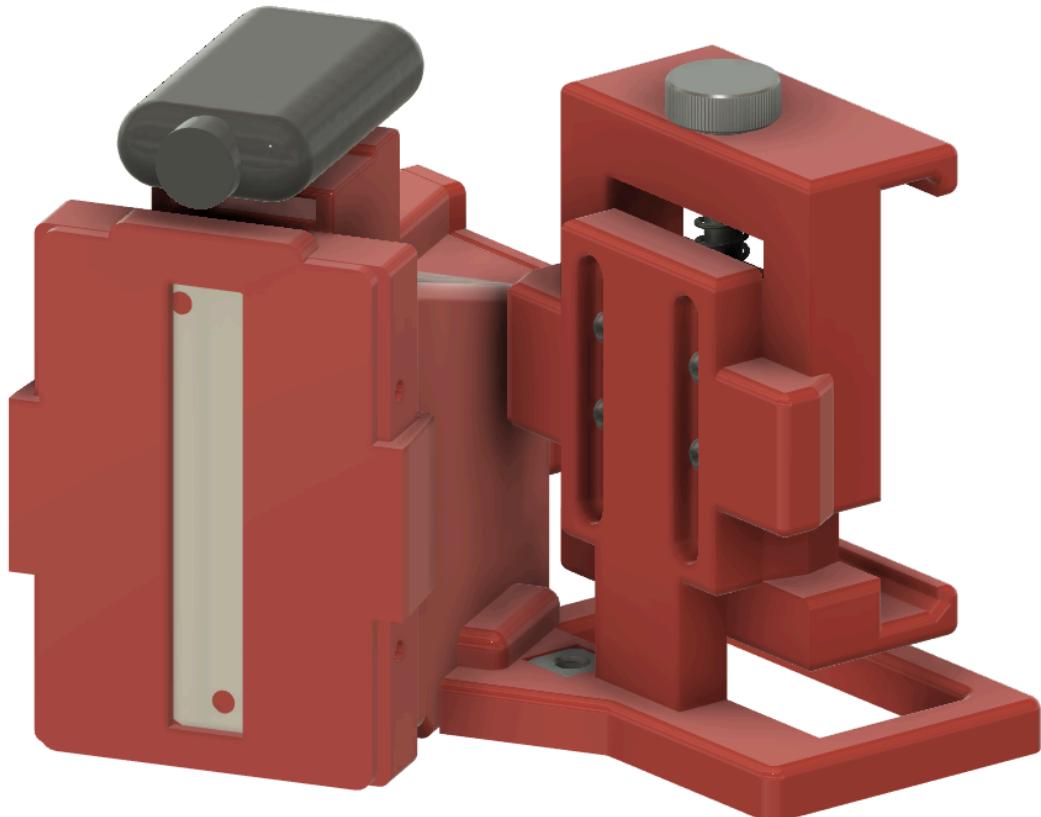


# Arducam Spectrometer Assembly Instructions

By Davis Fay

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## What You'll Need

### Printed Parts

- Print one of each of the following parts from the [GitHub directory](#):
  - Aperture\_Cap
  - Central\_Frame\_SP
  - Diffraction\_Cap
  - Grating\_Holder\_Inner
  - Grating\_Holder\_Outer
  - Phone\_Clamp\_Base
  - Phone\_Clamp\_Top
  - Phone\_Clamp\_Bottom
  - Aperture\_Cover (*optional*)
- Recommended print settings:
  - Nozzle Diameter: 0.4mm
  - Layer Height: 0.2mm
  - Infill Percentage: 15%-20%
  - Support Material: The only parts that require support material during printing are Central\_Frame\_SP and Phone\_Clamp\_Base; the rest will print without supports if oriented correctly.

### Preparing the Printed Parts

1. Remember to wear eye protection and to always practice proper knife safety when post-processing printed parts;
2. Use pliers and/or a sharp knife to remove any support material; and
3. All of the screw holes are designed to be self-tapping, but can sometimes be printed under-sized depending on slicer settings and printer precision:
  - a. If any of the screws are refusing to “bite” when first inserted and turned, check that the holes are wide enough to permit the screws to enter.
  - b. Drill out any undersized holes using a drill bit slightly smaller than the fastener being inserted; a 2.5mm or 7/64” bit both work for M3 screws.
  - c. Don’t drill too deeply - none of the self-tapping holes in the assembly are more than 12mm (~½”) deep.

## Hardware

- [Qty. 1] - [1,000 line per millimeter linear diffraction grating](#)
- [Qty. 2] - [9mm snap-off box cutter blades](#)
- [Qty. 2] - [M1.6 x 0.35mm, 12mm-long machine screws](#)
- [Qty. 12] - [M3 x 0.5mm, 10mm-long machine screws\\*\\*](#)
- [Qty. 2] - [1/4" x 20 square nut](#)
- [Qty. 1] - [0.284" ID compression spring](#) (or equivalent)
- [Qty. 1] - [1/4"-20, 2 inch long thumbscrew](#)

\*\* *Note - these fasteners are recommended, but may be replaced with any wood screw, sheet metal screw, [thread-forming screw](#), or machine screw of the same approximate diameter and length. If alternative fastener(s) are used, be sure to include the correct driver for them instead of the 2mm Allen key from the "Tools" list below.*

