Camera Profiling Spectrometer – Build Instructions

Glenn Butcher, 9/14/2020

This document provides step-by-step instructions to build a spectrometer tailored specifically to collecting data from digital cameras in order to build camera profiles. The investigation that culminated in this design can be read at https://discuss.pixls.us/t/the-quest-for-good-color-4-the-diffraction-grating-shootout/19984. Particularly, these instructions document the build of the "cheap" alternative discussed in the thread; adaptation to lab-grade optical components mainly involves cutting the incident light angle at a different value and making suitable holders for the components.

This design was selected to meet the following criteria: 1) uses commonly available construction and optical components, 2) easy to construct, to include only requiring fairly common woodworking tools, and 3) cheap. Depending on availability of materials and components, the entire device can be assembled for under $30US.

1. Materials

3 ½" x ¾" poplar board, 4' length: The base and cover will be cut from this board. I bought this and the rest of the lumber from Home Depot, a US home improvement store. 3' is needed to make the two parts, but the board comes in 4' length

2 ½" x ¼" poplar board, 4' length: The side walls will be cut from this board.

5 ½" x ¼" poplar board, 4' length: The end caps will be cut from this board.

¼" x ¼" square "stick" board, 4' length: Ten 2 ½" lengths will be cut from this board to make the slide tracks for holding the optical components.

1/16" cardboard: The optical component holders will be fabricated with this material. The cardboard that backs notepads is sufficient. If you cut the optical slit from cardboard, it needs to be as thin as practical, but not so thin that it transmits light.

1000line/mm plastic-substrate holographic-ruled diffraction grating: I bought mine from Arbor Scientific, https://www.arborsci.com/collections/light-optics/products/holographic-diffraction-grating-5-pk, #3.75US for a pack of 5. Edmund Optics also has the same part, https://www.edmundoptics.com/p/25400-linesinch-2quot-square-card-15pack/10/ , $17.95US for a pack of 15. If you order the diffuser from them, you may save on shipping if you buy the larger quantity of gratings from the same source. The 1000line/mm part is needed to match the incidence angle cut into the base/cover.

Diffuser material: I started my projext with a piece of plain white paper, which worked but made my spectra a bit dim. Wax paper would probably work better, but I ended up buying a 25mm ground glass diffuser from Edmund Optics, https://www.edmundoptics.com/p/25-x-25mm-120-grit-ground-glass-diffuser/26527/, $15.50US. The relevant criterion for this part is that it transmit the visible spectrum with a minimum of per-wavelength attenuation. The optical diffuser includes this data.

Wood glue: I used Elmer's school glue and things held together just fine. You're not building furniture here…

Adhesive tape: Only needed if you don't want to spend the time constructing a slide holder for the diffraction grating; you can just tape it to the cardboard...

2. Tools

Miter, or "Chop" power saw: The angles in the base, cover, and walls could conceivably be cut by hand with a carpenter's saw, but these angles are critical to the optical performance of the spectrometer so I recommend begging or borrowing an adjustable miter power saw. I have a basic Sears Craftsman miter saw from years of installing trim to my wife's specifications, and it worked fine. You need one that will let you select an angle at 1degree increments.

Power drill, 2" hole saw, ¾" wood bit: The hole saw bit is commonly available for cutting holes in doors for mounting doorknobs; it will be used to cut the camera aperture. The ¾" wood bit will be used on the other end of the box to drill the light opening. The diameters are approximate; if you already have saw/bit in a close dimension, it should work fine.

X-Acto knife: Used to cut the cardboard. A single-edged razor blade would also suffice.

