Newtonian Telescope Collimation with the *AstroSystems* Laser Collimator with Barlow attachment

AstroBeam II features

- **An easy to install, magnetically attached Barlow lens.**
- **New 635 nm laser module – easier to see and still safe**
- **Anti-roll thumbscrew.**
- **Gold anodize for nighttime visibility.**
- **Recessed Switch.**
- **One year warranty on materials and workmanship.**
- **Enclosed battery case.**

Introduction

The coherent collimated beam of light generated by lasers has made them a natural for collimating optics and they have been used for that purpose since the 1960's. The introduction of lightweight, low-power consumption laser diodes has now made them readily available to amateur astronomers. The popularity of using a laser for collimating optics stems from two advantages over other popular collimating methods. Collimating with a laser is *fast* and *easy*. There is also less need for interpretation as collimation proceeds and the laser is equally convenient to use at night. These advantages have made the laser collimator the first choice for experienced and beginning amateur astronomers.

Astrosystems developed the first commercially available laser collimator in 1994 with the AstroBeam I, a 1.25"/2" model that was an instant success. The first lasers made collimation far more intuitive and easy for beginners to learn.

The first two steps, preparation and mechanical alignment, need only be performed the first time the telescope is assembled. Thereafter, only the optical alignment and star testing are needed to collimate your telescope. Don't underestimate the importance of mechanical alignment. Most troublesome collimating jobs can be traced back to mistakes or assumptions regarding the placement of components.

Preparation

Position the telescope

Place the telescope on a horizontal surface or move it to the horizontal. Position the focuser so it is easily accessible. You will be moving back and forth from the rear to the front of the tube assembly to check progress and it helps to have things positioned for convenience.

Assemble the proper tools

Gather the necessary tools required to adjust the primary mirror holder, secondary mirror holder, spider and the focuser base.

Center spot the primary mirror

It is necessary to "spot" the center of the primary and secondary mirrors. To facilitate collimation at night, a white mark on the primary is most visible. The ideal spot can be made from any type of adhesive backed white paper or Mylar. Cut a square 3/4" on a side and use a paper hole punch to make a smooth 1/4" hole in its center. An adhesive backed paper reinforcing ring such as the type used on notebook paper will also work well. Insure that the center of the mark exposes the mirrored surface for reflecting the laser beam. The spot is placed at the center of the primary mirror.

NOTE: To avoid possible damage to your optics, remove rings, watches, bracelets, pens, pencils and any other loose articles from your person or around your work area that could fall on or scratch your mirror. It is also advisable to use a plastic or wood ruler when measuring your optics.

The center of the primary mirror can be determined by first finding its diameter and dividing by two. Use this radius to measure in from the edge at six or eight positions around the mirror. After several measurements you will begin to zero-in on the exact center. Use a fine tipped permanent marker to mark the center and then accurately position and attach your paper "spot." Use acetone or alcohol on a cotton swab to remove the permanent marker in the center of the spot.

NOTE: Don't worry about placing a spot on the optics, the center of the primary isn't used since the shadow of the secondary mirror covers this area.

Mark and "offset" the secondary mirror

Note: While offsetting the secondary is technically correct, it has no noticeable effects in a visual telescope. Only for large values of offset (>0.20") do we suggest incorporating it. In most cases the secondary spot will be centered, to offset the following instructions apply. Offset is the repositioning of the secondary mirror in the light cone coming from the primary mirror (see **Figure 1**). To make better use of the full light gathering ability of the primary mirror and more fully illuminate the edge of the low-power eyepiece field, the secondary mirror is positioned a small distance away from the focuser and an equal distance towards the primary. To realize why this offset is necessary we see that the light returning from the primary mirror is shaped like a *cone*. When this cone is intercepted at a 45 degree angle the shape is larger in area on the side towards the primary and smaller on the side towards the open end of the telescope. The diagonal is shaped like a 45 degree cut through a *cylinder* and so it is uniform in area front to back and side to side. Obviously these two shapes are not the same, so shifting the secondary mirror towards the "fat" side of the light cone will increase the illumination at the image plane.

