Adventures in Refractor Collimation

This is a collection of hints and tips gathered from renovating older refracting telescopes fitted with collimatable objective cells which some may find useful.

If your refractor does not have any cell adjustment screws and the cell is solidly fixed, (glued or screwed onto the tube) then this article may still be of interest because there are still objective issues that can and do happen.

Before I continue let me put your mind at rest, if you have a new scope or one that has been treated well you will very rarely experience any of these issues or need to adjust collimation. Refractors by their very nature are sturdy and if fitted with collimation facility, IMHO and experience, usually hold collimation better than some reflectors. However if you have purchased/acquired a scope that has been abused by previous owner/s then you may come across issues like these.

Please read the caveats and disclaimer at the end of this write up before proceeding with any adjustments on your scope.

If you suspect the collimation of your refractor, the first thing to do is star test it on a reasonably bright star or an artificial star.

Star Test

If your collimation is good you should have an in focus star image that is a close to a clean point of light, (not strictly true because there are usually small arcs surrounding an in focus star but for the purpose of this write up we shall say a point of light).

Now defocus the star by winding the focuser in slightly. You should see the star point image grow into a series of circles or discs (Airy Discs). For a well collimated scope these should be round and concentric. If the circles or discs are not concentric, collimation is suspect. If the circles are squashed then you may have pinched optics. As a double check, wind the focuser out back through focus and out of focus slightly. The discs will still be non concentric in a scope requiring collimation.

Recommended reading here is the good but pricey book – Star Testing Astronomical Telescopes – Willmann Bell Publishing

Focuser Alignment

Before starting collimation make sure the focuser is aligned correctly on the optical axis. The easiest way of doing this is to remove any star diagonal fitted and fit a laser collimator to the draw tube. Check the dot of the laser passes through the centre of the objective lens. If not, there may be several reasons:

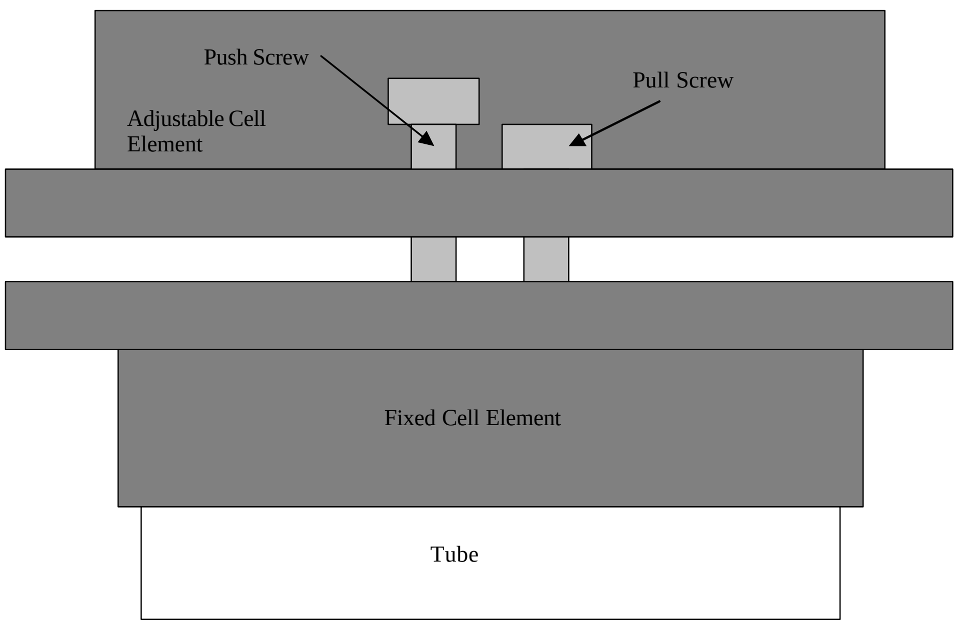
- Your laser is not collimated. To check, rotate the laser in the focuser and if the spot wanders your laser may be off. Collimate your laser then retest.
- Your focuser draw tube is slack or has droop.

