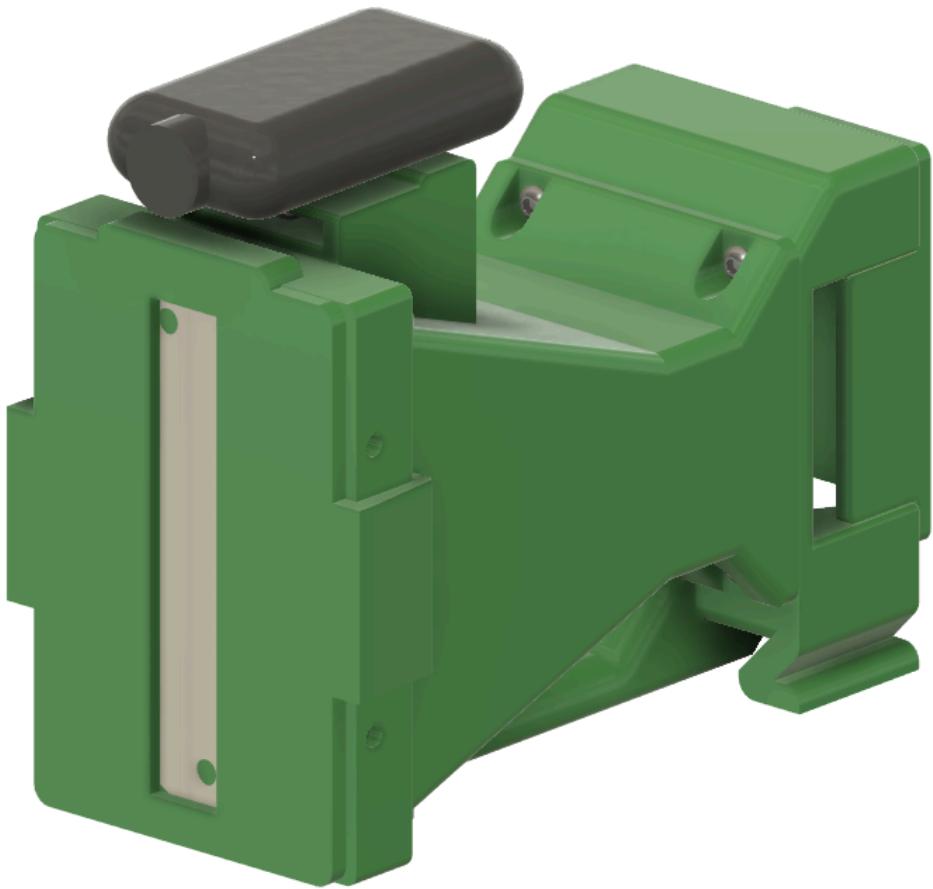


Arducam Spectrometer Assembly Instructions

By Davis Fay

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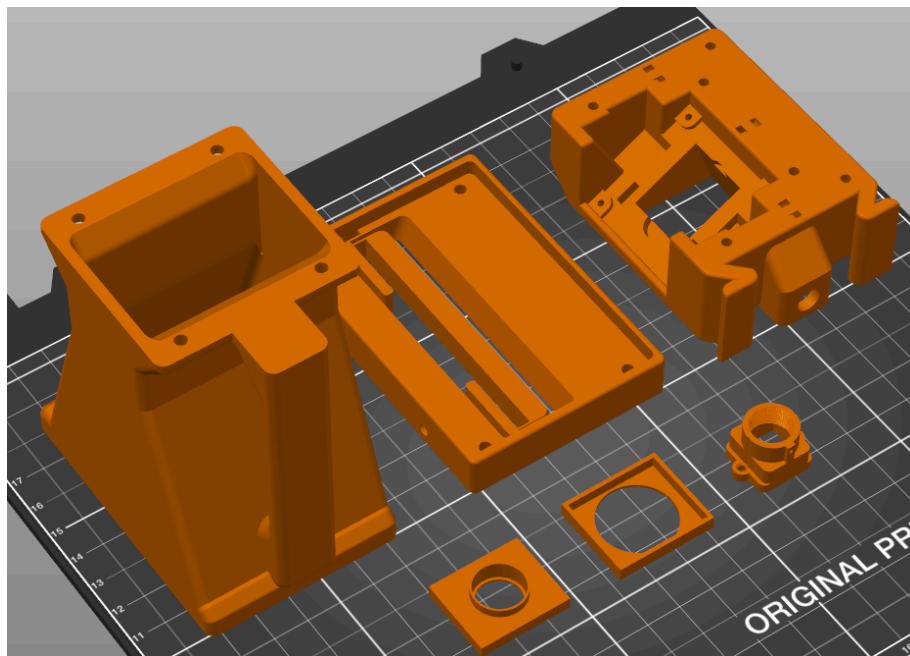


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What You'll Need

Printed Parts

- Print one of each of the following parts from the [GitHub directory](#):
 - Camera_Mount
 - Central_Frame_AC
 - Aperture_Cap
 - Grating_Holder_Inner
 - Grating_Holder_Outer
 - M12_Lens_Holder_18mm or M12_Lens_Holder_20mm (*depending on Arducam model*)
 - Aperture_Cover (*optional*)
 - Camera_Cover (*optional*)
- Recommended print settings:
 - Nozzle Diameter: 0.4mm
 - Layer Height: 0.2mm
 - Infill Percentage: 15%-20%
 - Support Material: When oriented as shown below, the only part that requires support material is *Central_Frame_AC.stl*.



