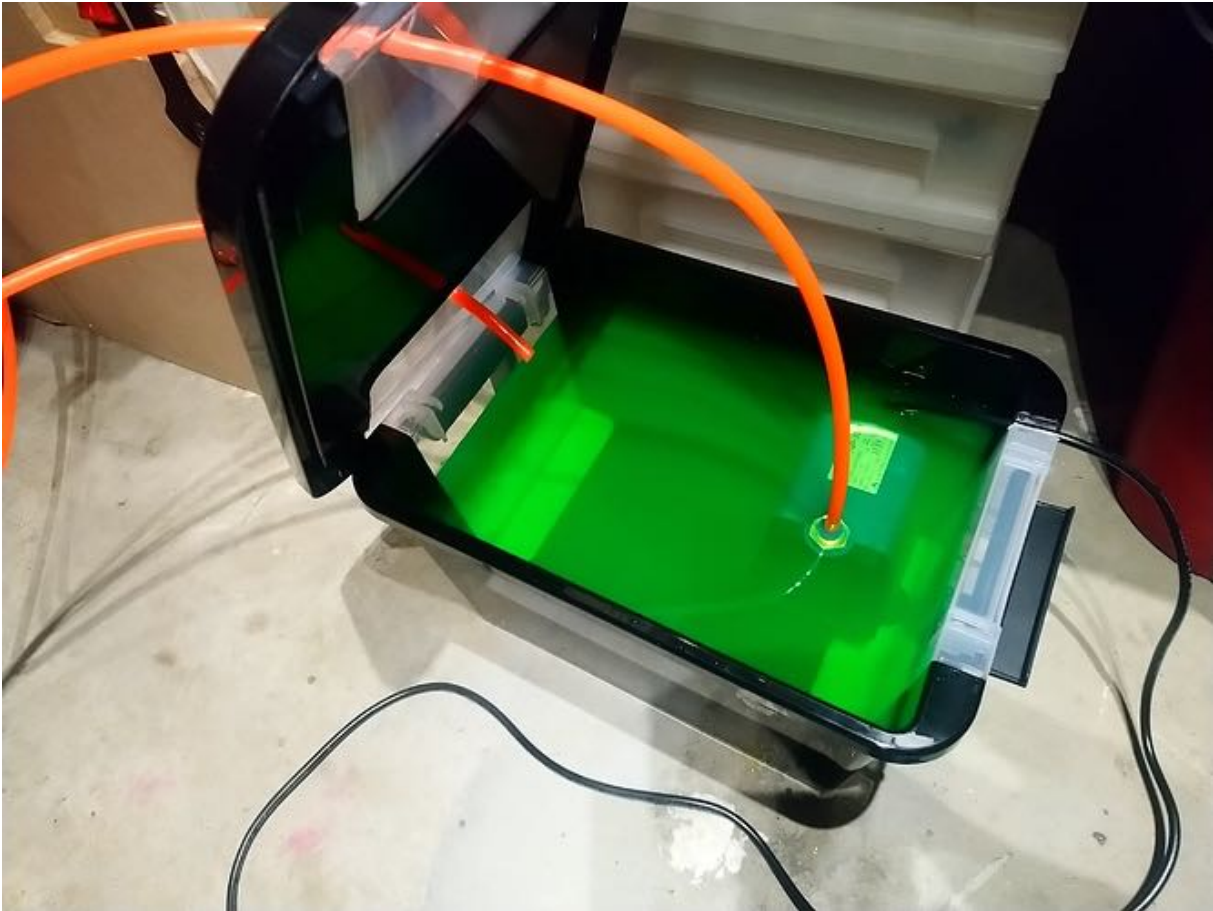
> (i) The container should be closed/sealed when operating, or dust/chips could find they way through the cooling system.

> (i) With a large enough tank, the volume of coolant alone is enough to keep the temperature low enough.

> (i) One should not use plain water as the coolant, the tubes are bound to become covered in fungus after a while. A common trick is to use automotive coolant, or other chemical products, to keep the cooling system clean

- or one can purchase a **closed-loop** cooling system:

and install it on the machine:

> ⓘ A section of the cooling loop should have fans, to keep the coolant temperature down.

6) While the spindle speed can be set manually at the VFD, it is very convenient to connect the PWM signal from the Shapeoko controller board to the VFD, and configure it such that it will control spindle speed automatically based on that signal. That way, there is no need for any manual action anymore: the Shapeoko controller will adjust the PWM signal based on the RPM value it finds inside the G-code files.

