Raspberry Pi camera calibration jig

This document describes how to build a calibration jig that illuminates a Raspberry Pi camera module with uniform-intensity, approximately-collimated light. Used in conjunction with a suitable RGB LED, it enables the sensor to be calibrated for colour response, allowing the vignetting and loss of saturation at the edge of the sensor to be compensated for in post-processing. It can also be used to calculate a suitable Lens Shading Table under some circumstances.

Bill of materials

Parts

- 1 x Raspberry Pi camera module
- 2 x M2x6mm screws
- 10 x M3x8mm screws
- 2 x 30mm O-rings
- 1 x white paper
- 3 x wires with female jumper connectors
- 1 x NeoPixel
- a little solder
- 1 x Arduino Mega
- 1 x Raspberry Pi
- 1 x SD card
- 1 x 5V micro-USB power supply
- 1 x keyboard, monitor, and mouse

Tools

- 1 x 1.5mm hex key
- 1 x 2.5mm hex key
- 1 x soldering iron
- 1 x wire strippers

printedpart

- 1 x camera mount
- 1 x long tube
- 1 x LED mount
- 1 x LED clamp

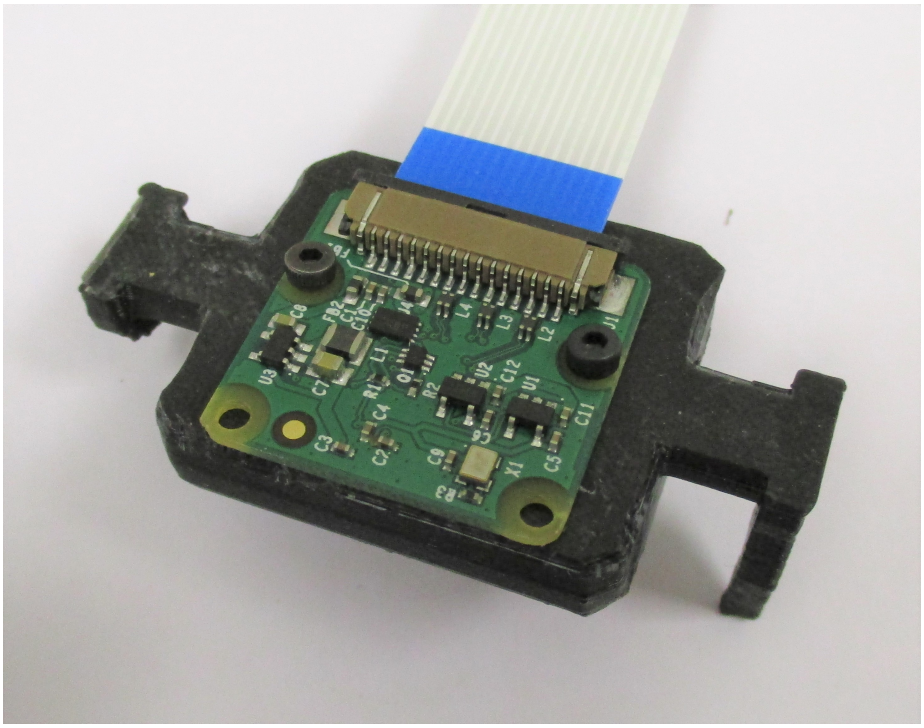
Assembly instructions

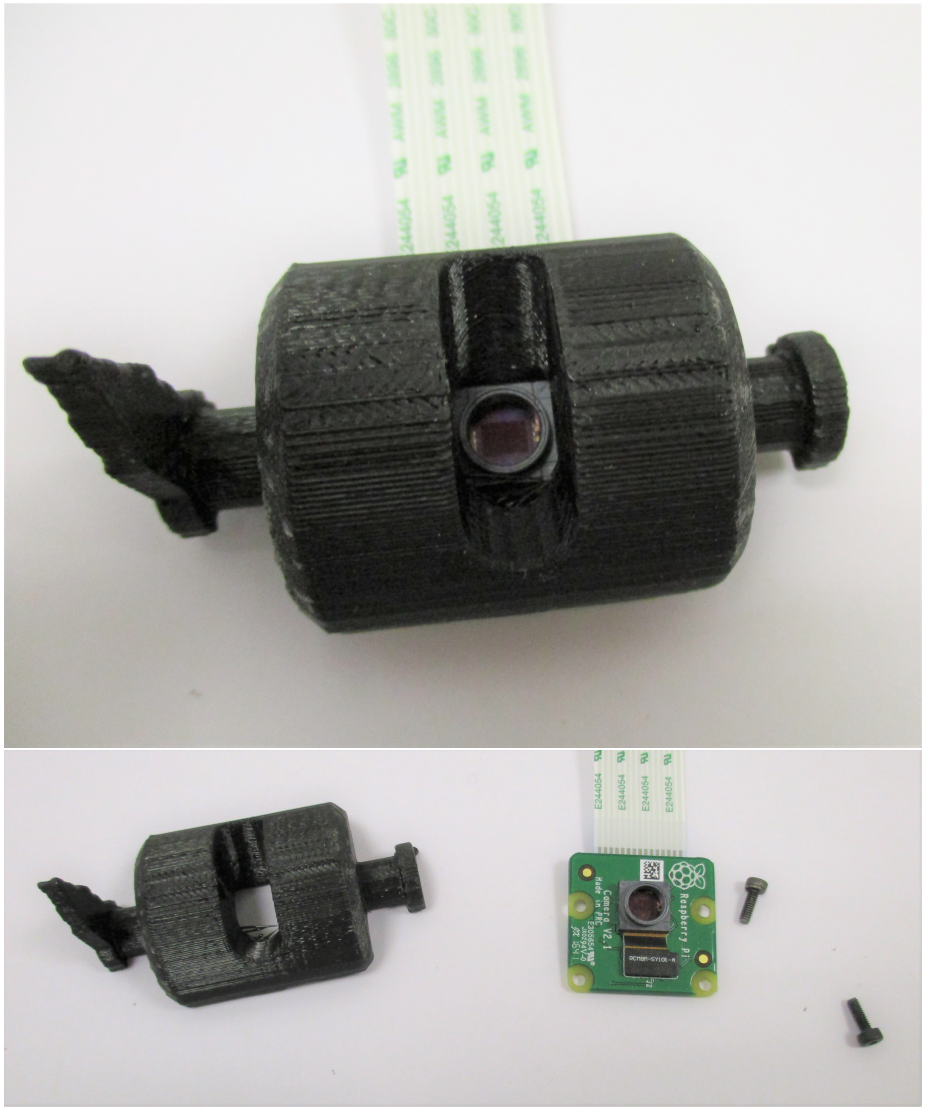
Step 1: Remove the lens from the camera module

First, remove the lens from the Raspberry Pi camera module. This is described in the OpenFlexure Microscope assembly instructions, but just consists of using the plastic lens tool (included with v2 of the camera module) to unscrew the lens. Be gentle, and take care not to damage the small ribbon cable connecting the sensor to the PCB.

Step 2: Fit the camera module into the mount

Place the camera module on the flat side of the camera mount and fix it in place with two M2x6mm screws. You will need a 1.5mm hex key.