Hardware

- [Qty. 1] - Arducam OV2710* USB camera ([purchasing option](#))
- [Qty. 1] - [16mm fixed focus wide angle lens](#)
- [Qty. 1] - [1,000 line per millimeter linear diffraction grating](#)
- [Qty. 2] - [9mm snap-off box cutter blades](#)
- [Qty. 8 - 11] - [M3 x 0.5mm, 10mm-long machine screws**](#)
- [Qty. 4] - [M2.5, 6mm-long thread forming screws**](#)
- [Qty. 2] - [M1.6 x 0.35mm, 12mm-long machine screws](#)
- [Qty. 1] - [1/4" x 20 square nut](#) for tripod or gimbal mount (optional)

* *Note - This model of Arducam is obsolete; see link for one purchasing option and stay tuned for updated hardware options in future revisions.*

** *Note - these two fastener types are recommended, but may be replaced with any wood screw, sheet metal screw, [thread-forming screw](#), or machine screw of the same approximate diameters and lengths. If alternative fastener(s) are used, be sure to include the correct drivers for them in addition to the ones in the "Tools" list below.*

Tools

- Safety goggles
- Scissors
- Pliers
- A small, sharp knife
- Allen key set (1.5mm and 2mm for screws listed above)
- Phillips head screwdriver (P1)
- Precision screwdriver set (for removing Arducam lens mount)
- 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)
- Glue stick (optional)

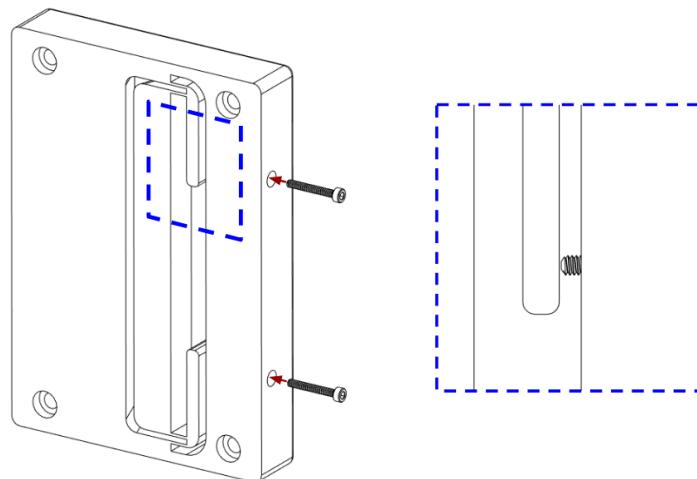
Instructions

Preparing the Printed Parts

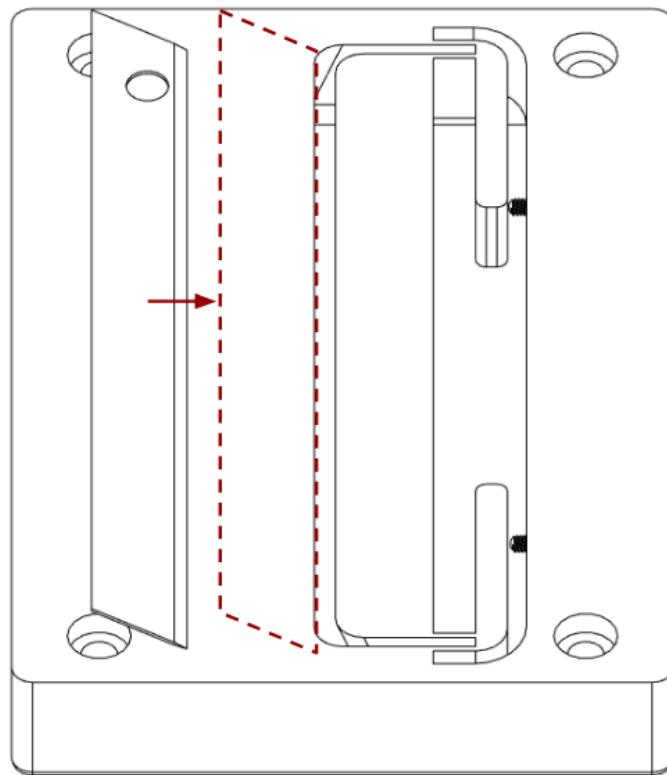
1. Remember to wear eye protection and to always practice proper knife safety when post-processing printed parts;
2. Use pliers and/or a sharp knife to remove any support material; and
3. All of the screw holes are designed to be self-tapping, but can sometimes be printed under-sized depending on slicer 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 (~ 1/2") deep.