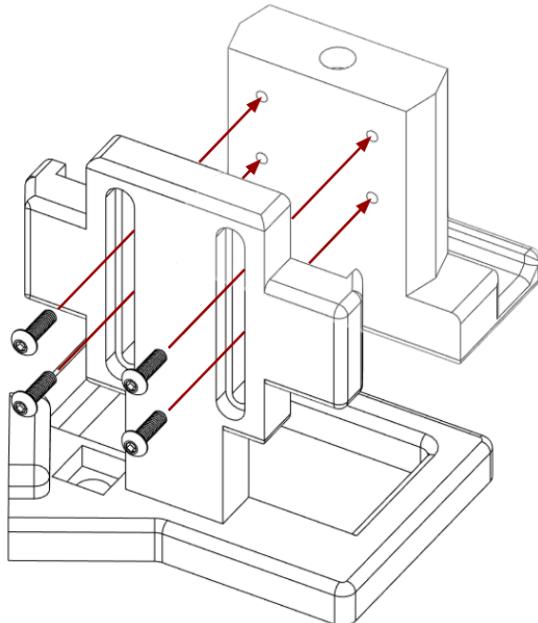
## Tools

- Safety goggles
- Scissors
- Pliers
- A small, sharp knife
- 2mm Allen key
- Phillips head screwdriver (P1)
- Hand drill (for drilling out undersized holes if needed)
- A roll of duct tape, gaffer tape, or equivalent opaque tape
- Glue, such as Elmer's glue or cyanoacrylate (super glue)
- Sandpaper (any grit)
- Glue stick (optional)

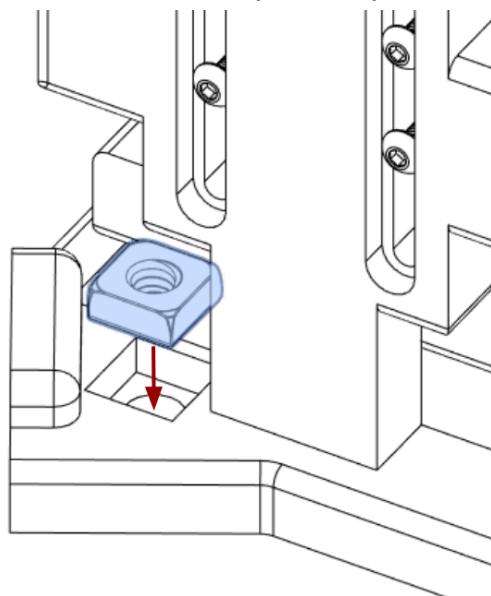
## Instructions

### Assembling the Smartphone Stand

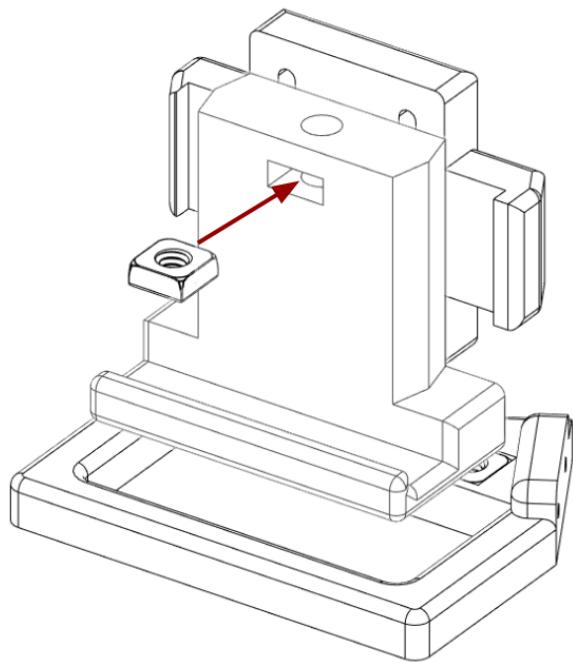
1. Select the following:
  - a . Phone\_Clamp\_Base
  - b . Phone\_Clamp\_Top
  - c . Phone\_Clamp\_Bottom
  - d. Two 1/4"-20 nuts;
  - e. Thumbwheel;
  - f. Spring;
  - g. Four (4) M3 screws;
  - h. 2mm Allen Key;
  - i. Glue; and
  - j. Sandpaper.
2. Place the phone clamp base on a flat surface with the pentagonal side down, such that the rectangular cutout in the bottom of the stand is on the opposite side of the vertical segment from you;
3. Take the clamp bottom part and hold it against the base part such that the four holes in the back of the clamp can be seen through the vertical slots in the stand;
4. Use the 2mm Allen key to insert one of the M3 screws through one of the vertical slots in the stand and into the corresponding hole in the lower row of the four holes on the back of the clamp;
5. Tighten the screw into the hole until the two printed pieces are held loosely together, such that:
  - a. The mating faces of the two parts should be flush to one another;
  - b. The clamp part should be able to slide and rotate relative to the base part with no more than light resistance.
6. Repeat Steps 4-5 for the other three screws until all four holes in the clamp part are filled - the clamp should still be able to slide up and down relative to the stand with no more than light resistance;



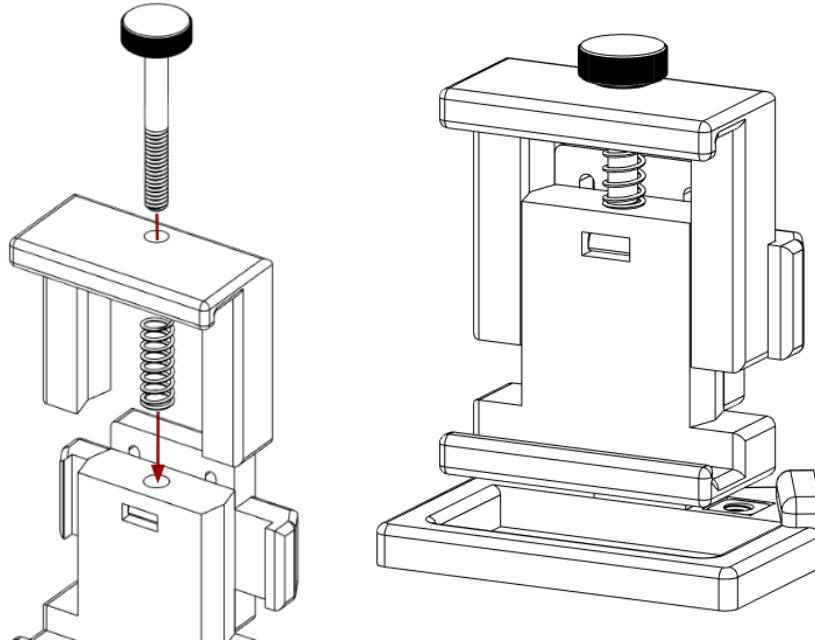
7. Take one of the 1/4"-20 square nuts, scuff one side of it with the sandpaper, and add a few drops of glue to the scuffed side;
8. Insert the square nut glue side-down into the square depression in the stand part;