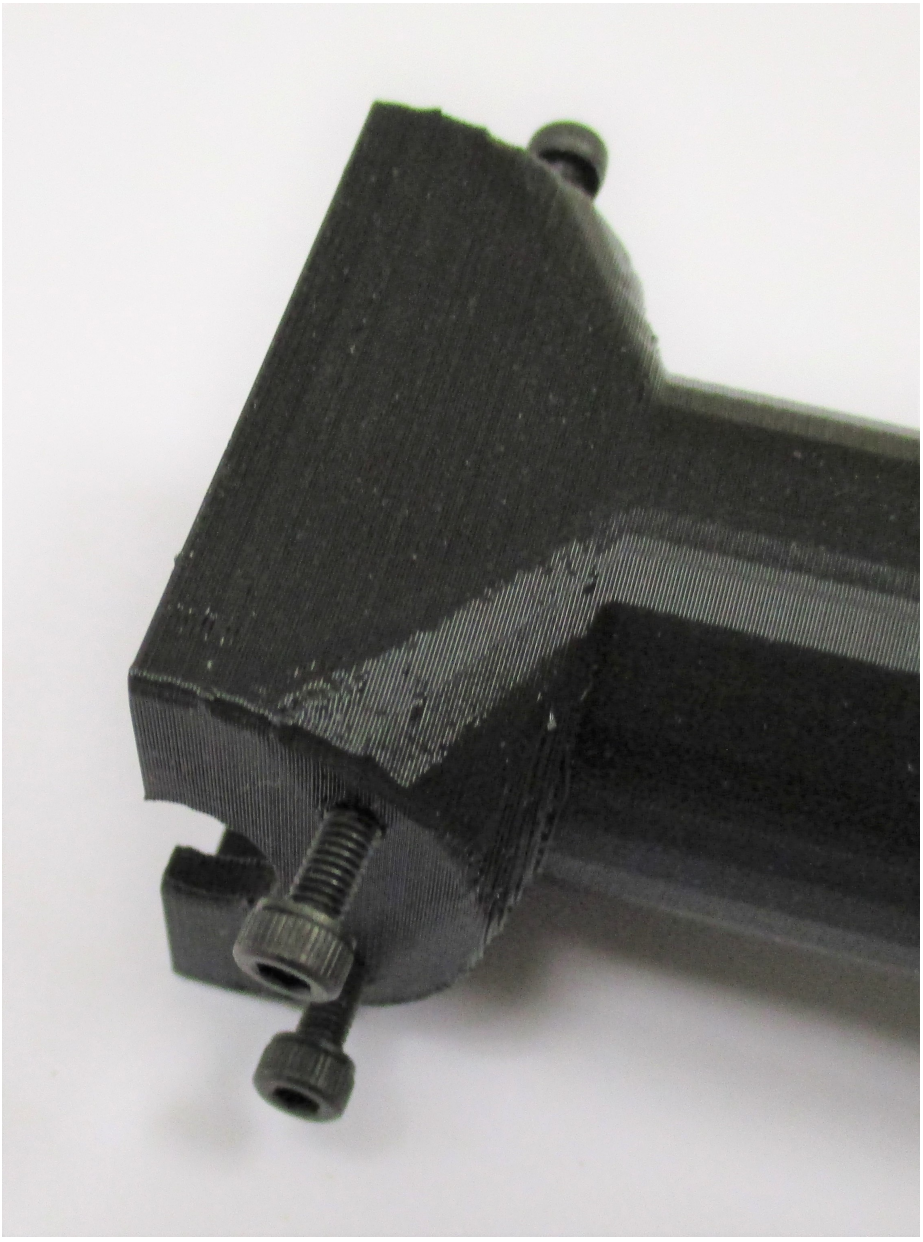




Step 3: Add screws to the tube

Screw four M3x8mm screws into the long tube using a 2.5mm hex key.