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;

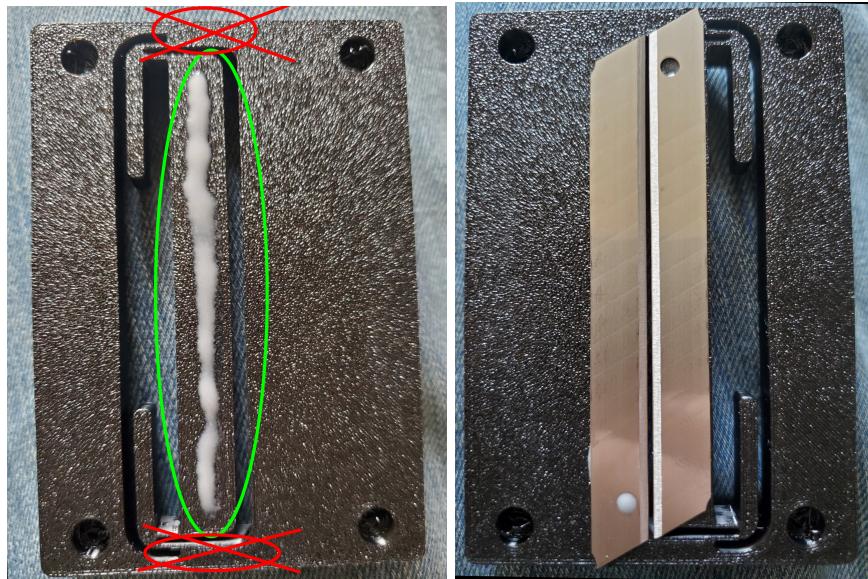


4. Repeat Steps 2 and 3 for the other M1.6 screw;
5. Place the aperture cap on a flat surface with the “front” face of the part pointing upwards (i.e. convex side down);
6. Take one of the razor blades and lay it on the left side of the upper face of the part, with the sharp edge facing towards the slit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



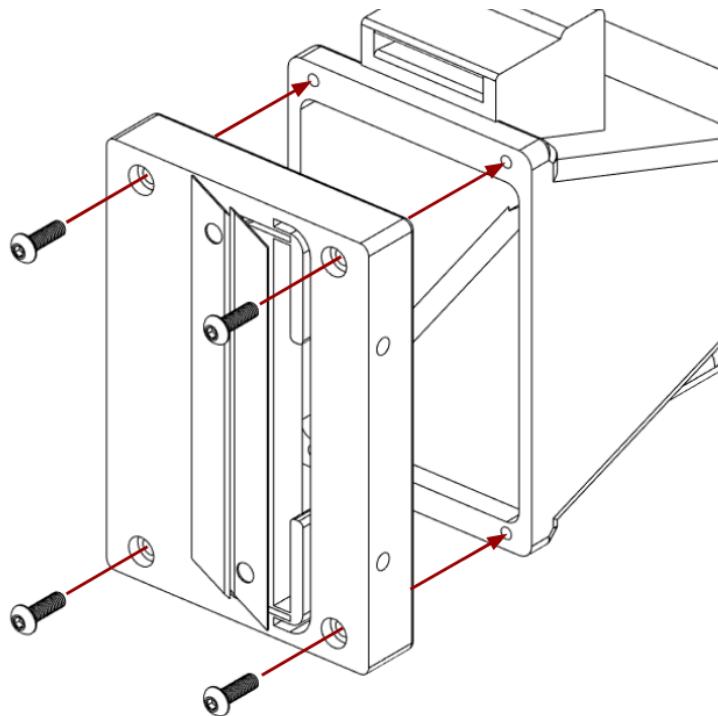
13. Once the razor blades are correctly positioned and aligned, use strips of tape to cover every opening in the front face of the aperture cap except the central vertical slit.

- a. (Optional) A 3D-printed cover (Aperture_Cover) can be used in place of tape if desired.
- b. If using the 3D-printed cover, it will be installed in the next section of the instructions.