9. Take the second 1/4"-20 square nut and insert it into the rectangular slot in the other side of the clamp part, such that the threaded hole in the nut aligns with the hole in the top of clamp;

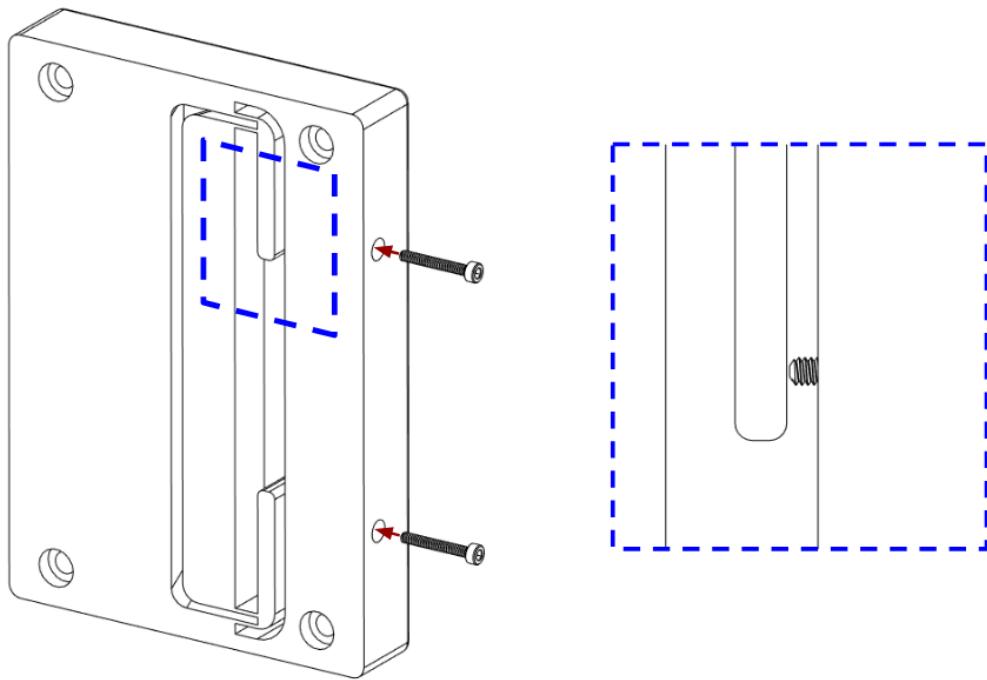


10. Take the spring and place it over the hole in the bottom clamp part, then slide the top clamp part over the bottom clamp part until the spring rests between them; and
11. Insert the thumbscrew through the spring and both clamp halves, then thread it into the recessed square nut until the spring is under light tension.