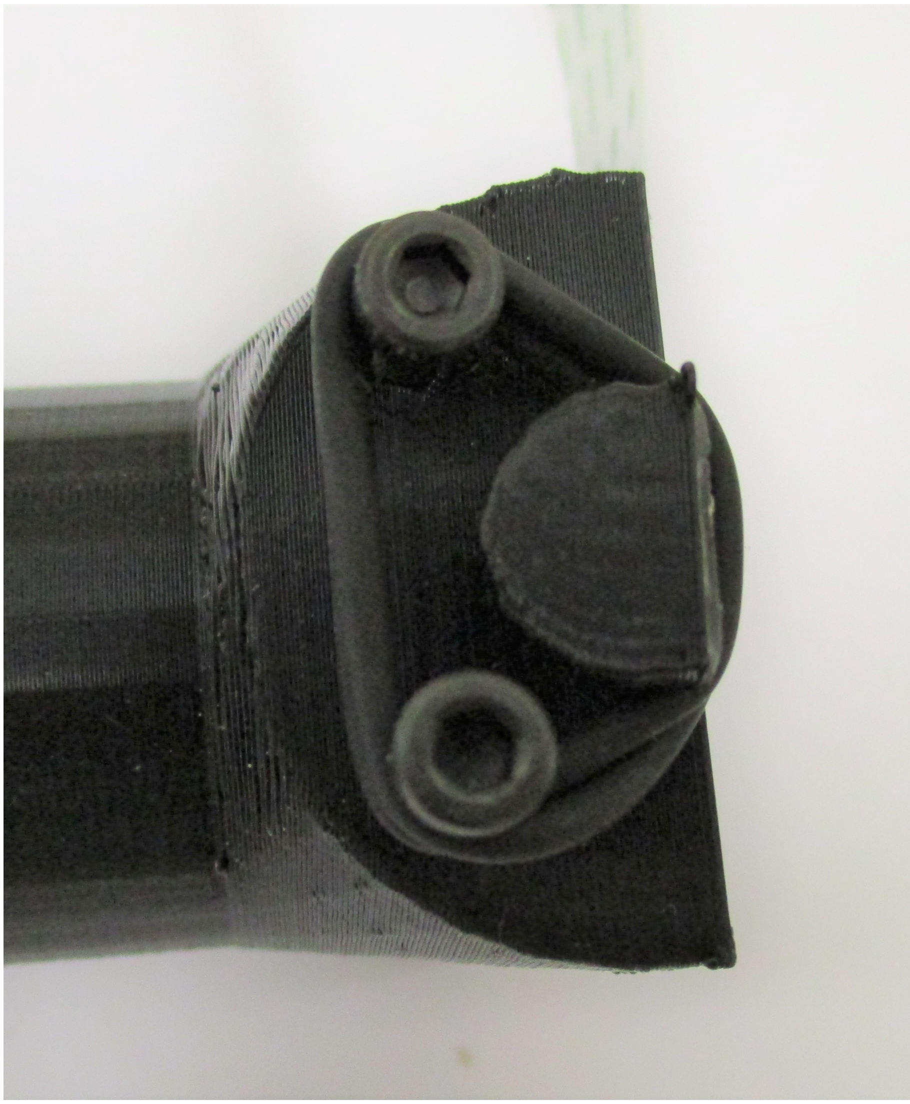
Wera
Hex-Plus
2,5

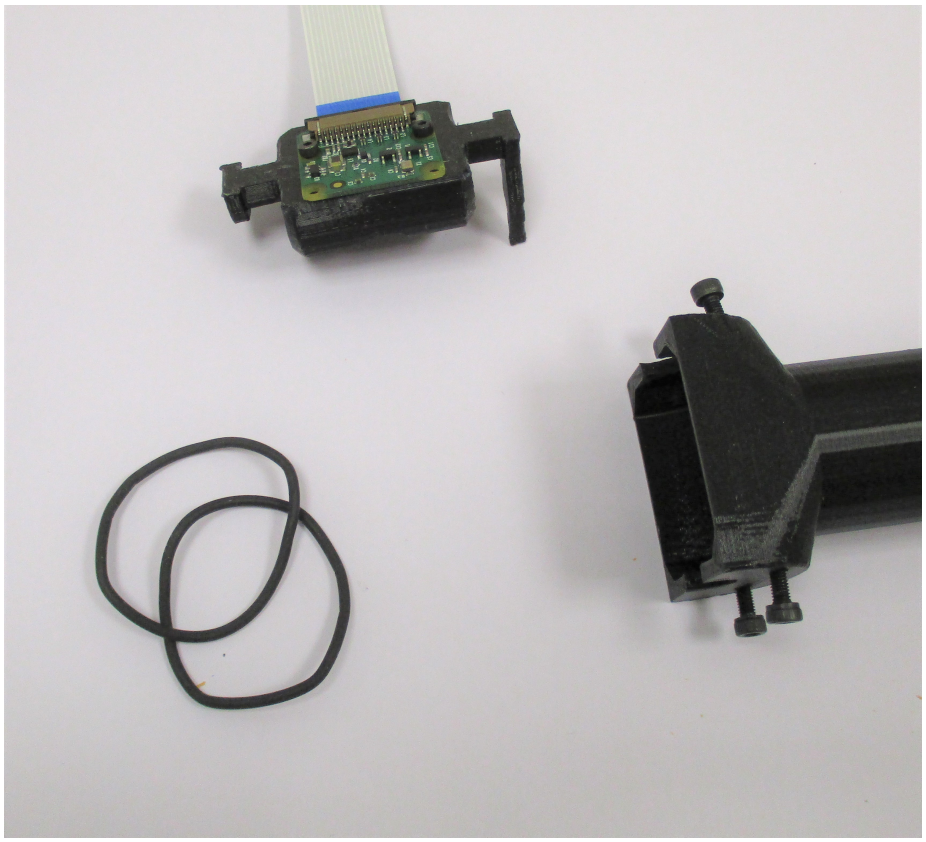


Step 4: Fit the camera mount into the tube

Place the camera mount into the long tube, and secure using two 30mm O-rings, one either side. The 30mm O-rings are wrapped around the M3x8mm screws and the protruding parts of the camera mount. Each O-ring is wrapped around

twice, to ensure the mount is held tightly.