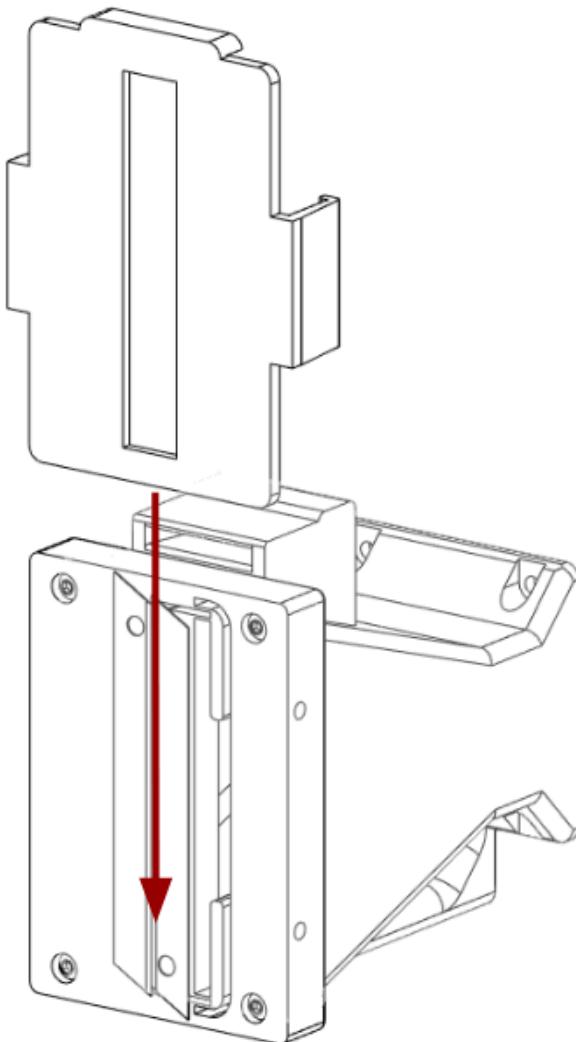


Installing the Aperture Cap on the Frame

1. Select the following:
 - a. the aperture cap assembly from the previous step;
 - b. the central frame printed part;
 - c. the (optional) 3D-printed front cover;
 - d. Four (4) of the M3 screws; and
 - e. 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; and
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.



Installing the Arducam Lens

1. Select the following:
 - a. the Arducam;
 - b. the replacement lens;
 - c. The lens mount 3d printed part;
 - d. Precision Phillips screwdriver (for miniature screws);
 - e. Knife.
2. Take the replacement lens for the Arducam and check whether it has an IR filter installed (as shown below);



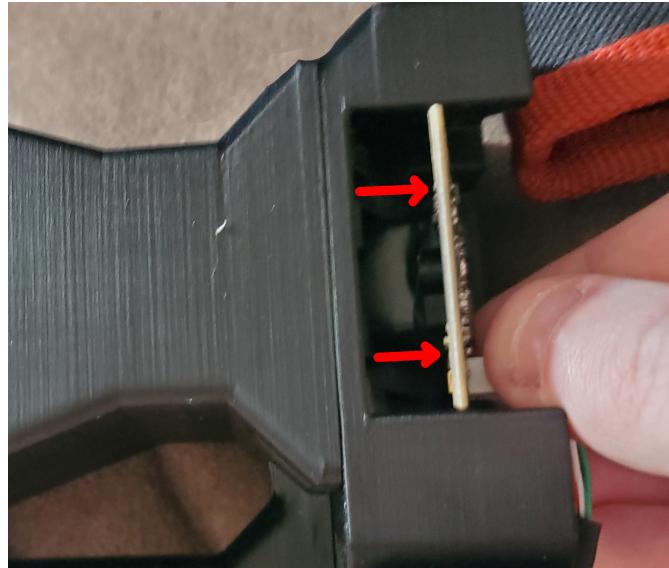
3. If the lens has an IR filter, use a knife or similar instrument to carefully break that filter off of the lens by applying gentle pressure at each of its corners, taking care to avoid injury or damaging the lens in the process;



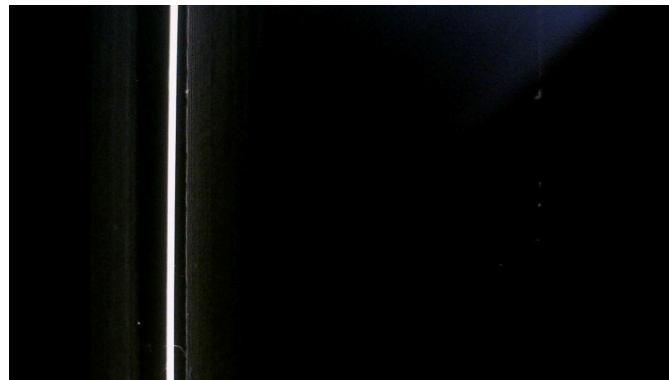
4. Take the 3D printed lens mount part and gently screw the replacement lens partway into it;
 - a. Tighten the lens only enough that it sits securely (without wobbling) in the 3D-printed lens mount, since tightening the lens to the correct depth takes place in a later step.
 - b. Be careful not to smudge or scratch the surface of the lens when handling it! Leaving the lens cap on the lens during assembly can be helpful.
5. Remove the existing lens and lens holder using the screwdriver, but hold onto the screws for use in the next step.
6. Using the precision screwdriver and the screws from the old Arducam lens assembly, attach the 3D printed mount with the new lens to the Arducam board.

Focusing the Optics

1. Select the following:
 - a. The camera mount part;
 - b. The central frame assembly with aperture cap attached;
 - c. The Arducam with new lens installed;
 - d. Arducam USB cable;
 - e. 1.5mm Allen key (for tightening the M1.6mm screws);
 - f. A sheet of printer paper;
 - g. A PC or laptop computer; and
 - h. Duct tape (or equivalent).
2. Connect the Arducam to a computer using the USB cable and pull up the camera feed on a display;
3. Place the frame assembly and the camera mount assembly on a flat surface;
4. Slide the Arducam into the diagonal depression in the back of the camera mount until the lens extends through the flat front face of the part;
 - a. Be careful not to accidentally touch the lens or scratch it against the camera mount during insertion;
 - b. Do not screw the camera into place yet, as it needs to be free to swivel in place for the next step in the calibration process.
5. Slide the frame assembly and the camera mount assembly together until their inner faces are flush to one another;
 - a. Align the two assemblies such that the four screw holes in the inner face of the camera mount are visible through the four screw holes in the central frame part;
 - b. The central frame and camera mount assemblies can optionally be screwed together using one or more of the M3 screws, but focusing the lens usually requires multiple attempts so screwing the frame together is not recommended at this step.
6. Carefully rotate the Arducam within its depression in the camera mount until the slit at the other end of the spectrometer comes into view, as shown in the image below;