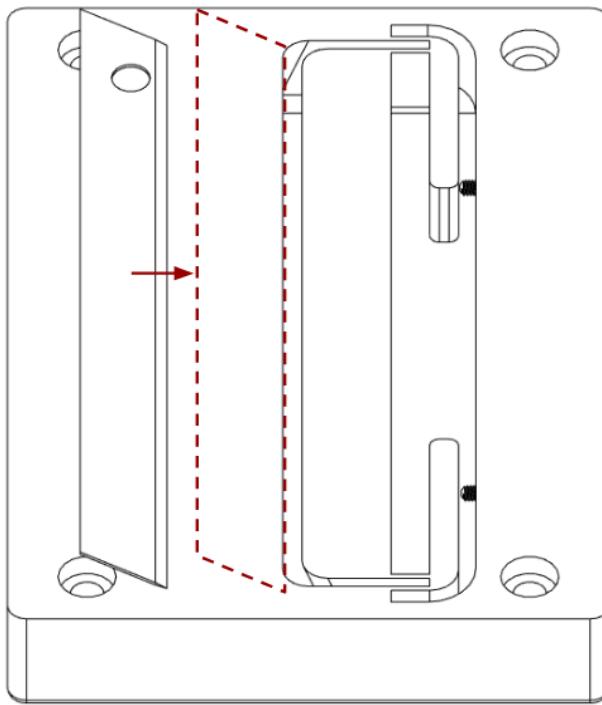


## Assembling the Aperture Cap

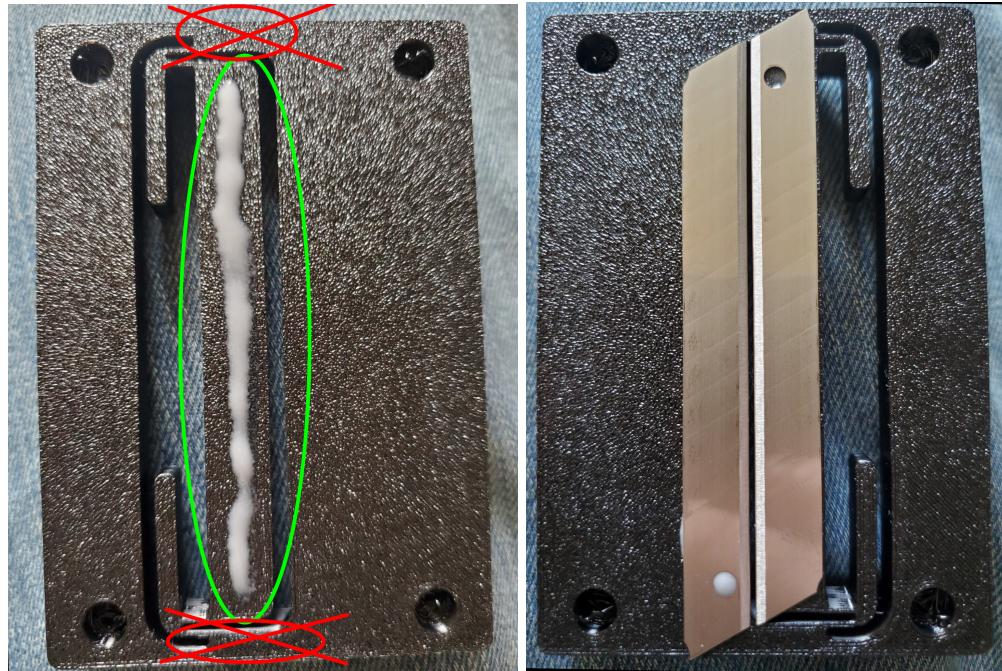
1. Select the following:
  - a. Two razor blades;
  - b. The printed aperture cap part;
  - c. The two M1.6 screws;
  - d. 1.5mm Allen key (for M1.6 screws);
  - e. Glue; and
  - f. Tape.
2. Insert one of the two M1.6 machine screws into one of the holes in the vertical side of the aperture cap printed part;
3. Using the 1.5mm Allen key, tighten the M1.6 screw until the tip of the screw just barely touches the inside of the small vertical tab indicated below - this will be used later for fine adjustment of the aperture slit;



4. Repeat Steps 2 and 3 for the other M1.6 screw;
5. Place the aperture cap on a flat surface with the “front” face of the part pointing upwards (i.e. convex side down);
6. Take one of the razor blades and lay it on the left side of the upper face of the part, with the sharp edge facing towards the slit in the middle;
7. Arrange the razor blade such that the sharp edge of the blade is parallel with the left side of the central slit and just barely overlaps it;



8. Lift the razor blade out of the way and carefully apply a few drops of glue to the area where it lay on the printed part;
9. Quickly put the razor blade back in position and confirm that it is correctly aligned, then press firmly on the top of the razor blade for 60 seconds while the glue cures;
10. Repeat Steps 6 through 9 for the other razor blade, with the following changes:
  - a. The razor blade blade should initially be placed on the right side of the face of the part with the sharp edge pointing towards the center;
  - b. The sharp edge should overlap, and be parallel to, the inner edge of the central tab on the 3D printed part;
  - c. Glue should only be applied to the surface of the central tab (i.e. inside of the curved “slot” in the middle of the part), and should not be applied to the outer edges of the 3D printed part that the razor blade overlaps (see below); and
  - d. The two razor blades should be as parallel as possible, and should be no more than 1mm apart (but not touching).



11. Allow the glue to set and secure the razor blade(s) in place before proceeding;
12. Use the two M1.6mm screws in the side of the aperture cap to calibrate the width of the slit between the two razor blades:
  - a. Alternate tightening each of the M1.6 screws using the 1.5mm Allen key until the slit is approximately 0.1mm wide;
  - b. The slit is correctly calibrated when the corner of a sheet of printer paper can pass between the razor blades with only light resistance at any point along the slit's length.



13. Once the razor blades are correctly positioned and aligned, use strips of tape to cover every opening in the front face of the aperture cap except the central vertical slit.

- a. (Optional) A 3D-printed cover (Aperture\_Cover) can be used in place of tape if desired.
- b. If using the 3D-printed cover, do not install it yet - it is added after the aperture cap has been installed onto the rest of the spectrometer assembly during the next stage.



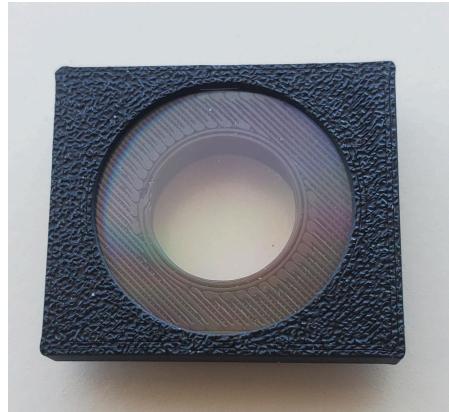
#### Assembling the Diffraction Grating Mount

1. Select the following:
  - a. the two “lens cap grating” 3D-printed parts;
  - b. the “diffraction cap” 3D-printed part;
  - c. one of the purchased diffraction gratings\* ; and
  - d. a sharp knife (e.g., an Xacto knife or razor blade).
2. Caution: Do not touch the diffraction grating material with ungloved hands, as skin oils will smudge the grating and distort the resulting spectrograph;
3. Take the outer half of the 3D printed grating holder (the larger one) and place it on a flat surface as follows:
  - a. The “hollow” side of the printed part (with the rectangular cavity in it) should be facing upwards; and

