My 114mm Travel Scope

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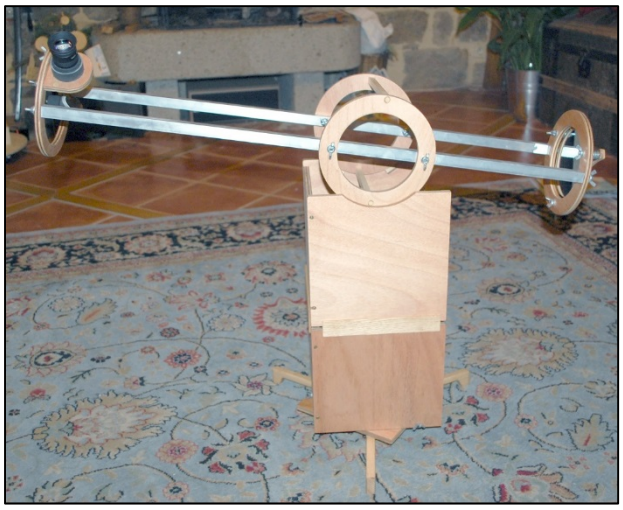



During my last trip in the US, I was able to pick a 114mm/25.4mm primary/secondary mirror pair for 18$ (Telescope warehouse on eBay). After a lot of back and forth, I decided to make a travel telescope out of it.

A travel scope is a telescope that is designed to be pulled apart and reassembled relatively rapidly and that can therefore be used for trips (as its name indicates).

This article explains the design that I used what I learned and the things that I learned during the process. Hopefully, it can serve as a warning to others!

The total cost for the scope (I had wood and nuts available to me), was around $40! Not bad!

Want to make a travel scope but too lazy to read the whole thing? Read this:

Play with this app: http://stellafane.org/tm/newt-web/newt-web.html

The top ring will need to have an inside diameter at least 25mm larger than the primary diameter to avoid vignetting (dimensions will differ for larger/smaller mirrors). This will be the guiding factor for the rings outside diameter.

Make ALL the rings the same size!

Use aluminum for the struts, wood is NOT rigid enough, trust me!

If you do not have a commercial spider, the easiest/simpler spider is the one that I used here. I tried 3 other designs and it is really the easiest to make.

Find a real focuser if you can. You lucky guys in the US can probably do good with a plumbing parts focuser. Mine sucks!

Pay attention to the wood grain orientation. My telescope does not look “great” because I did not.

Unique issues with a 114mm telescope.

114mm scopes are SMALL. This means that we have a lot of SMALL parts to make. Small parts are harder to make (because you work closer to the blades), and because you need more precision.

114mm means a relatively light mirror. This means that the center of gravity of the tube will be further away from the mirror than for larger scopes. As a result, the 'down swing length' of the bottom part of the tube will be longer (as a percentage at least). So we will need a 'taller' base.

Information on tools and material can be found at the bottom of this document.

Various notes

I Used 10mm plywood throughout, but 8mm could be used and would reduce the weight.

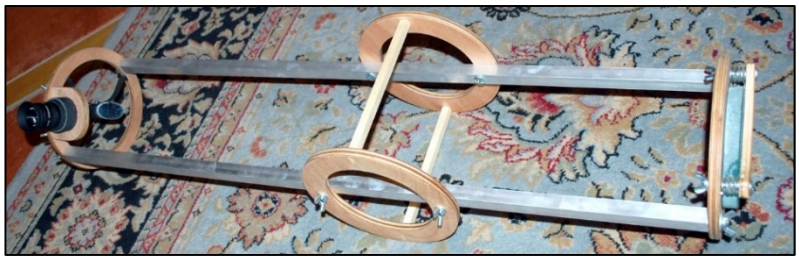
Resist the urge to drill aligned holes in 2 or more pieces of wood at once. It is very hard to be perfectly vertical, and even if you are, drill bits can wander. Instead, make a template (a paper drawing with the hole's center marked), and use a "pointy thingy" to mark the center on your wood through the paper.

Part 1: The Optical Tube

The optical tube is an assembly of 4 rings, 2 struts, a mirror back, focuser and spider.

You will need 4 rings of the SAME outside diameter and if possible the same inside diameter (although this is not a must).

The outside diameter is at least the primary diameter + 25mm + 2*strut thickness (15mm in my case). You can make it a little bit bigger to get more rigid rings. For my scope, I used a 175mm diameter.



You want the extra 25mm on the diameter because you need to admit light at a slight angle from the optical axis. For an 800mm tube, an extra 12.5mm allows for an angle of 0.9 degree which corresponds to the so called 75% light area of the scope. It also probably helps if the optical components are not 100% coaxial with the tube.

Step 1: Mirror Cell

The mirror cell has two main parts, the ring (one of the four rings) and the mirror back.