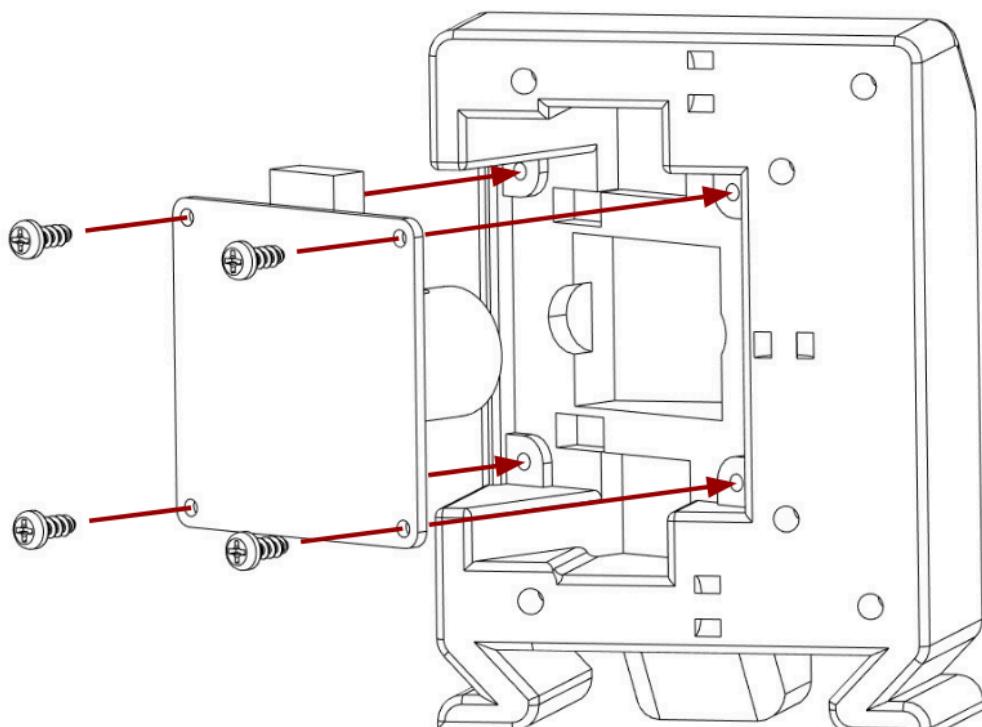
7. With the slit in view, compare the feed from the Arducam to the properly-focused image below:



- a. The lens is focused correctly when both edges of the slit are straight, clean lines with no fuzzing or blurring.
- b. Note that the colors of the two image portions in your camera feed may not match the ones in the reference image above, depending on the filament used to print the aperture cap, the lighting conditions in the scene behind it, and the amount of light leaking around the Arducam.
8. If either of the edges of the slit are blurry in the camera feed, separate the camera mount assembly from the central frame and adjust the focus of the lens by tightening or loosening the lens in its holder;
9. Repeat Steps 4 - 6 until the lens of the Arducam is correctly focused; and
10. Separate the camera mount and Arducam from the rest of the assembly, taking care not to bump or scratch the lens of the Arducam in the process.