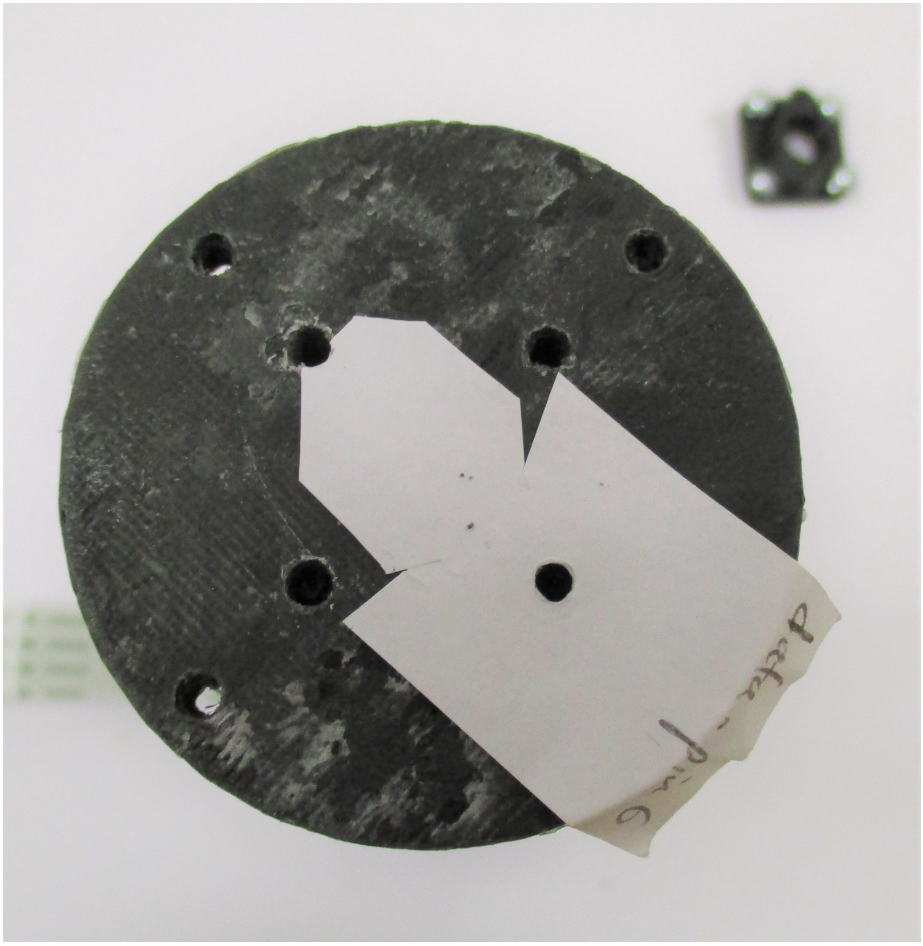


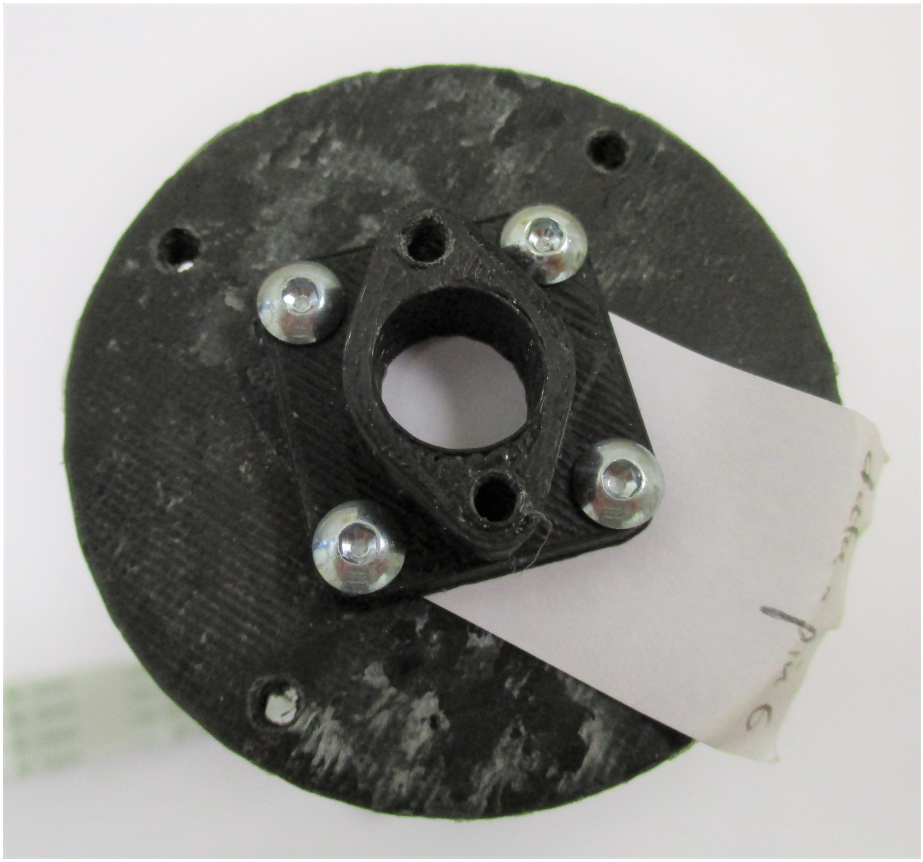


Step 5: Add the paper diffuser

Place the piece of white paper on the bottom of the long tube, then clamp it in place with the LED mount and four M3x8mm screws, using a 2.5mm hex key.