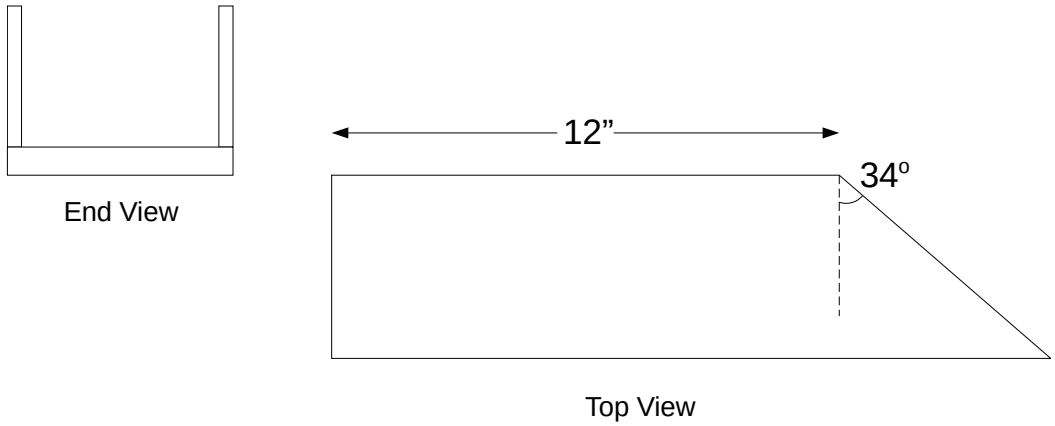
Metal straight-edge ruler: Used to both measure and as a guide for cutting with X-Acto knife.

Carpenter's square, small: Used to stroke cutting and gluing lines on the boards. Mine is a two-piece affair, one piece being the metal straight-edge ruler.

3. Box Fabrication

Wood-Cutting: Here's the objective:

The base and cover (the two large pieces) measure 12" on the short side, and the angle is 34 degrees corresponding to the 1000lines/mm grating. The walls (the two smaller pieces to the left) have the 34 degree angle cut vertically, note they are different lengths depending on to which side they will be mounted. The end plates (the two pieces on the right) have different dimensions; the larger piece is cut to span the length of the angled end of the box and in height extend to the top of the cover and about an inch past the bottom of the box. The smaller piece is sized to cover the entire other end of the box.

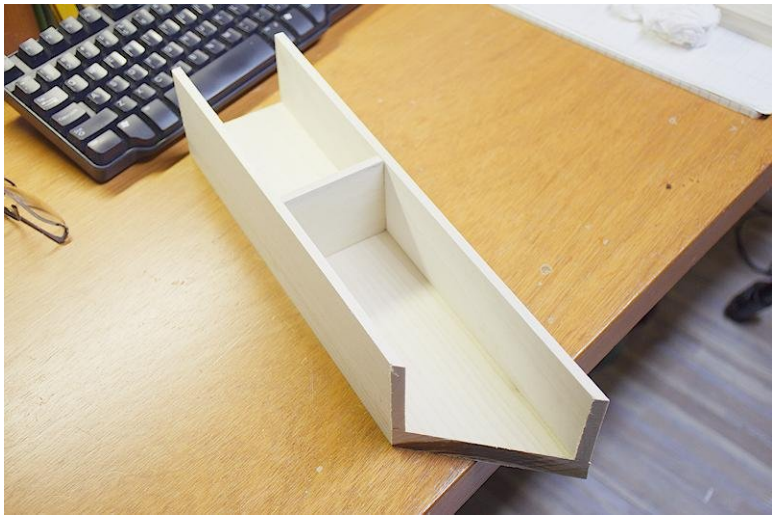


The diagram depicts the erection of the walls on the base and the principal measurements.

First, set the chop saw to cut at a 34º angle. With that angle, cut the ends of the 3 ½” x ¾” (base and cover) board; it doesn’t matter what orientation the angle as you’ll be able to flip the finished pieces over to fit. Next, cut that same angle vertically in the 2 ½” x ¼” (side wall) board.

Next, with the base-cover board measure 12” in from each 34º vertex and draw a straight right-angled line across the board. Set the saw back to 0º, then cut the base and cover pieces off the ends of the board along those lines. Tip: Before making these cuts, pull the saw blade down to the board surface and line up the blade edge to the edge of the line, putting the blade thickness down in the part of the board you don’t want to keep.

Then, do the same cuts with the walls, the difference being you’ll have to measure the length by standing up each board in it’s place on the base, marking the other end flush with the base end, and drawing the cutting line on that mark.



This image shows the wall alignment on the base; the vertical board in the center is a temporary spacer.
The end caps are now cut to fit the box ends. For the square end, with the chop saw cut a piece off the end of the 5 ½” x ¼” board the width of the box, 3 ½”, then measure 4” along the height and cut off the remainder. You now should have a piece that will completely cover the square end: base, walls, and top. For the angled end, measure the length of the angled end of the base and cut a piece off the end of the 5 ½” x ¼” board of that length. Leave the height alone; this board will extend down the face of the table.