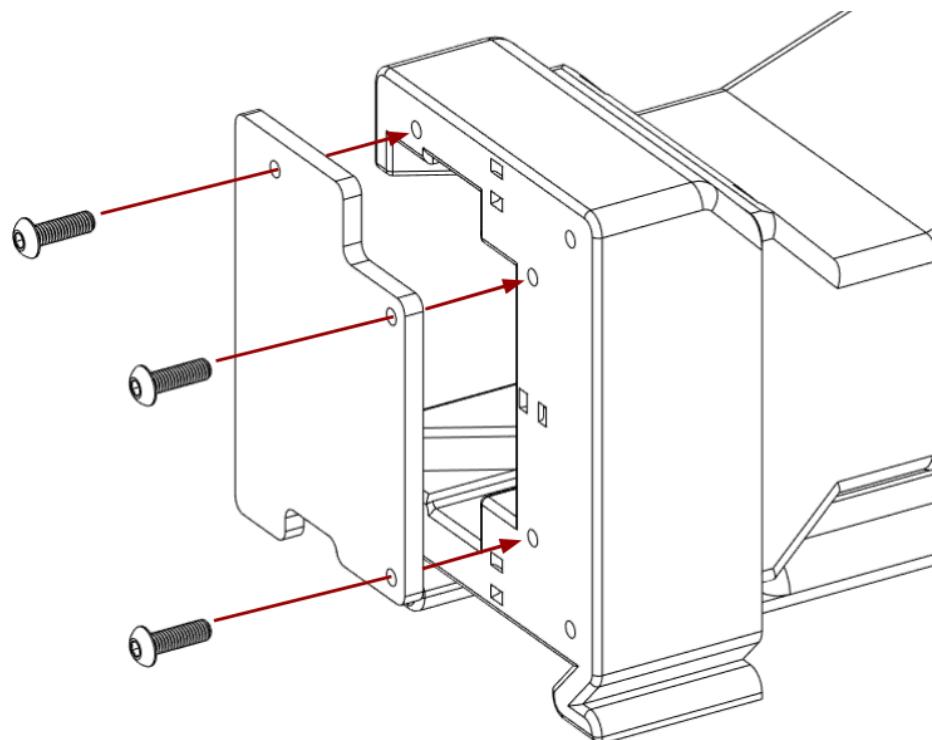
Installing the Arducam

1. Select the following:
 - a. the Arducam camera module;
 - b. the camera mount printed part;
 - c. the four M2.5 screws; and
 - d. P1 Phillips head screwdriver.
2. Place the camera mount on a flat surface with the feet side down.
3. Align the Arducam with the diagonal depression in the back of the camera mount part.
4. Place one of the M2.5 screws on the tip of the Phillips head screwdriver.



5. Use the screwdriver to insert the M2.5 screw through one of the holes in the Arducam board and into the corresponding hole in the depression of the camera mount part.
6. Once positioned, tighten the screw until it sits snugly against the back of the Arducam board; do not overtighten!
7. Repeat steps 4-6 for the other three holes in the Arducam board; and

8. Cover the back side of the camera mount to prevent light from leaking into the spectrometer enclosure:
 - a. A 3D printed cover (Camera_Cover) may be installed into the back of the camera mount using three of the M3 screws; or
 - b. The rear of the camera cavity can also be covered with the same opaque tape (duct tape, gaffer tape, etc.) used elsewhere in the assembly.



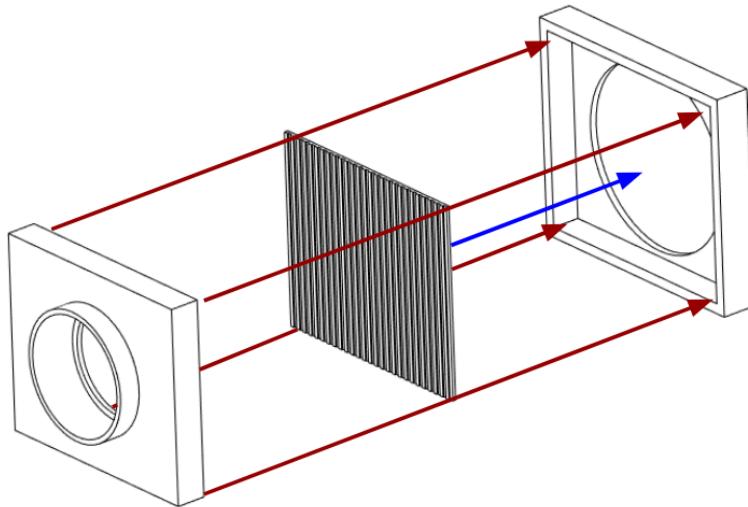
Assembling the Diffraction Grating

1. Select the following:
 - a. the two “lens cap grating” 3D-printed parts;
 - b. one of the purchased diffraction gratings* ; and
 - c. 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;

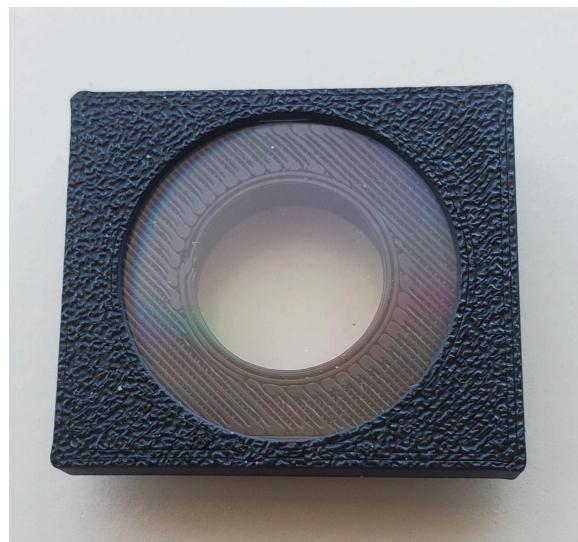


5. Use the knife to cut along the inside perimeter of the printed part to create a rectangle of diffraction medium that is slightly smaller than the rectangular cavity;
6. Before proceeding, confirm that the cut sheet of diffraction medium lies flat within the outer 3D printed part and that it is free 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**; and



1. 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.