> ⓘ Final tip: to optimize the life and precision of your spindle, it's useful to run a "spindle warmup" routine at the beginning of a session in the shop. The warmup routine consists in initially running the spindle at very low RPM for a little while, then gradually ramp up the speed, to the maximal value, over about 10 minutes. Below is a simple G-code macro to do just that.

```
 1   M3S2000
 2   G4 P60.0
 3   M3S4000
 4   G4 P60.0
 5   M3S6000
 6   G4 P60.0
 7   M3S8000
 8   G4 P60.0
 9   M3S10000
10   G4 P60.0
11   M3S12000
12   G4 P60.0
13   M3S14000
14   G4 P60.0
15   M3S16000
16   G4 P60.0
17   M3S18000
18   G4 P60.0
19   M3S20000
20   G4 P60.0
21   M3S22000
22   G4 P60.0
23   M3S24000
24   G4 P60.0
25   M5
```

Laser upgrade

⚠️ If you are considering adding a laser to your Shapeoko setup, whatever you do put safety considerations at the very top of your priority list. Eye safety is priceless, so if you are going to do this, you need to have SEVERAL layers of safety measures in place. And the fire hazard is obvious.

It's tempting to leverage the X/Y capability of the Shapeoko, to move a laser module around and engrave/cut the surface of parts. A typical setup will look something like this:
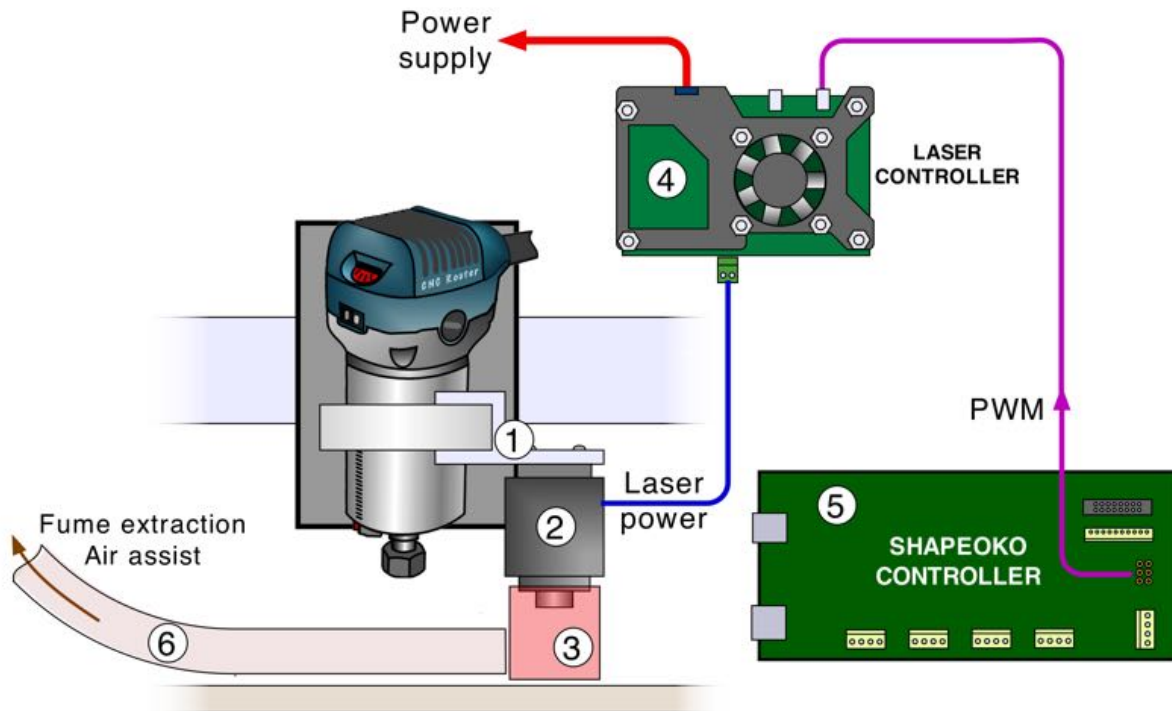
1) The laser module is usually attached somewhere on the router mount, in such a way that it can be installed/removed easily, when switching back and forth between CNC operation and laser operation.