The mirror back has the same diameter as the main rings. I made mine triangular (prettier and lighter) but it could be a circle. The mirror back provides a platform for the mirror that can be tilted in every direction to align the optics. Once

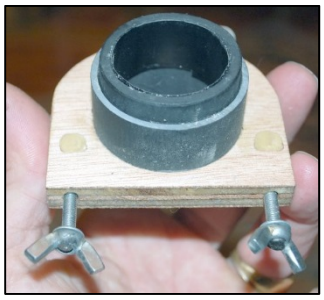
the mirror back is cut, drill 3 holes in the 3 spokes (at the same distance from the center) and the corresponding holes in the mirror ring. You are now ready to assemble them together. My springs had a relatively large diameter, so I did not need washers for them, but I needed to stabilize them (so that they would stay coaxial with the screws). I used a little bit of light foam. Once fitted, disassemble, put a coat of finish on everything, let dry.

Glue the mirror to the mirror back; put 3 dabs of silicone and place the mirror on it (centered), press just a little bit (being careful with the mirror), but not too much, you want to leave enough height of silicone to let its own elasticity absorb any wood movement, but not so much that it will sag when lifting the mirror horizontally. Protect if possible (place a card box on top) and let dry overnight.

Reassemble the mirror cell, put some pressure on the springs, BUT NOT TOO MUCH, we should be at "resting/middle" position now, leaving adjustment in both directions on all 3 springs. Make sure that there is enough force to avoid movement of the mirror under its own weight when moving from horizontal to vertical. Set aside. Have a drink.

Step 2: Focuser Ring and Spider

You will need to mount the spider and the focuser on this ring. I tried 3 different spider designs before going for this one. The issue is that the smaller the scope, the smaller the parts, and the HARDER it gets to make it! The design used here is honestly the simplest to make! so, if you are not going commercial, I suggest that you use it. The “Hub” is built out of a dowel slightly smaller than 25.4 diameter (my secondary is 1”) with a center threaded hole of 6mm. The mirror part is cut at 45°. I then made a vertical cut in the hub part, used that as a base to drill a vertical hole large enough to let the head of a 4mm bolt go through (it has to go just pass the threaded hole, but have enough material on the other side to not go through). The design is from http://stellafane.org/tm/dob/ota/holder.html



The main thing to understand in this design is that the metal needs to be rigid enough to not bend under its weight or telescope movements, BUT needs to be flexible enough so that you can bend it to collimate the scope. Hack saw blades are NOT OK as they are too rigid. I used a 1cm high strip of tin (cut on the table saw, by sandwiching a piece of tin between 2 boards and using a blade that I only use for metal). For a larger scope with a larger secondary, you might need something more rigid.

Paint it all in mat black.

Once you have the spider ready, you need to work on the focuser area. I used a simple wood piece with a hole just big enough to allow me to force a PVC tube in it, with a secondary tube sliding in it for focusing. I painted the whole thing mat black and added some strips of electric tape to reduce the diameter to get the right friction.

I attached it to the focuser ring with 2 handmade wing bolts which screw in a washer/nut which I have sealed (with wood putty) in the focuser. You can see the wood putty in the picture above, hiding the nuts/washers.

The focuser will be the first thing fixed on the ring. You want to make its axis intersect the ring axis. The best way to do that is to center the focuser hole in the focuser block and to make the 2 outer corners of the focuser tangent the outside diameter of the ring. Make sure that the focuser is placed at around 35°~45° angle compared with what will be the horizontal of your optical tube.

Now, you can see where to place your spider. It should be held with 2 small 3mm wood screws, but do not fix it yet.

Step 3: Struts

Assemble (temporarily) the focuser board and the ring. Measure the focuser center to ring distance. Also measure the primary mirror surface to the top of the mirror cell ring.

Take your mirror focal length, subtract half of the internal diameter of the focuser ring, subtract the focuser height (make it at least 60mm), subtract the distance from primary mirror to mirror cell ring top and ADD the focuser ring to focuser center distance. This is your strut length. Cut the aluminum bars to the right length (I use a regular 24 tooth 7-1/4" blade that I only use for metal on the table saw for this). You will now need to fix the 8mm (6mm might be enough) bolts IN the struts. My bolts were slightly too large, so I had to grind them. Once in, I fixed them in place using aluminum 2-part epoxy putty. Make sure that they are as concentric as possible. Let harden.

Step 4. Drill Rings

You will need to drill all 4 rings in the same way and the same spot. See note above about drilling holes. The hole in the focuser and mirror rings will be used for the struts, the holes in the 2 other rings will be used for storage. Drill 8 holes.

Pay attention to the placement of the holes on the focuser ring to place the focuser where you want it. You can also try to make it pretty by making sure that the holes are placed in the orientation of the wood grain (Note that if you use my design with the spacer for the side rings, they will be assembled at 90° angle compared with the 2 other rings).

The holes will need to be placed so that the outside of the struts are tangent to the outside of the ring. For me, this meant at 15mm/2 = 7.5mm from the edge.

Make sure that ALL the holes in the rings (and pivot) are aligned so that you can stack them all in the box and attach them all to avoid movement while traveling.

We will now locate the center of gravity of the tube.