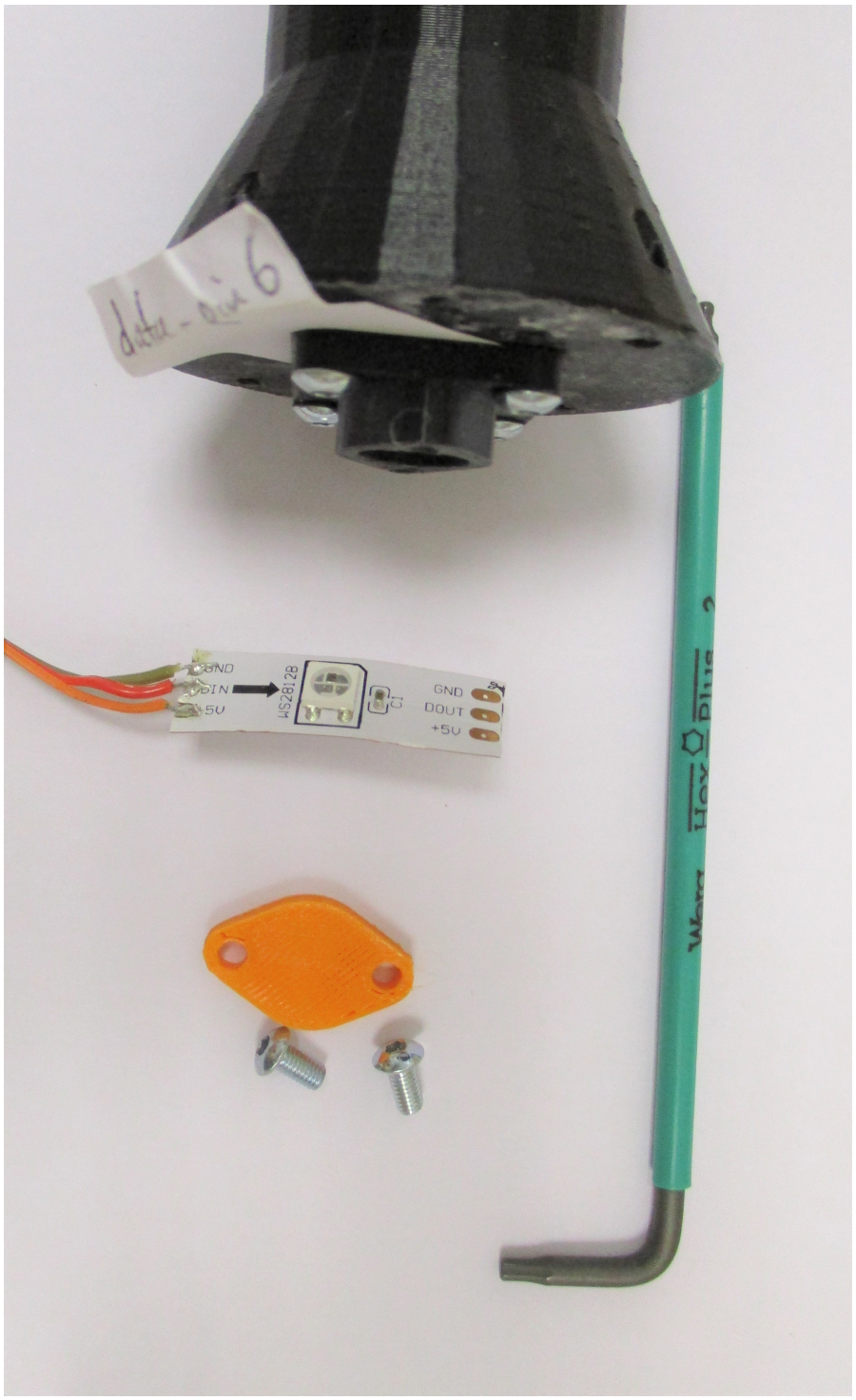

Hex-Plus 2

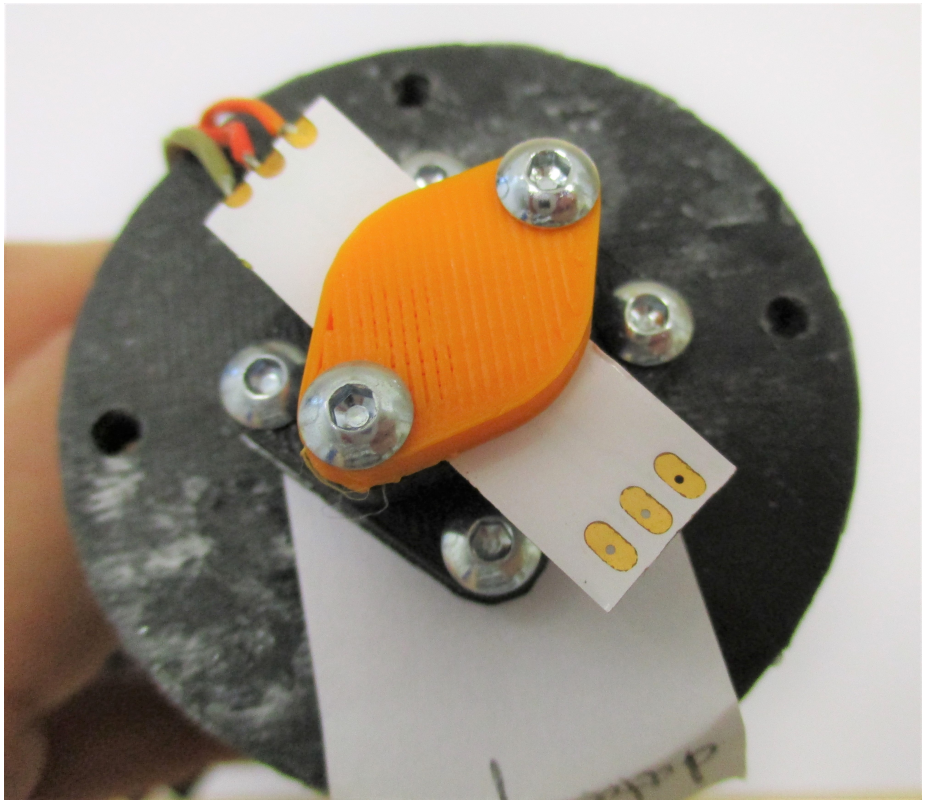




Step 6: Add the LED

Solder wires with female jumper connectors to the data and power pads on the NeoPixel. Clamp the NeoPixel onto the LED mount using the LED clamp and two M3x8mm screws, using a 2.5mm hex key. You will probably need a soldering iron, solder, and wire strippers


GND
DIN
5V
WS2812B
GND
DOUT
+5V



Step 7: Connect to electronics

Connect the NeoPixel to the Arduino Mega, wiring the 5V and 0V lines to ground and power on the Arduino, and the data line to digital pin 6. Connect the Raspberry Pi camera module to the Raspberry Pi. The arduino doesn't need a powers supply as it's powered via USB from the Raspberry Pi, and the Raspberry Pi will require an SD card, a 5V micro-USB power supply, and a keyboard, monitor, and mouse or some other way of controlling it (e.g. a network cable).

Included Files

After this section are other files, usually descriptions of parts and tools.

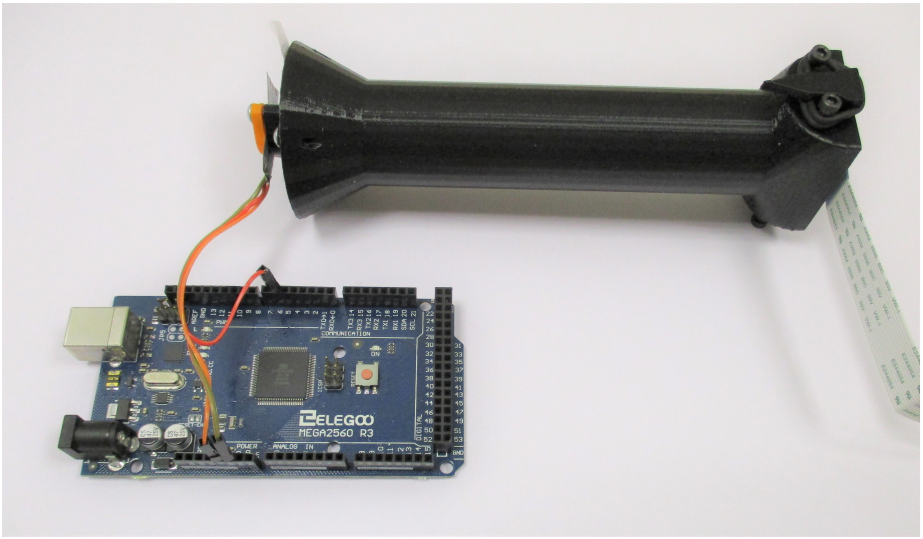


Figure 1:

Raspberry Pi Camera Module

We use almost exclusively the v2 camera module, which has a better sensor and a better lens. The design should also work with v1, though removing the lens will be considerably harder.

Newer camera modules come with an included plastic tool for removing the lens - this is much better than the printed tool and should definitely be used in preference.

M2x6mm screws

Details

- **Supplier:** Anglian Fasteners Limited
- **Supplier's part number:**