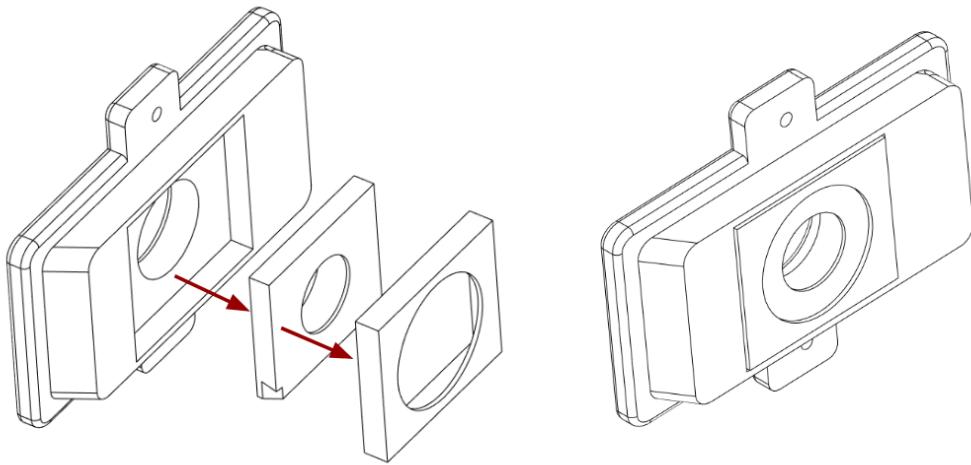
- b. When looking down at the printed part the two short sides of the rectangle should be the left and right sides, and the two long sides should be top and bottom.
- 4. Lay the diffraction grating so the rainbow is perpendicular to the wide edge of lens cap, the premade squares are easier to align than the sheets, then just cut it out roughly within the cap shape so it can rest inside and snap in place without bends or wrinkles;



- 5. Use the knife to cut along the inside perimeter of the printed part to create a rectangle of diffraction medium that is slightly smaller than the rectangular cavity;
- 6. Before proceeding, confirm that the cut sheet of diffraction medium lies flat within the outer 3D printed part and that it is free from smudges and debris;
- 7. Take the inner half of the grating holder and place it on top of the outer printed part with the diffraction grating laying inside of it\*\*;
- 8. Press firmly and evenly downwards on the back of the inner printed part until it is fully inserted into the outer printed part, as shown below; and ensure there are no bends or wrinkles in the plastic sheet. You could substitute the plastic for glass diffraction grating but it is much more expensive. You can even use a piece of a CD with the covering stripped off if you look at an older DIY spectrometer manual.



9. Take the combined inner and outer lens cap grating partsX and insert them into the rectangular depression in the back of the diffraction cap 3D-printed part\*\*, such that the diffraction grating is closest to the back surface of the diffraction cap (as seen below).



*\*Note: If creating the diffraction grating rectangle from a source other than the one listed at the beginning of these instructions, ensure that:*

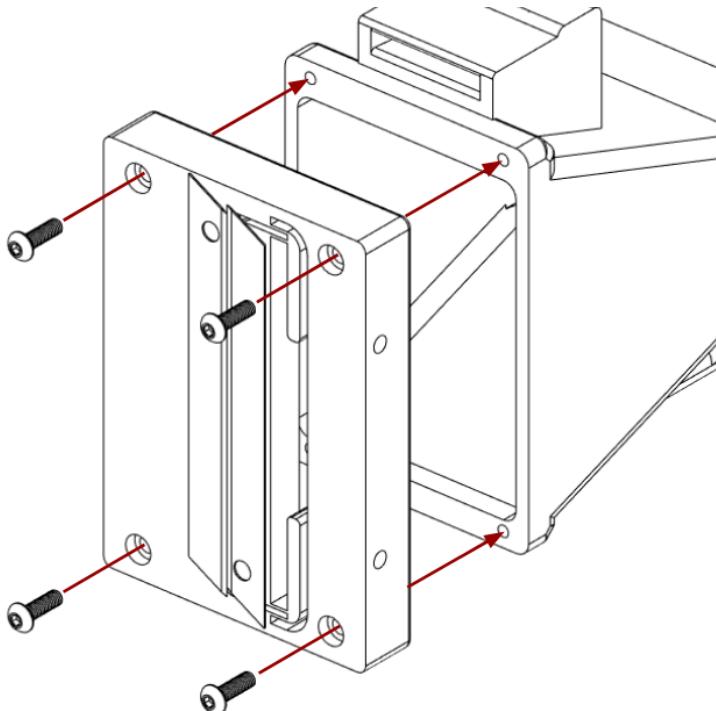
- *The optical properties of the medium are similar (e.g. number of lines per millimeter);*
- *The grating is large enough to completely cover the inside of the outer lens cap grating printed part when laid upon it; and*
- *The grating lines are parallel with the short sides of the rectangle (i.e. vertical with respect to the orientation of the device).*

*\*\*Note - Print settings or variations in the printed parts can interfere with the assembly of the lens cap grating. If the printed parts fit together too loosely, use tape or a carefully-applied drop of glue to stick them together. If the printed parts don't fit together at all, gently sand the outer edges of the inner piece and test the fit again before adding the diffraction grating material between them.*

### Assembling the Spectrometer

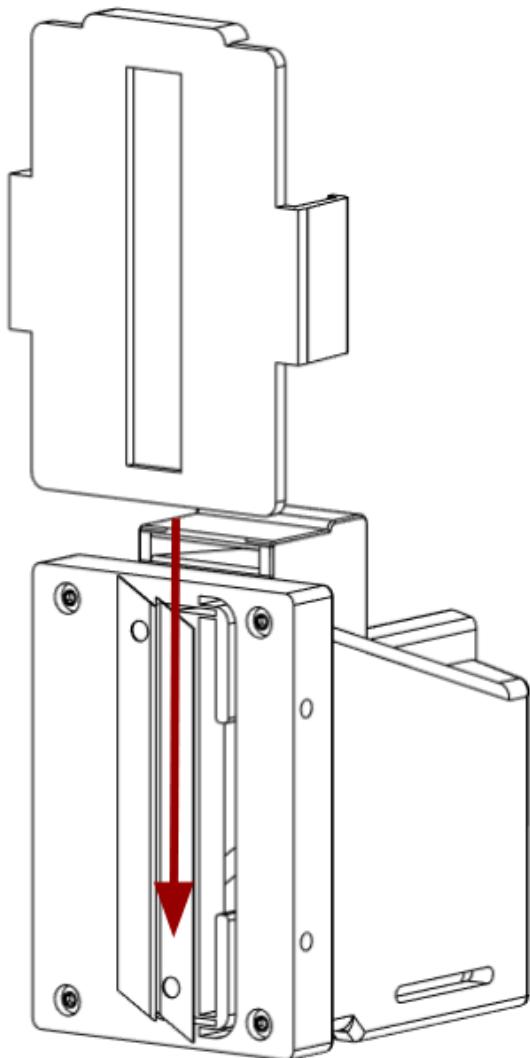
1. Select the following:

- a. the aperture cap assembly from earlier;
  - b. the central frame printed part;
  - c. the diffraction cap assembly from the previous step;
  - d. the (optional) 3D-printed front cover;
  - e. six (6) of the M3 screws; and
  - f. the 2mm Allen key;
2. Place the central frame part on a flat surface as follows:
    - a. The end with the larger of the two openings is facing upwards; and
    - b. The side with the handle in it is facing towards you.
  3. Take the aperture cap assembly and place it on top of the central frame as follows:
    - a. The flat side of the aperture cap should face outwards; and
    - b. The side of the aperture cap with the two M1.6 screws in it should be on the right.
  4. Take one of the M3 screws and insert it through one of the corner holes in the aperture cap so that it sits against the corresponding hole in the central frame;
  5. Use the 2mm Allen key to tighten the M3 screw until it holds the aperture cap and the central frame together, but do not fully tighten yet;
  6. Repeat Steps 4 and 5 for the other three M3 screws, using a diagonal “X” pattern;

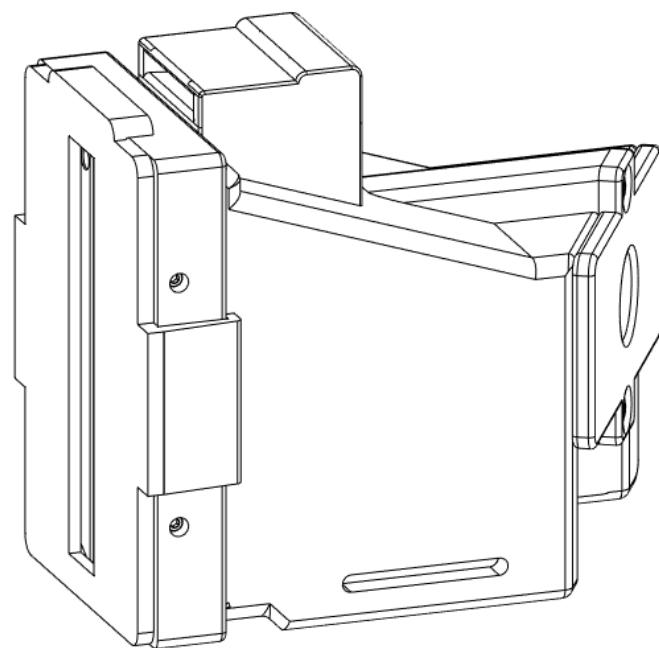
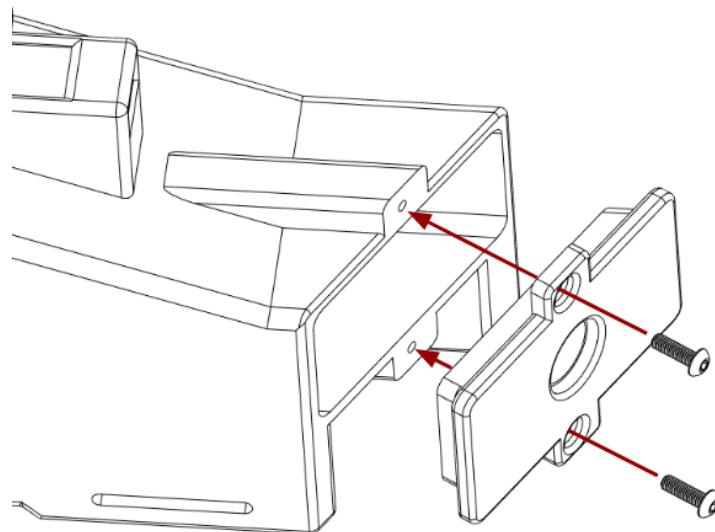


7. Confirm that the aperture cap and the central frame are flush and are oriented correctly;

8. Use the 2mm Allen key to fully tighten the four M3 screws, following the same "X" pattern as in Step 6;
9. If using the 3D-printed aperture cover, place the bottom edge of the cover against the aperture cap and slide it from the top face of the aperture cap downwards, as shown below;



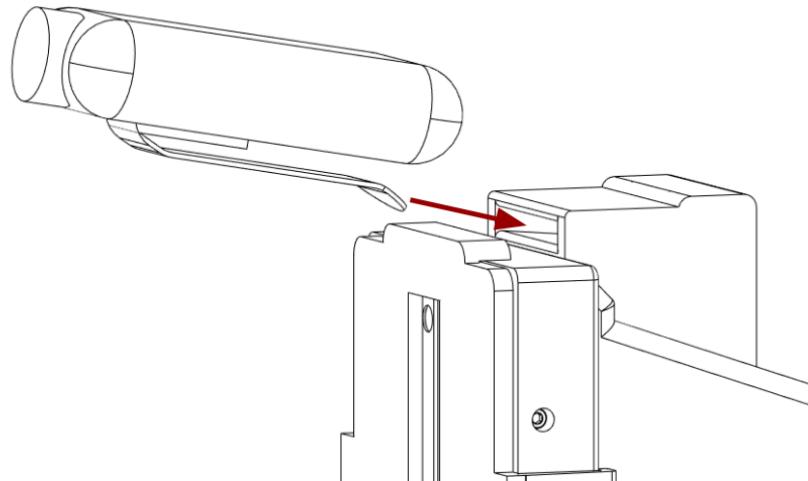
10. Take the diffraction cap assembly and place it over the open end of the central frame part such that the diffraction grating itself is inside of the frame; and
11. Use the 2mm Allen key to secure the diffraction cap assembly in place on the frame with two of the M3 screws, as shown below.