Rack & Pinion focusers use several methods to control this from simple felt packing which may be worn or missing to adjustable tension screws acting on a bar of material applying friction to the draw tube opposite the pinion. Replace felt or adjust the tension, depending upon the methods used on your scope, until the spot is central. Crayford focusers will droop if the tensioner is not set correctly, try adjusting the tension screw until the spot is central.

- The focuser is tilted in relation to the tube.
  If your focuser is screwed into the tube or glued then there is no adjustment but can still be out of line if the scope has been subject to major trauma, e.g. been dropped. However if your focuser is push fit in the tube with radial fixing screws then some adjustment may be possible by slackening the screws slightly and adjusting the focuser. Enlarging the screw holes in the tube a slight amount will provide some adjustment (unless the screws are countersunk that is).

Collimation

The most common form of collimatable lens cell uses 3 sets of push pull screws set equidistant around the perimeter of the cell, these tilt the lens cell in relation to the tube and provide centring of the optical axis.



Note

Some cells also have further collimation around the perimeter of the cell for positioning the lens elements exactly in the centre of the cell, (this type is not covered by this write up YET).

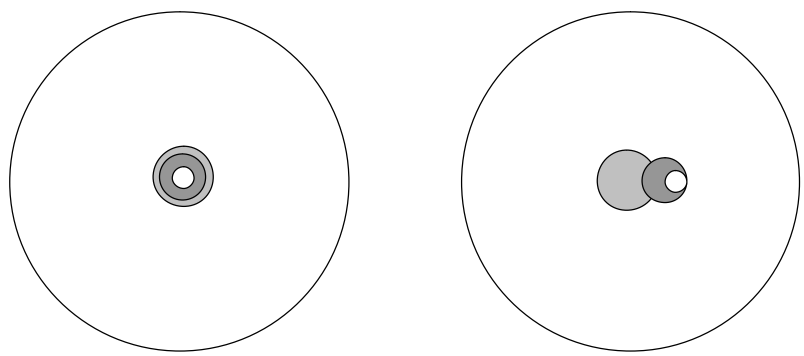
Tools

- Cheshire eyepiece
- Screwdriver/spanner or allen key (whichever is required for the screws fitted to your scope).

Procedure

- Ensure the scope is held securely and supported to allow easy access to the cell collimation screws. I prefer to fit the scope normally in the mount, this means the test can be done in comfort making flitting between objective and Cheshire eyepiece easier.
- Fit the lens cap to the objective.
- Fit the Cheshire eyepiece to the focuser, (do not use a diagonal).
- Look through the eye hole of the Cheshire and you should see a series of round spots. These represent the reflections of the Cheshire eyepiece from the different surfaces of the objective elements. The spots can be very faint and difficult to see, I found that performing the test in the daylight with the angled window of the Cheshire well illuminated (but not in direct sunlight) helped considerably. Some folks use a torch to illuminate the Cheshire window but I found the reflections set up by the torch too distracting.

For a well collimated scope all spots should merge into one concentric set of spots but a scope out of alignment will show a series of spots in a line, see diagram.



Good Collimation

Example of Poor Collimation

- Slacken off the push screw and tighten the pull screw a fraction on the opposite side of the cell from the position of most misalignment of the spots.

Note what happens.

- If the misalignment gets worse then retrace your steps and slacken the pull screw and tighten the push screw.
- If the alignment improves then this is the way to go.
- If nothing happens then the cell is bottomed out and the pull screw has no adjustment left. In this case slacken all three pull screws and tighten all three push screws until there is a small but even gap between the 2 parts of the cell.
- Continue adjusting in small increments until all spots are concentric.
  This may take some time and involve adjusting the other sets of screws as well but take care to avoid using large adjustments and also avoid leaving too few threads on the pull screws to

hold the lens in place. You do not need a large gap between the adjustable and non adjustable cell elements.

Once the spots are concentric then check that all collimation screws are firm but not over tight and wait for a clear night sky or use an artificial star to check star test the scope.