- **URL:** http://www.anglianfasteners.co.uk/
- **Material units:** NONE

These screws attach the Raspberry Pi camera board to the optics module. The exact details of the screws are unimportant, but the holes in the PCB are only 2mm in diameter.

M3x8mm screws

Details

- **Supplier:** Anglian Fasteners Limited
- **Supplier's part number:** 14315
- **URL:** http://www.anglianfasteners.co.uk/
- **Material units:** NONE

These screws attach the various parts of the jig together. They don't need to be particularly fine quality, and the type of head is not particularly important. We usually use either hex socket head or button head so they can be easily driven using a hex key. NB the bill of materials specifies a 2.5mm hex key; if you use button head screws, you may need a 2mm key instead, and if you use a different head type you will need the appropriate screwdriver.

Viton O ring, 30mm inner diameter, 2mm cross section

Details

- **Material:** Viton or Nitrile
- **Inner diameter:** 30mm
- **Cross-section:** 2mm
- **Outer diameter:** 34mm
- **Supplier website:** [http://www.simplybearings.co.uk/]

The O-rings function as springs, to pull the camera mount against the long tube. I use Viton O-rings, 30mm inner diameter, as they provide about the right force. You can substitute for rubber bands, but it's difficult to specify the size directly, and they tend to perish and snap in a few weeks. These are the same viton o rings used in the openflexure microscope, so we had plenty available.