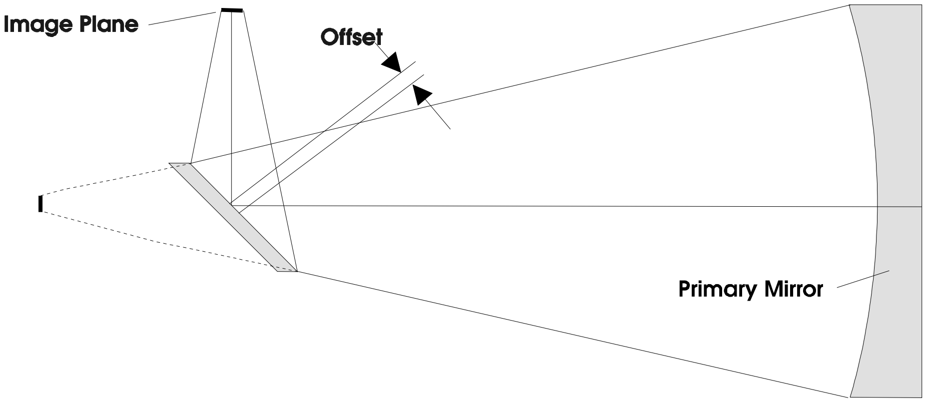


Figure 1. The center of the secondary mirror is offset away from the focuser and towards the primary.

To calculate the amount of offset to maximize illumination of the field use the following formula:

$$s' = \frac{N\,(D - N)}{4\,(F - L)}$$

s' = the secondary mirror offset
N = Secondary mirror minor axis
D = Diameter of primary mirror
F = Focal length
L = Intercept distance measured from the secondary mirror to focal plane.

An example using the above formula:
A 20" telescope has a focal length of 100 inches. The tube outside diameter is 22", the secondary minor axis is 3.1", and the focuser height is 1.5". The focal plane is 1/4" above the fully racked in focuser, this distance is known as "in-travel."

N = 3.1"
D = 20"
F = 100"
L = 11" + 1.5" + 0.25" = 12.75"

By inserting the values in the example we have:

$$s' = \frac{3.1\,(20 - 3.1)}{4\,(100 - 12.75)} = \frac{3.1\,(16.9)}{4\,(87.25)} = \frac{52.39}{349} = \mathbf{0.15''}$$

The offset for this telescope is 0.15", or just over 1/8". The easiest way to introduce offset is to position a spot, using a pointed permanent marker, on the secondary mirror center. Then mark a second spot, shifted by the amount of the offset multiplied by 1.4, along the centerline towards the end of the secondary mirror in the direction of the tube front (see **Figure 2**). In the mechanical alignment section this spot is centered under the focuser to move the secondary mirror the correct horizontal offset toward the primary mirror, while the spider is repositioned to move the secondary mirror away from the focuser by the same amount.

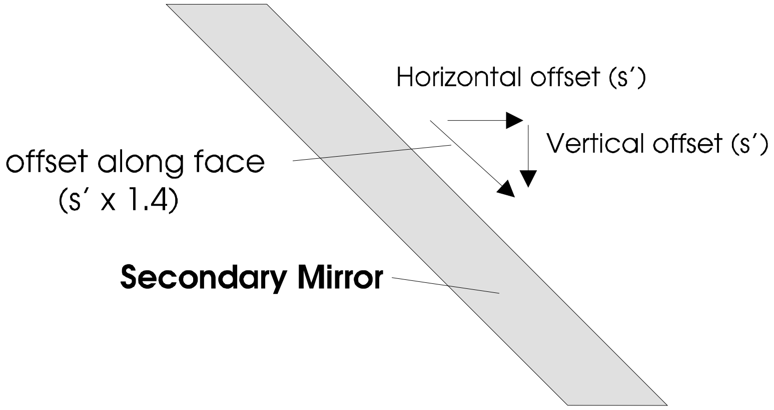


Figure 2. Comparison of the calculated offset in the vertical and horizontal with the offset times 1.4 as measured along the face.