Congratulations you now have a collimated scope ☺
Colimation sounds complicated but once practiced this job can be done in a matter of minutes.
But it may not be over yet ☹

Other objective issues
If your scope is new to you but has been around the block a bit then it may have suffered the plight of older telescopes, finger trouble or worse. Previous owners may have stripped the lens to clean or just messed about with it without really knowing what they are doing, so here are a couple of experiences I have come across with scopes that appear to have good collimation but still fail to perform to their best.

Pinched optics
If the star test shows misshapen/squashed Airy discs this is usually indicative of pinched optics. The most common cause I have found so far is the lens retaining ring has been tightened too much. I had one scope where the Airy disc was round but the concentric rings were uneven. I had to wear gloves to loosen the retaining ring it was so tight. Thankfully the lens recovered its figure after setting the correct tightness. See caveats re tightening this retaining ring.

If the Airy disc is squashed and you have a cell with additional perimeter collimation screws then suspect that these may have been over tightened. I have no experience of this myself, yet, so would advise caution on slackening any of these screws. Perhaps a tentative 10 degree loosening of one screw and observing the consequences on star test may be in order here, it’s up to you.

Air spaced element spacing
Air spaced objectives use shims between lens elements, some use small rectangles of foil, others use O ring type spacers.

If O rings are used there must be a ring between the front and rear elements to keep them apart and this ring must not be kinked or squashed. If the ring is missing you will not get a reliable collimation image through the Cheshire (one dot missing) and if its kinked you may not be able to get all dots concentric during collimation.

If foil spacers are used these must be spaced equidistant around the lens and be of the same thickness. I have experienced both examples; one case a foil spacer had been replaced by a piece of cigarette foil, it looked OK but was approx half a thou thinner than the others and caused misalignment resulting in a ghost image of bright objects. If the spacers have moved refit them so they are equidistant, e.g. 120 degrees apart. Ghost images can very prevalent in uncoated object lenses as there is no antireflective coating to reduce internal reflections.

Object lens element alignment
Most doublet objectives (triplet not covered yet) are made up of a rear plano-concave rear element and a double convex front element (with some exceptions). In some cases the front element is not always symmetrical (cross section wise) and may have a different curve on each face therefore it is most important that this lens is oriented correctly. If the lens does not perform and is a bit fuzzy or hazy on planets try turning this lens round.

Some doublets are figured and matched such that they must be orientated exactly to each other. Some thoughtful manufacturers mark the sides of the lenses with a pencil line of dots, check these line up if you are suffering fuzzy images. If there are no marks then it is a matter of trial and error to get this orientation correct. Focus the scope as best as you can on a planet with plenty of detail, say Jupiter or Saturn. Take note of the image. Take the scope indoors strip the objective and rotate the front element 20 to 30 degrees in relation to the rear, re assemble and refocus on the planet, has it improved? Repeat until the image improves then reduce the amount of rotation to fine tune.

All the above tests can be a long painstaking job and require great care and attention to avoid damage to the lens / scope but will pay dividends if you've started with a good lens; no amount of adjustment/tuning will make a poorly made lens perform however.
For example I had a 1970s doublet that gave atrocious fuzzy images on the planets but I knew it could perform better, I turned the front element, put the spacers in the correct order and tuned the elements as described and was rewarded with a superb lunar and planetary telescope, well worth the effort.

Caveats!

- Follow manufacturers precautions when using laser collimators
- Always take great care when dismantling the lens elements.
- Ensure your work area is clean and covered with clean paper.
- Handle lenses carefully and with optical cleaning cloths or cotton gloves.
- When re assembling object lenses always use a blower to clean lens faces of dust before assembly.
- Never over tighten the lens locating ring in the cell, this will stress the lens and possibly pinch the optics, the ring should be just finger tight to hold the lens in position, some advocate having the lens slightly loose in the cell so it rattles if shaken, this will depend on the lens design and I would be wary of adopting that method especially if inter element foil spacers are not glued in place.

Disclaimer!
This is an account of my experiences and is intended as a pointer to possible problems that refractor owners may experience and should be taken as such and not a step by step guide. Scopes, lenses and cells all vary, this guide is a generalisation only. It's also your decision and your responsibility if you decide to adjust/strip your scope/lens. If in doubt don't do it.