(15)

## Installing the Light

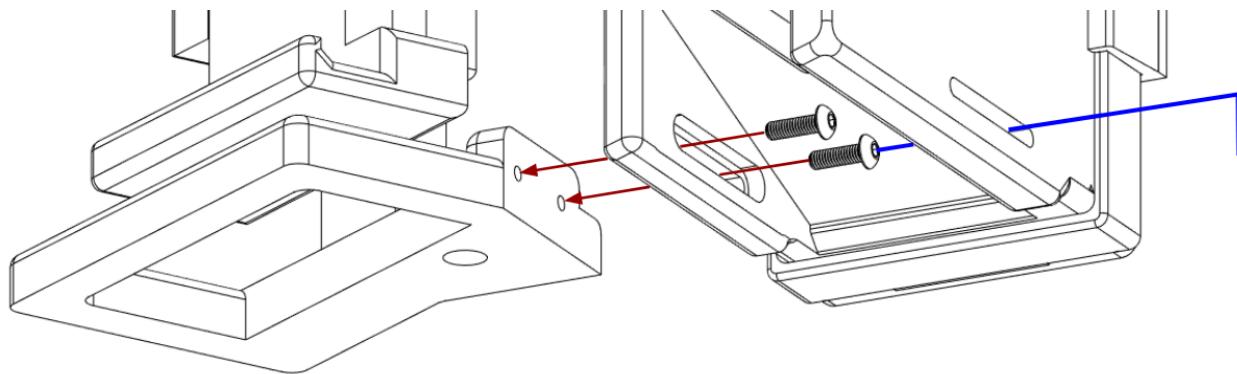
1. Select the following:
  - a. the spectrometer assembly from the previous step; and
  - b. The LED light.
2. Hold the LED flashlight so that the metal pocket clip on it points downwards;
3. Align the clip on the flashlight with the rectangular hole in the top of the spectrometer frame;
4. Slide the end of the clip into the rectangular hole until the LED light is secured in place:
  - a. If using the recommended flashlight model from the materials list, the light should click into place once the clip has been inserted a certain depth into the rectangular hole.
  - b. If not, it may be necessary to use some tape or glue to firmly secure the light in place on top of the frame.



5. Turn the light on and off to confirm that the light works and that the button is easily accessible.

## Attaching the Phone Mount to the Spectrometer

1. Select the following:
  - a. the spectrometer assembly from the previous step;
  - b. the phone mount assembly from earlier;
  - c. two (2) M3 screws; and
  - d. the 2mm Allen key.
2. Place both assemblies on a flat surface and arrange them as follows:
  - a. the spectrometer assembly is facing away from you, i.e. the aperture side points away from you; and
  - b. the phone clamp is facing towards you, i.e. the “C” profile formed by the two halves of the clamp opens towards you.
3. Slide the base of the phone mount towards the spectrometer assembly until the raised face of its base (with the two holes in it) comes into contact with the left side of the spectrometer;
4. Confirm that the holes in the base of the phone clamp are visible through the slot in the bottom-left “foot” of the spectrometer frame;
5. Insert one of the M3 screws through the slot in the bottom-left foot of the spectrometer frame and into one of the two holes in the phone clamp base;
6. Tighten the M3 screw until the two parts are held flush to one another, but do not fully tighten it yet:
  - a. The two parts should be able to slide relative to one another with no more than light resistance;
  - b. If necessary, the 2mm Allen key can be inserted through the accompanying slot in the lower-right foot of the spectrometer frame in order to reach the screw inserted in the lower-left foot.



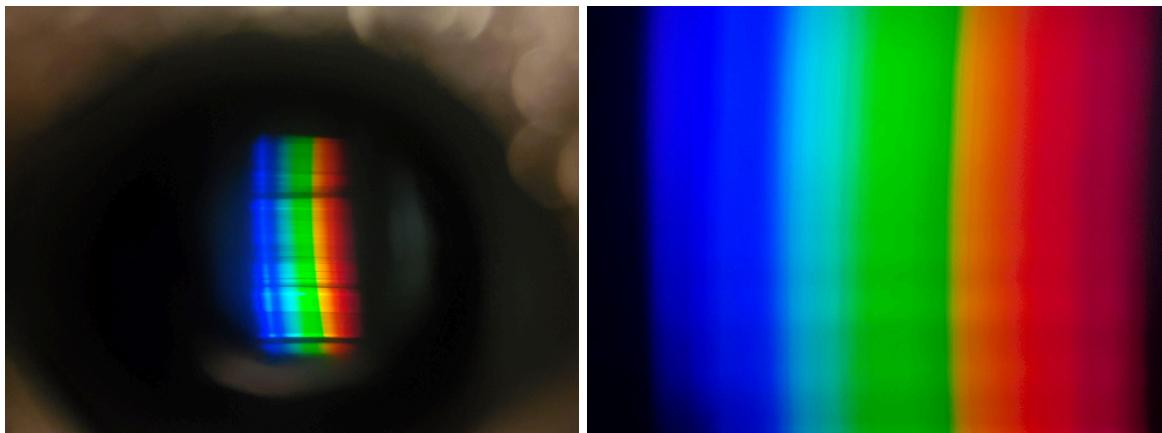
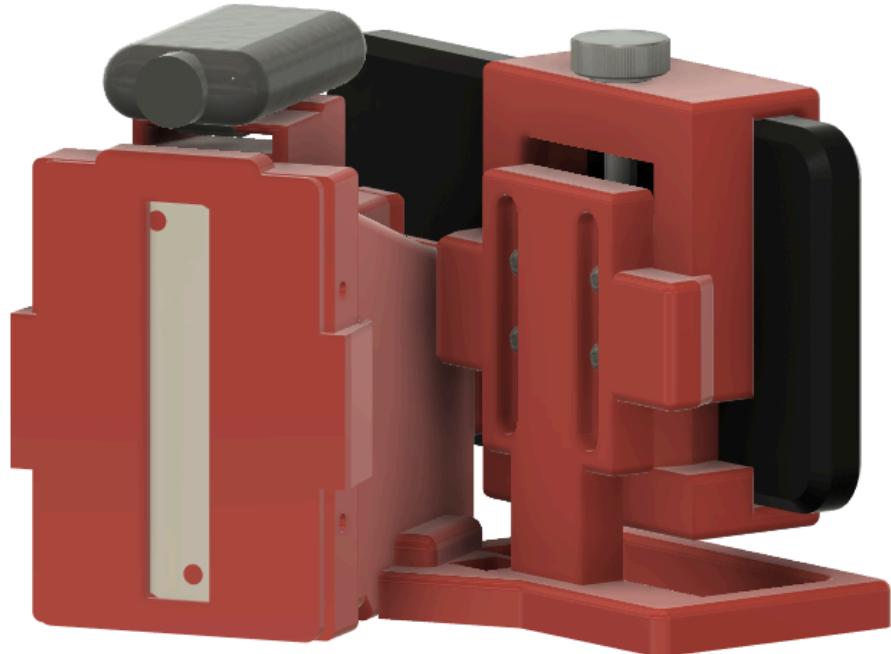
7. Repeat Steps 5-6 for the other hole in the phone stand base, such that the phone stand and spectrometer can slide linearly relative to one another but can't twist or separate.