Mark the tube opposite the focuser

Mark a spot on the side of the tube opposite the focuser by carefully measuring from the front of the tube down an equal distance (on the outside of the tube) as to the center of the focuser drawtube. A piece of adding machine paper works well to find the dimension around the tube (or upper cage). Wrap this paper around the outside, measure its center, rewrap the paper and drill or punch a tiny hole through to the inside. Place a mark or spot on the inside to complete preparations.

Mechanical Alignment

Mechanical alignment is the accurate positioning of components in the tube assembly. The importance of mechanical alignment lies in the fact that all the following steps are either easy or difficult, depending on how well the telescope components are mechanically positioned.

NOTE: Truss tube owners are proceeding on the assumption that when the telescope is assembled the upper cage is centered over and square to the mirror box. Measuring this to verify will save time and frustration later.

Center the primary mirror in the mirror box

With open end mirror boxes it is a simple task to measure in from the mirror box sides to the side of the mirror. With closed tubes, centering the mirror relative to the mirror mount and then centering the mirror mount relative to the tube works well. Mirror cells supplied with a sling can be adjusted in combination with cams or locating pads to center the primary mirror. It's a help to first turn the collimating screws so they all have the same amount of travel in both directions.

Square the focuser to the upper cage (or tube)

With the secondary mirror and holder removed we can use the laser (without Barlow lens) to square the focuser. The focuser mounting screws are loosened and shims or the use of adjusting feet (if the focuser is so equipped) are used to center the laser spot on the mark opposite the focuser.

Offset and square the spider

As described earlier, half of the secondary mirror offset is incorporated by shifting the spider away from the focuser. This can be done by loosening the spider mounting screws near the focuser and tightening the screws opposite to shift the entire spider assembly away from the focuser by the vertical component of the offset. The spider is next squared to the optical axis. This is checked by sighting through the spider bore towards the primary. The spider bore should look directly at the mirror center spot. Adjustment can be made by drilling the mounting holes oversize and shifting the spider vanes to square.

Position secondary laterally under focuser

Insert the laser collimator in the focuser (without Barlow). Replace the secondary mirror and holder and position it under the focuser. Now, adjust the secondary so the laser beam can be seen on the secondary spot. Washers or adjustment nuts can be used to position the secondary (see **Figure 3**). This adjustment combined with the preceding step of repositioning the spider will position the secondary mirror with the proper offset.

Position the secondary mirror rotationally under the focuser

Remove the laser and sight through the focuser drawtube. Rotate the secondary holder and mirror until the reflection of the primary mirror is centered all around. Move towards or away from the focuser until the edge of the primary is just seen in the secondary. A smaller adapter or peep hole sometimes simplifies this step. When the primary mirror reflection is centered, lock the secondary in place. This completes the mechanical alignment.