White paper

A small (a few cm square) piece of white paper is used as a diffuser. There are no special requirements - other than you might need to cut or tear it to fit between the screws. Normal 80gsm printer paper is what we used, but it shouldn't be too sensitive.

Wires with female header connector

You will need three wires, which are bare wire on one end (for soldering to the NeoPixel pads) and finished with a female header connector. The easiest way to make these is by cutting a female-female jumper lead in half, though you can also crimp your own if you have a suitable crimping tool.

NeoPixel

We use an RGB LED for illumination - specifically, a single NeoPixel. We've used one LED cut out of a 30 LED per metre strip. There are plenty suppliers, official and unofficial, of these LEDs. You can use any form factor - but the strip is nice, because it will fit neatly into the clamp.

Solder

You will need solder to connect the wires to the NeoPixel. This can be any solder you have to hand - no special requirements.

Arduino Mega

We used an Arduino Mega to control the NeoPixel. This was because we had one available in the lab - almost any Arduino would do, though you might need to tweak the sketch slightly, or use different pins. These can be obtained from many different suppliers, for example RS Components.

NB we have assumed that your Arduino comes with an appropriate USB cable, for power and control. If you buy an unofficial clone, it may not - so you'll need to order one.

Raspberry Pi

Any model will do! NB if you buy a Pi Zero, only the Zero+ has a camera connector, and even that needs a special lead. Of course, if you're using a camera that's not the Raspberry Pi camera module, you can use whatever USB-compatible device you like. Bear in mind that the holes in the microscope stand are designed for a Model B, so Model A or Zero won't fit correctly.

The Raspberry Pi will need a suitable 5v power supply, an SD card, and most likely a keyboard, monitor, and mouse to function correctly.

SD Card

The Raspberry Pi will need an SD card for the operating system. This is a very standard part, available from many places e.g. RS Components. 8Gb is plenty for this experiment.

Raspberry Pi Power Supply

You will need a PSU for the Raspberry Pi, ideally one of the official ones (which provide a decent current, and are slightly over 5v). These can be obtained from many places, e.g. RS Components. NB the connector on the Pi 4 is different, so if you use one of those, you'll need the USB-C version of the power supply.

Keyboard, Monitor, and Mouse

In order to use the Raspberry Pi, you will need a USB keyboard and mouse, and a monitor with an HDMI (or micro-HDMI for the Pi 4) connector. Alternatively, you can run your Pi "headless" and connect with a wired or wireless network connection; instructions can be found online for this.

1.5mm hex key

You will need either an appropriately-sized hex key ("Allen key" in British parlance) or an appropriate screwdriver to tighten your M2 screws. If you have a different head type, you may need a different hex key, or indeed a slotted or cross-head screwdriver.

2.5mm hex key

You will need either an appropriately-sized hex key ("Allen key" in British parlance) or an appropriate screwdriver to tighten your M3 screws. If you have

a different head type, you may need a different hex key, or indeed a slotted or cross-head screwdriver.

Soldering iron

A soldering iron is probably needed in order to connect the wires to the NeoPixel. Any soldering iron should do - this is fairly basic soldering onto the pads of the NeoPixel's flex.

Wire strippers

You will need some wire strippers in order to remove the insulation from the wires. There are no particularly special requirements.

Camera mount

The camera mount is a semi-cylindrical block that mounts the camera, and allows it to be tilted within the calibration jig.

Printing instructions

The camera mount should be printed with the flat side on the print bed. This means the camera mounts onto the flat bottom of the part. It does not require support material, and if you use a brim you should be careful to remove it so it doesn't snag the mount or the delicate ribbon cable on the camera module.

STL Files

`camera_holder.stl`

Long tube

The long, ridged tube serves to collimage the light from the diffused LED, so it is incident on the camera module at a constant angle.

Printing instructions

The long tube should be printed vertically, with the end that mounts the LED on the bottom; this should be the orientation in the STL file. It does not require support material, but you may find that using a brim helps it to stick to the bed during printing.

STL Files

`illumination_tube.stl`

LED mount

The LED mount leaves a little space between the LED and the diffuser, so that the light can spread out a little and the colours can mix together (the three LEDs in the NeoPixel are not in exactly the same place).

Printing instructions

Print the LED mount with the large flat side on the print bed. No support material should be required - a brim may or may not be used, and if you use one you don't need to be too careful about removing it.

STL Files

`neopixel_adapter.stl`

LED mount

The LED clamp fits over the NeoPixel and fixes it in place.

Printing instructions

Print the LED clamp flat on the print bed - no support should be needed, but a brim might help it stick (and you don't need to be too careful about removing it). One side of the clamp is flatter than the other - this side should be on the bottom.

STL Files

`neopixel_clamp.stl`