## Aligning the Optics

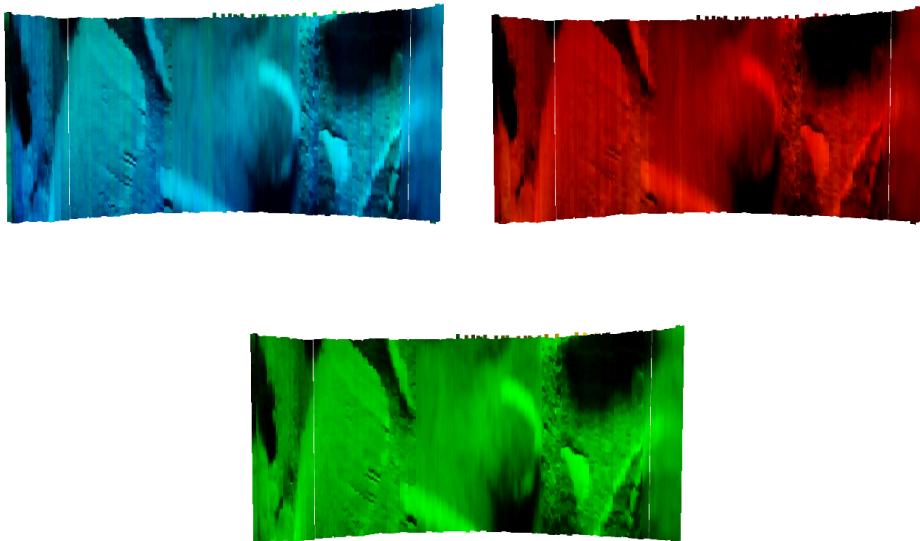
1. Select the following:
  - a. The combined spectrometer assembly from the previous stage; and
  - b. The smartphone that is to be used for the experiment;
2. Insert the smartphone into the phone clamp with the screen facing towards you, i.e. such that the camera in the phone is facing the spectrometer assembly;
3. The position of the phone camera relative to the spectrometer assembly in the following three ways:
  - a. To adjust the vertical position of the camera, hold the phone clamp base with one hand and move the clamp assembly up or down with the other;
  - b. To adjust the horizontal position of the camera (i.e. left-to-right within the clamp), loosen the thumbscrew on top of the phone clamp assembly and slide the phone back and forth, then re-tighten the thumbscrew; and
  - c. To adjust the normal distance between the plane of the camera and the face of the diffraction cap on the spectrometer, loosen the screws in the lower-left foot of the spectrometer frame and slide the phone clamp base forwards or backwards, then re-tighten the screws.
4. Using the three methods described in Step 3, align the smartphone with the spectrometer such that:
  - a. The camera is centered on the hole in the aperture cap that opens into the interior of the spectrometer;
  - b. The back face of the phone and the outer face of the diffraction cap are parallel to one another; and
  - c. The phone is pressed evenly and securely against the outer face of the diffraction cap in order to block out as much external light as possible.
5. The camera's autofocus should take care of tuning the image, else you can control the camera settings in your camera app or while using the spectral identification software we provided.

Try it out here: <https://wonnx-cameraid.netlify.app/>

## Assembly Complete!



Turn on the camera app on your phone, turn on the flashlight, and shine it off a blank piece of printer paper. This should be your result. Important note: different cameras can give dramatically different results based on the exposure presets, not all matching lab results but still usable for pattern matching with machine learning/statistical analysis.



Hyperspectral scan results using the phone's onboard motion sensors.  
All done in-app: <https://wonnx-cameraid.netlify.app/>

## **Next Steps**

Check the [GitHub page](#) for instructions on configuring the software and using the spectrometer.

The spectrometer can be mounted in a variety of ways:

- When placed on a flat and level surface, the spectrometer is designed to stay level to that surface and can be placed or slid horizontally along it.
- The 1/4"-20 nut in the bottom of the spectrometer handle can be used to mount the spectrometer on a standard U.S. tripod, gimbal, or similar device, although it is recommended that all of the connections (especially the phone clamp) be checked for security prior to mounting this assembly.