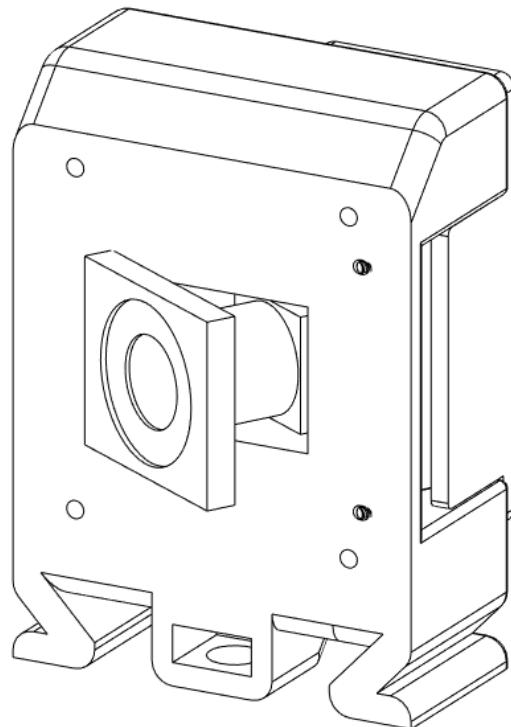
**Note: If creating the diffraction grating rectangle from a source other than the one listed at the beginning of these instructions, ensure that:*

- 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.***

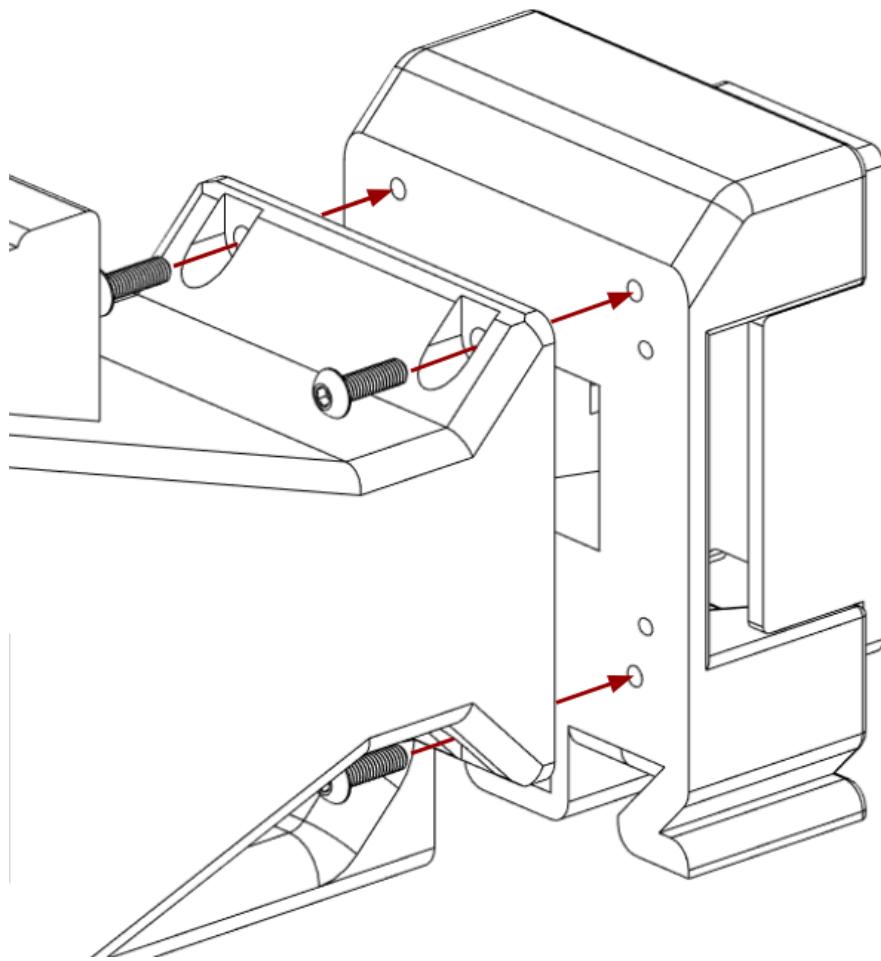
Installing the Diffraction Grating Assembly

1. Select the following
 - a. The camera mount assembly with the Arducam correctly installed;
 - b. The assembled diffraction grating from the previous step;
2. Place the camera mount (with Arducam board installed) on a flat surface with the lens of the camera facing you;
3. Confirm that the diffraction grating assembly is oriented correctly, with the long sides of the rectangle on top and bottom (as shown below); and
4. Gently slide the diffraction grating assembly over the end of the Arducam lens, taking care to avoid touching the glass surface of the lens or the diffraction grating material.



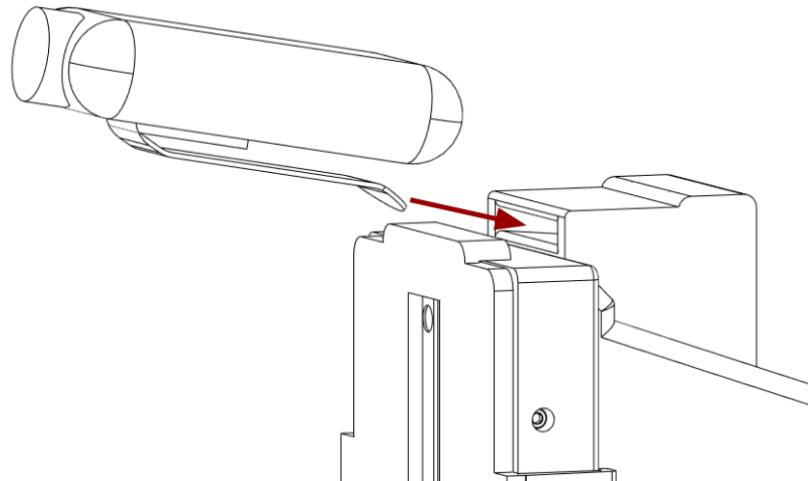
Combining the Spectrometer Subassemblies