At this time, pick the board you want to use as the base, then determine which surface is to be up by orienting the angle to point the board in the direction from which you want the light to shine upon the square end. The angle should sit flush with the front table edge. Once you've determined its top side, draw a line down the center of the board from end-to-end, this will be the optical path. It's easier to do this now, vice trying to fit a straight-edge and your hands between the walls…

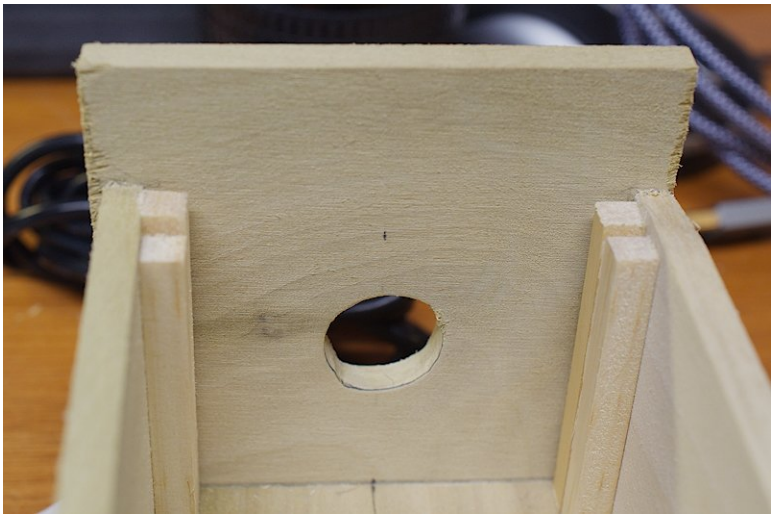
Now, drill the port holes in each end cap. For the square end, draw an X from corner to corner of the end cap and drill a 3/4" hole on the center of the X. For the angled end, first determine the part of the end cap that will extend over the table by measuring 4" down from the top edge, then draw a line right-angled across the end cap at that point. Then, draw an X from the top corners to the opposite corners marked by the 4" line and drill a 2" hole on the center of the X. The port holes should line up on the optical path and be centered between the base top surface and the cover bottom surface.

Assembly:

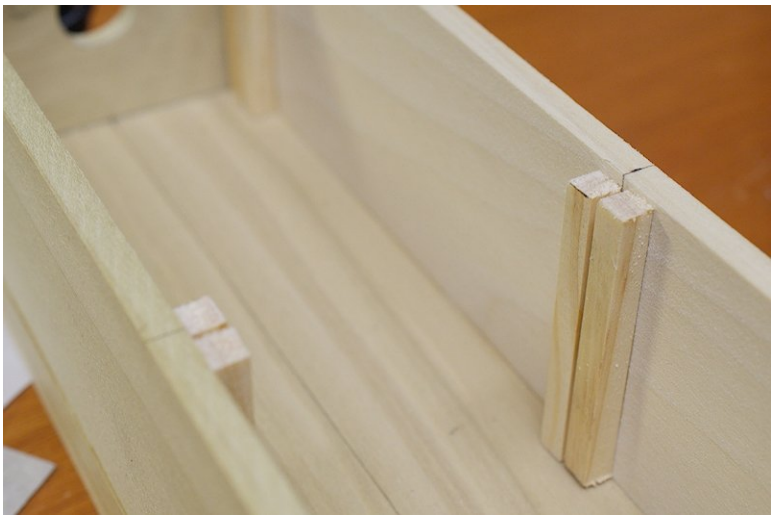
Now, glue the walls to the base as indicated in the previous photo. Run a small bead of glue on the bottom edge of the first board, then place that edge on the base and align it so the wall ends are flush with the base ends. Hold the board straight up and still for about 5 minutes, until the glue starts to set. Tip: a right-angled surface is handy for bracing the wall as the glue sets; the chop saw table and guide can provide such a setup (unplug the saw before you use it in this fashion). After the first wall is set, do the same with the other wall.