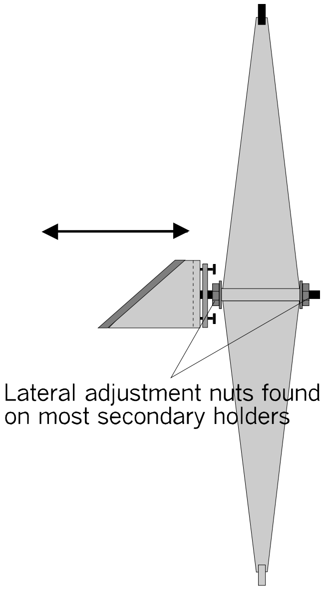


Figure 3. Lateral adjustment

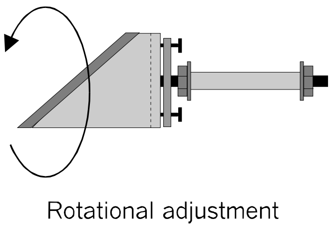


Figure 4. Rotational adjustment

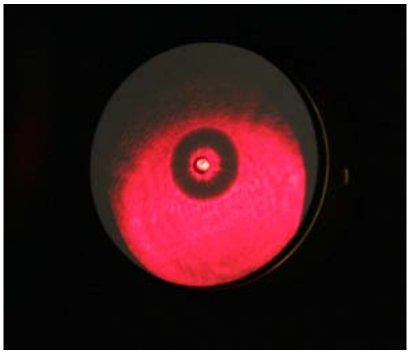
Optical Collimation

Adjust tilt of secondary mirror

Using the laser (without Barlow Lens) and the collimation screws supplied on the secondary holder, adjust the secondary mirror tilt to center the laser beam from the secondary in the primary mirror center spot. This can be easily seen from the front end of the telescope. With open tube telescopes, get close to the primary and adjust the beam in the center of the spot, extra accuracy at this step will improve the final results.

CAUTION: If the tilt of the secondary is off when starting, the return laser beam from the primary mirror may miss the secondary completely and exit the front of the tube. **DO NOT** look into the laser exiting the front of the tube or allow anyone else to do so. Incidental exposure to a 3-5 miliwatt laser is not immediately harmful but we recommend you avoid any unnecessary eye exposure.

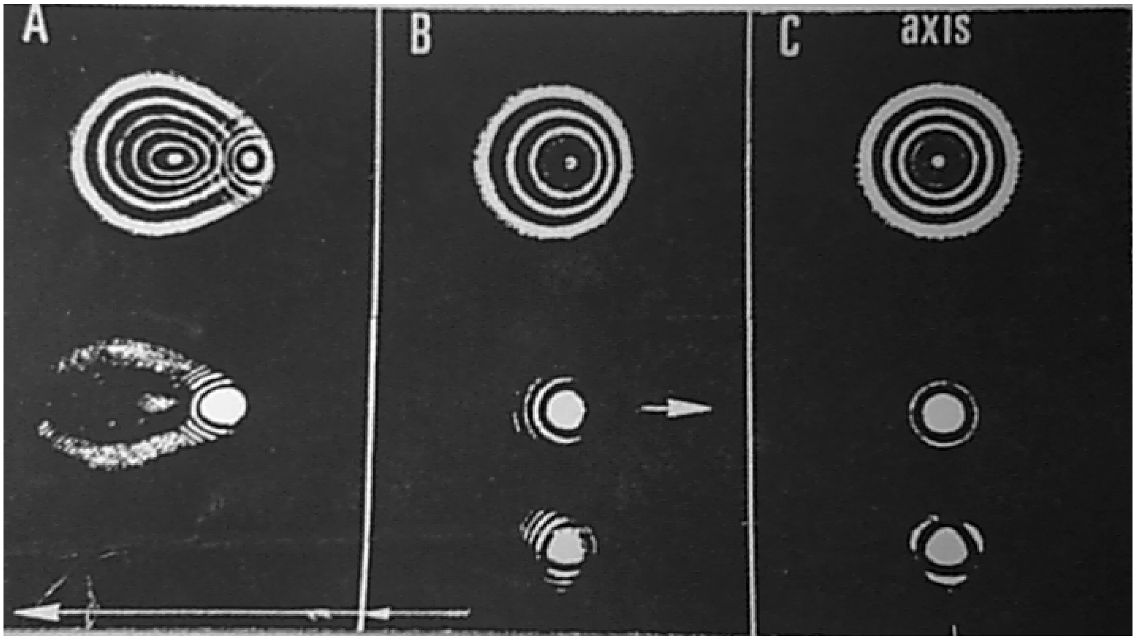
Adjust the tilt of primary mirror with the Barlowed Laser



Snap the magnetic Barlow lens on the front of the laser and insert in the focuser. The diverging beam will cover the primary mirror's center spot, but will not necessarily look concentric or round (not a problem). The primary collimation screws are used to adjust the tilt of the primary so the silhouette of the center spot (the photo at right shows a round spot, any shape is OK) is centered on the hole on the bottom of the laser. The matte white surface makes it easy to see the image and center it accurately. Telescopes with an open bottom end can be adjusted from the primary end by looking past the primary to the reflection of the bottom of the laser as seen in the secondary mirror. It is then a simple matter to adjust the primary mirror so the center spot image is centered on the bottom of the laser body. Telescopes with a closed cell can be adjusted incrementally by moving to the front of the tube to observe the reflection of the bottom of the focuser and laser body as seen reflected in the primary mirror. Having someone help at this stage speeds the process. Once the return image is centered on the hole in the laser body, the telescope is collimated.