2) One must select a laser module which matches the intended use. Modules mounted on Shapeokos are typically in the range of [2-10W] power, which grants the ability for engraving, and cutting thin and soft material (think plywood). If your main goal is to do a lot of laser cutting through thick/hard material, you should probably consider a standalone laser cutter instead.

3) The laser beam area should be covered by a **shroud**, filtering the harmful laser light. This is your first line of defence, so think twice before you decide to not have one. If not at the module level, it could be done on your enclosure's front window. The second line of defence is obviously to **use laser goggles at all times when operating the laser.**

> ⚠ One might think that since the laser is always pointing down towards the material, this is inherently safe. But dangerous reflections are a thing, especially when engraving metals.
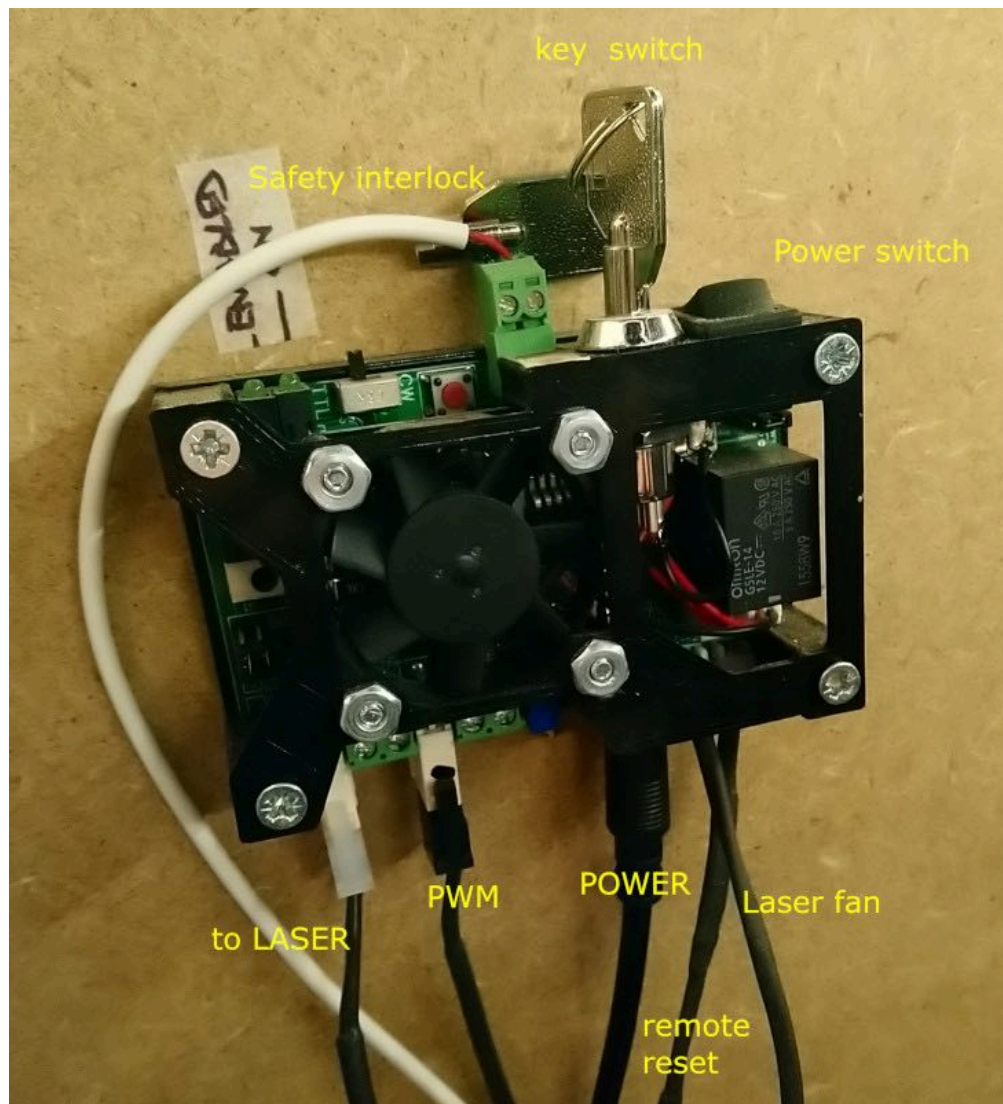
Here's what my 4.8W laser setup looks like:
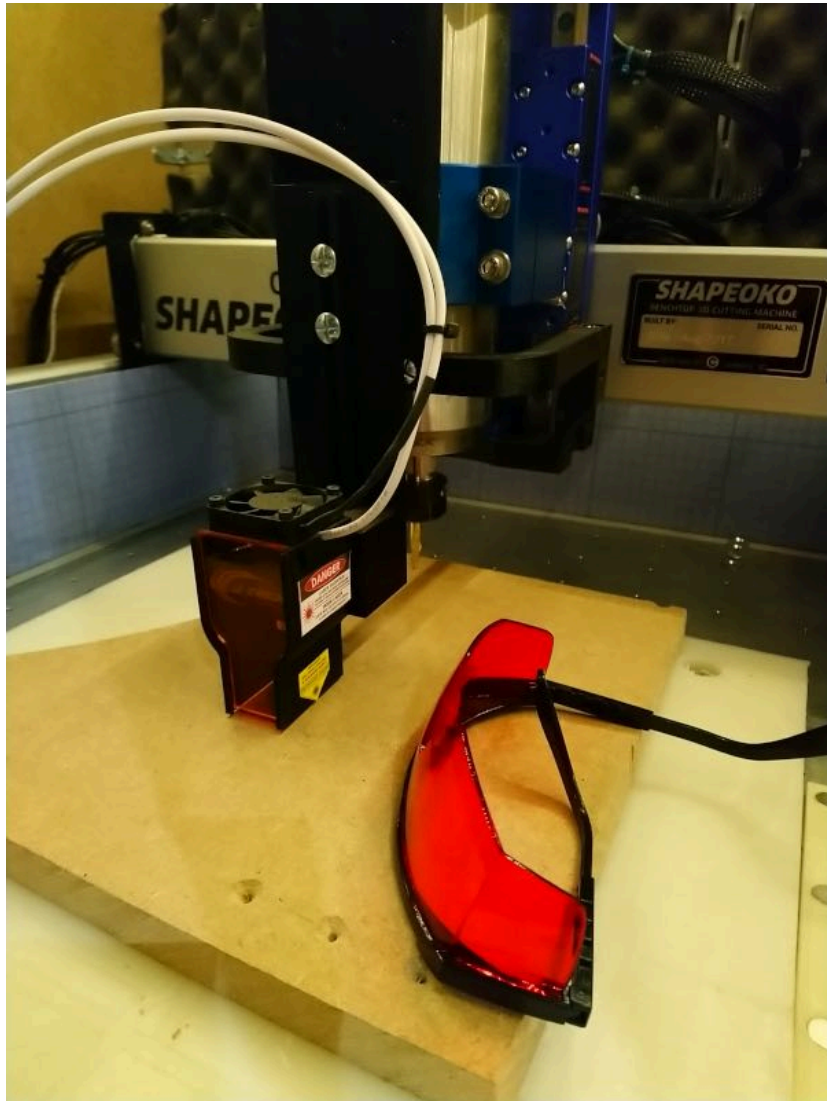
4) The laser is connected to a controller, that will usually:

- provide and modulate its input power based on an input analog signal (PWM)
- power the laser fan
- implement a variety of safety features (switches/interlocks)

Here's a picture of my controller (from the J-Tech laser kit):

5) The PWM signal driven by the Shapeoko controller will be used to modulate laser using G-code instructions. GRBL generates the PWM signal based on the requested spindle speed value, from 0V for 0 RPM, to 5V for the max RPM value configured in GRBL parameter $30. When using the Shapeoko in laser mode, the software generating the G-code will make use of that capability to control the laser power.

6) While the laser burns the material, it will produce fumes, which is bad for a couple of reasons:

- fumes are toxic, more so on some materials.
- fumes get in the way of the laser, reducing its efficiency and precision

So it's a good idea to add a ventilation system to extract fumes.

A final word on safety. It seems to me that the mininum one should do to use a laser module safely is:

- have the **laser power interlocked** with the presence of whatever physical protection/cover you are using: it must be impossible for power to get to the laser (voluntarily or by accident) if the protection is not present.
- wear proper **laser goggles** at all times as soon as the thing is POTENTIALLY turned on (that includes moments when the power if off, but under the control of the machine i.e. the G-code/controller). Never, ever trust a single element of software or hardware alone to keep you safe.
- **stay by the machine** while it is running. Seriously, don't burn down your house for a laser cut gone wrong.