Assemble the focuser/mirror and struts. Place one of your "Average" weight eyepieces in the focuser (you want to balance with a medium weight). Using a dowel, or a long (but thin, <=1cm) piece of square wood propped high enough to be at least half a ring diameter high, balance your assembly, note the balance points on each struts and take the average distance. This corresponds to the center of gravity.

Now, for your side rings, you have two options. You can either use the holes that we have already drilled and use them to bolt the side rings to the struts, OR you can (as I did) use these holes for spacers and drill 4 other holes (2 per ring) to bolt the side rings to the struts. In this case, I suggest that you drill these holes much closer to the inner diameter of the ring as it will clear more space on the outside of the rings for bearing guides (see picture).

With all this together, you now should have an optical tube assembly! You can put it together, and, hand held, go out and look at the moon! Rejoice in your work! First focusing might be hard….

Part 2: The Base

In my case, I wanted the base to be also the storage box, so I went for this two interlocked U system.

I made the INSIDE of the box one ring diameter + two ring thicknesses. This means that the side rings rest on 4 small stops glued on the INSIDE of the box. The side walls of the box guide the rings (force them to stay in the box), the spacers between the 2 side rings make sure that they do not bend inward. The side of the box is cut in a circle with a diameter slightly smaller than the rings to guide them while letting the wing nuts go by (hence the 4 hole per side ring, with strut bolts closer to the interior diameter design).

If I had to do it again, I would probably have the box 2 thickness smaller (in all dimension), reducing the stored scope volume to 75%.

Because of distance between the side rings and the mirror I have to have at least 35cm from the top of the base to the bottom of it. This is why I went for the 2U design. I can stack the 2 part of the box and get a 40cm high base. I made three H-shaped wood ‘sticks’, with friction fit, to connect the two parts of the box.

The bottom is made with two squares of same size, with a piece of PVC used as the axis. This allows, when storing everything to let the secondary protrude/stick up from the focuser ring.

The part that attaches to the bottom of the U channel is held by 3 wing bolts (same fabrication as for the focuser).

At the beginning, I tried to have 3 feet attached directly to the bottom part of the base, but this did not provide a large enough base and was unstable. So I changed the design to the 3 detachable feet that you see in the final design. See the countersink holes for the bolt heads in the base to avoid friction. Felt is used as a bearing material between the 2 plates. I used a PVC pipe as the axis. It is forced in the top plate and loose fit on the 2nd. But, if I had to do it again, I would use a threaded tube with a nut under the rotating plate to reduce tilt.

Storage and Travel

The telescope can be disassembled and stored in the box for travel. And there is enough space for eyepieces in it also.

The telescope that can be assembled and collimated in less than 10 minutes, weighs 2.5kg, it takes a space of 22 x 22 x 22cm plus the 2 struts, and has enough space left to store all the accessories (I made a foam form that I place in the top part for that)

Two holes in the box, aligned with the holes in the ring allow for sandwiching of all the parts (using threaded rods, not in the picture) for traveling.

I also drilled two small holes to fix the focuser to the board to stop it from moving around. I place all the hardware in a small plastic box coming from the local pharmacy.

The latest changes (not shown here) are:

- 4 side bolts, similar to the ones used for the focuser to close the box and a leather handle to carry it.
- A shroud (mat plastic, pinched from a file folder). I tried holding it using scratch, but the scratch would not glue to the wood, so I used blue tack at the end.

Things left to do, or that I would do differently:

I would pay more attention to wood grain to make it look nicer.

I would pay more attention to the focuser height. At this point in time, my focuser is only 25mm high due to the fact that the focal length for far away object is not the same as the focal length for close ones…

I would get a bigger mirror ☺

I probably would make the ring ride on top of the box (not on the inside), to reduce the box size to 75% of the current volume (20 x 20 x 20cm instead of 22 x 22 x 22cm). It makes quite a difference!

Material:

- 8 or 10mm plywood.
- 2 800mm or more aluminum squares tubes.
- 8mm, 6mm and 4mm bolts, washers and wing nuts.
- Small (3mm or smaller diameter) wood screws.
- Aluminum epoxy malleable compound (fix it type thing, like play dough, but hardens after 30 min or so)
- 3 relatively stiff springs in the 20mm range and at least 6mm inner diameter.
- PVC pipe in 45 and 35mm.

Tools:

Honestly, you need a table saw to build such an object. Base models retail for around $100. I suggest that you purchase and mount on them a small (7-1/4”) thin blade with lots of teeth (40 or more, often called plywood blades). Small/thin blades cut with less effort, tend to have a nicer finish on a low end table saw. Also, make yourself a zero clearance plate. It will be a nice project to get acquainted with your table saw. These will be necessary to cut some of the smaller parts of the travel scope.

Apart from that, usual tools (jig saw, drill, files, sanding paper…) will be needed.

- Saw to cut the plywood (table saw or bandsaw/jigsaw are best)
- Sanding material (power or not)
- A way to make circles is great also (lathe, circle jig on router...), but you can always hand cut them and sand them round.
- A drill and drill bits for the various diameters that we use.

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