After the walls are set and not moving, place the cover loose on the walls to use for aligning the end caps. Do the square end first, it's easier. Run a small bead of glue on the wall and base ends, then place the end cap on the walls and base. Do not glue the end cap to the top; the top will be left loose for removal. Before the glue sets, make sure the port is aligned with the optical path line on the base. After the square end cap is set, do the same with the angled end cap; set the box with the angle on the table edge, run the glue bead on the walls and base ends, then place the end cap on the walls and base. Again, before the glue sets, make sure the port is centered on the optical path.

Finally, build the optical component holders. First, cut ten 2 ½" pieces from the ¼" square stock; actually, cut them about 1/8" shy of that so they don't inadvertently push up on the top when it's in place. Now, starting with the square end, first build the two holders for the diffuser and the slit. The first holder will actually use the end cap wall as one of its sides, and the second holder will use the first holder as one of its sides. The gap should accommodate the cardboard thickness plus a bit, so the cardboard can easily slide in and out. Here's the configuration for the diffuser and slit:



Next, the holder for the baffle. It goes midway down the optical path:



Now, the holder for the diffraction grating will look a little different, because we're not going to do fancy angled cuts to accommodate the walls. Here's how it looks:

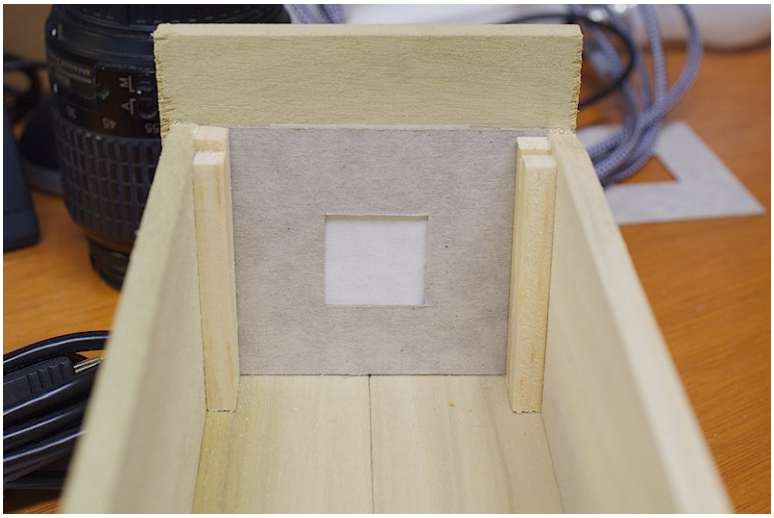
Remember in each case to leave enough room for the cardboard fixture to easily slide in and out; loose is okay. Tip: cut a cardboard blank to use in determining the fit; you'll use it later to construct one of the optical fixtures.

After the glue has set, you now have the complete spectrometer light box. You may want to mount the top with a couple of hinges, but I find it more convenient to leave it loose for easy removal.

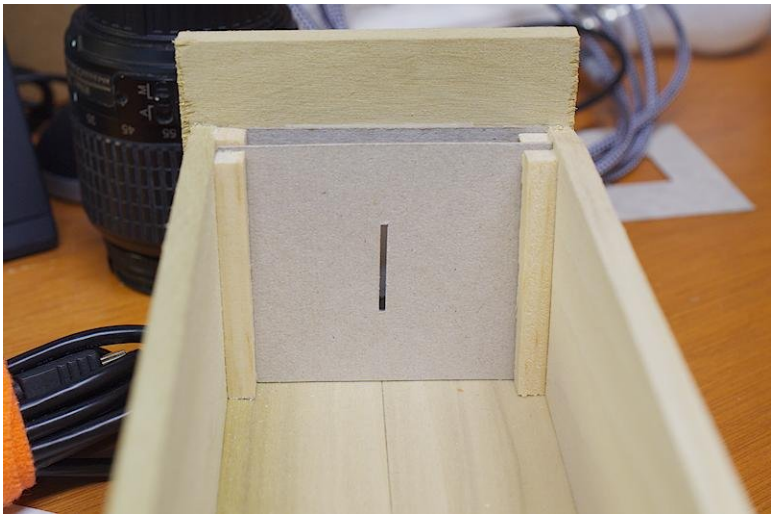
4. Optical Fixtures

From the cardboard, you now will fabricate fixtures for the following components 1) diffuser, 2) slit, 3) baffle, and 4) diffraction grating. Start by cutting three cardboard rectangles to fit the inner dimensions of the box, 3" x 2 ½". Actually, you'll need to cut them about 1/16" shy of that, so they slide easily into the holders and they don't push up on the top. Mark the optical path on each by drawing an X from corner-to-corner.