1. Select the following:
 - a. The camera mount assembly from the previous step;
 - b. The central frame assembly with aperture cap installed;
 - c. Four (4) of the M3 screws;
 - d. 2mm Allen key; and
 - e. One (1) 1/4"-20 square nut.
2. Insert the 1/4"-20 square nut into the rectangular slot in the middle of the three "feet" of the camera mount assembly;
3. Check that the nut is aligned with the hole in the bottom of the foot and that the hole is clear of obstructions:
 - a. The nut should be fixed in place once the central frame is attached to the camera mount;
 - b. Optionally, the nut can be fully secured by applying a drop of cyanoacrylate to its vertical "back" face before inserting it into the slot.
4. Place the camera mount assembly and the central frame assembly on a flat surface with the open end of the main assembly facing the side of the camera mount with the lens sticking out of it;
5. Slide the camera mount and frame parts together until their mating faces are flush to one another, taking care not to bump or dislodge the lens cap grating on the Arducam;
6. Insert one of the M3 screws through one of the four holes in the central frame part and into the corresponding hole in the corner of the camera mount assembly;
7. Use a 2mm allen key to tighten the M3 screw until the two inner faces of the printed parts are touching, but do not yet fully tighten the screw;
8. Repeat Steps 5 and 6 to add screws to the other three holes, starting with the opposite corner to the first one and moving in an "X" pattern;
9. Return to the first screw and tighten it completely using the 2mm allen key; and
10. Repeat Step 9 for the other three screws by following the same "X" pattern used to insert the screws in Step 8.



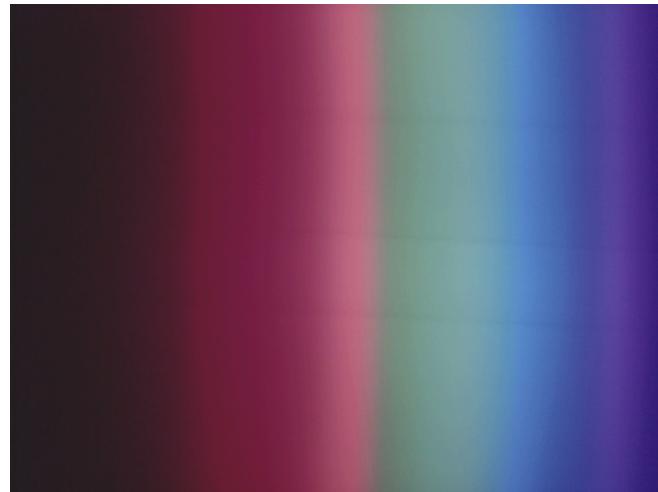
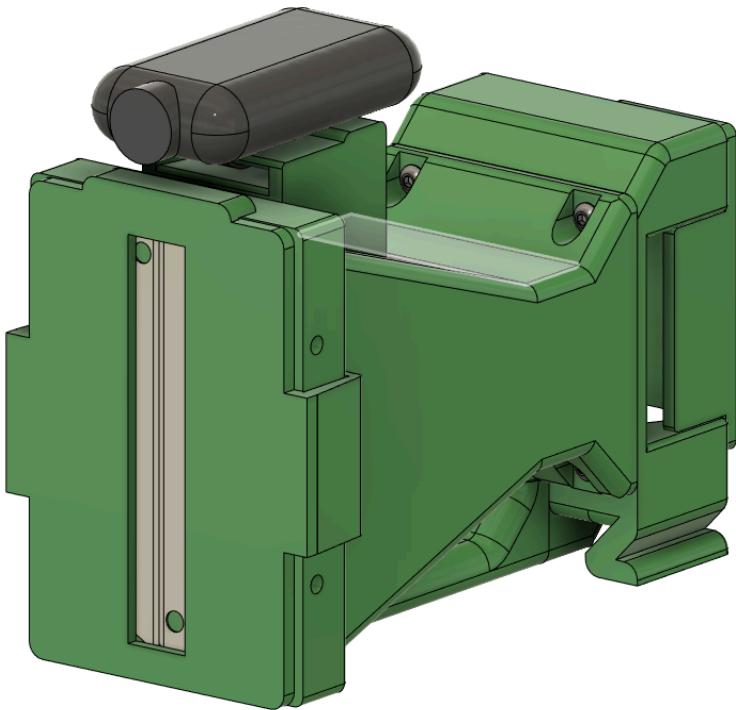
Installing the Light

1. Select the following:
 - a. The spectrometer assembly; 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.

Assembly Complete!



Plug the device in, turn on the light, 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 somewhat usable for pattern matching.

Next Steps

Check the [GitHub page](#) for more information about the project.

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.
- There is a horizontal handle on the bottom of the spectrometer for handheld use.
- 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.
- There are extra sets of holes in the back of the camera mount part that can be used to install pole clamps onto the spectrometer.