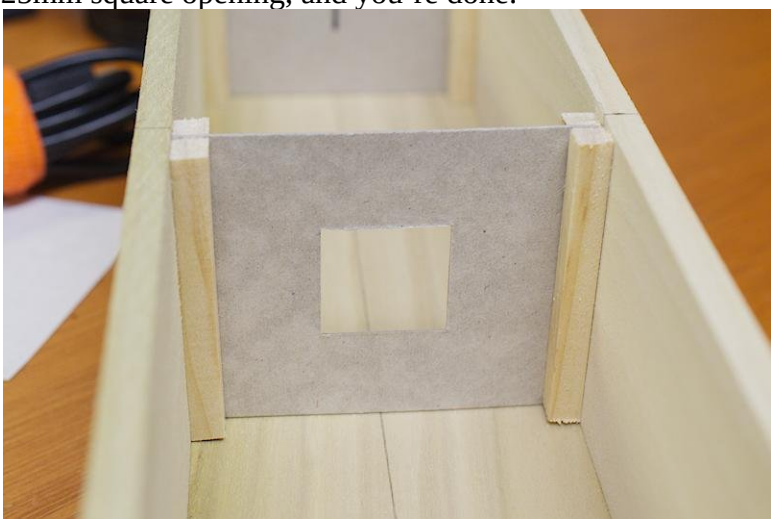
For the diffuser, we'll assume the wax paper, so first measure a 25mm square centered on the center of the X and cut it out with the x-acto knife and straightedge. Cut a piece of the wax paper larger than that opening and paste/tape it over the opening.



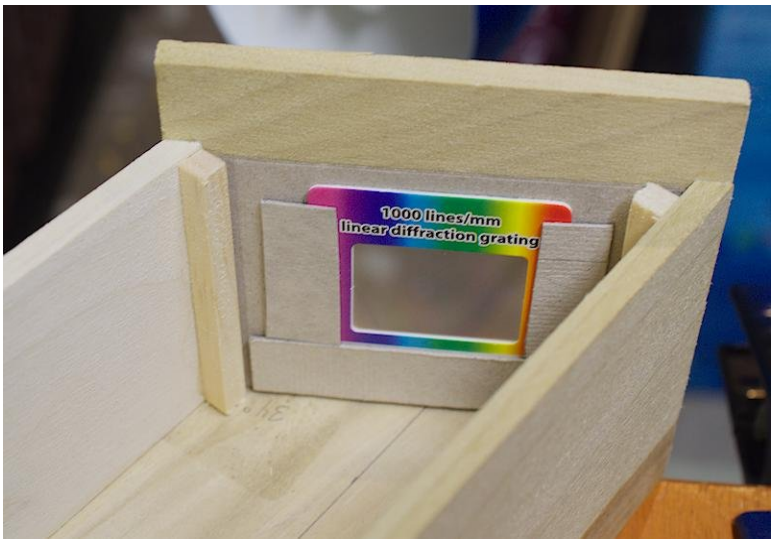
For the slit, measure a 1mm x 25mm rectangle centered on the center of the X and cut it out with the x-acto knife and straightedge. You'll want to spend some time and patience cutting this out carefully so the slit is as perfectly parallel as you can make it.



For the baffle, do another 25mm square opening, and you're done:



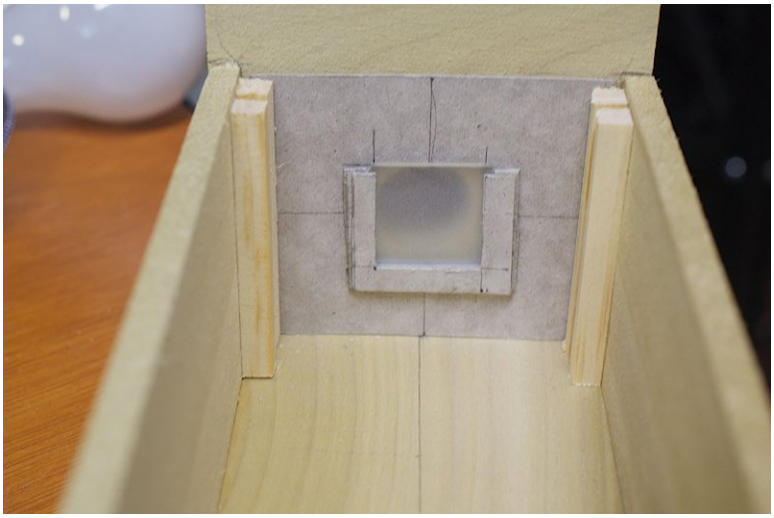
The diffraction grating holder is a bit different, as the dimensions across the inside face of the camera end are different. Mine is about 3 ½” wide, but the same height as the others. Mark the optical center of the card, then



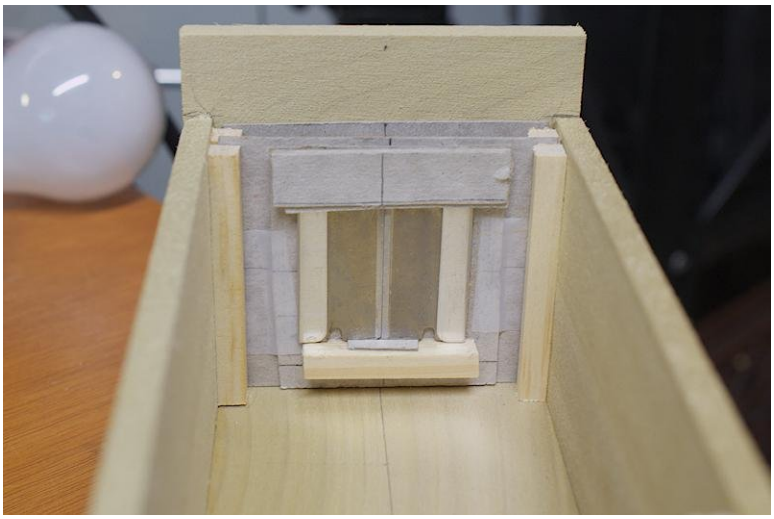
mark and cut a 1 3/8w” x 1”h opening in the card. That should line up approximately with the inner opening of the grating’s slide mount. In the picture below you’ll see I made a slide-in holder for the grating, but you can just tape it in place.

And there you go…

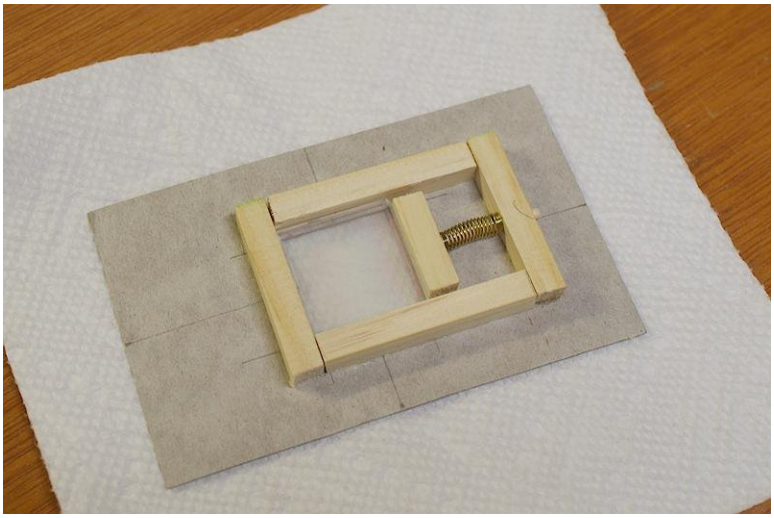
Just to provide an idea of where you might go with this, here are a few pictures of the 42° spectroscope with the lab-grade 1200line/mm diffraction grating:



The 25mm diffuser requires a holder. Since it is a $15US part, I didn’t worry about impinging on the edges…



This is a razor-blade slit, which provided better accuracy as well as the ability to change the slit width easily. My cardboard hack holder is rather dodgy; I'm thinking of replacing it with a neodymium magnet holder.



Here's the $108US diffraction grating in a Rube Goldberg holder. Touching the ruled surface is verboten, so I fabricated a holder from the ¼" stock and a ball-point pen spring and toothpick shaft pressure edge.

Have Fun!!!!