Fine Optical Collimation - Star Test

Optical collimation can be checked and fine tuned by sighting on a star. This is a very sensitive test, if we tilt a f/6 mirror to shift the image in the focal plane by 1/100 inch, perceptible coma results. If the collimation screws have 16 threads per inch this will correspond to as little as 1/8 turn. Interpreting the images seen in this test will take some experience. Locate a star of third or fourth magnitude fairly high in the sky. This improves the chances of a good image and insures the primary mirror makes positive contact on its flotation pads. Using a medium-power eyepiece defocus the image. **Figure 5** below shows stars outside of focus in the top row and inside of focus in the bottom row. Should your image appear like **5A**, exhibiting gross coma, astigmatism and diffraction, something is severely misaligned or has shifted and returning to mechanical alignment will be necessary. Usually the stars appearance will look much like **5B**, showing a small amount of decentering. For more detail shift to a high-power eyepiece. Work by trial and error rather than trying to figure out which primary mirror collimation screw to adjust. The lower arrow shows direction in which to displace the image in the field to return the beam on axis. Once this is accomplished and checks out with high power, the telescope is perfectly collimated.



A. Large centering error **B.** Small centering error **C.** Perfect centering

Figure 5. Adjusting primary mirror with a star.

Telescope Diagnostics with the Laser

The laser collimator can be used as a powerful diagnostic tool. Loose or broken parts, flexure and other common difficulties can be found with a little experimentation. Recheck the collimation after an hour or two of observing to insure that expansion/contraction or loose components have not changed the collimation. Be aware that binding of the primary mirror resulting in it not resting on its support pads properly is one of the most common causes of collimation change. Double-check that the support components for the optics are adjusted.

Spider/Secondary Holder evaluation

With the laser on (without Barlow lens) and the system collimated, tap each spider vane in turn. While looking at the laser spot in the primary mirror, a large amount of vibration on one particular vane can indicate trouble. Gently press on the sides of the secondary holder and look for consistent movement of the beam in the primary. Gently torque (twist) the upper cage or top of the tube where the spider mounts, and look for any inconsistent movement of the laser spot.

Focuser

Check the focuser for loose mounting screws, flexible shims or mounting plate flexure. The laser itself can be moved in the focuser to check drawtube fit and stability.

Tube and Optical Supports

Move the telescope in its mount and look for any laser spot movement due to tube flexure, loose truss poles or truss pole mounts. This is an excellent way to determine the actual amount of clamping force needed on truss poles. Try loosening one or two to see the affect of a loose pole.

Mirror Cooling Fans and Drive Motors

Turn on any motorized accessory attached to the telescope and look for telltale oscillation of the laser spot. Any perceptible motion of the laser spot will be easily seen at 100x or more when observing.

Care / Maintenance / Changing batteries

DO:
Keep your laser collimator clean and avoid rough handling.
Use a lens duster or canned air to blow any debris off the laser module lens.

Replace aged batteries, even though they may still function.
The Laser Collimator uses 2 AA batteries. The laser is rated for 5 volts maximum, operating at higher voltages will void the warranty and shorten the laser diode life. If batteries are older than 2 years but still functioning, replace them anyway. Old batteries have a higher probability of leaking if accidentally discharged.

Use care when removing battery pack and changing batteries.
On a table at a comfortable height, remove the thumbscrew that holds the cap. Slide the battery pack out of the body, taking care not to pull the wires attached to the laser module. Also be sure not to let the battery pack or cap hang free, placing undue strain on the laser module wires. Use a small Phillips drive screwdriver and remove the screw in the battery pack. Slide the cover off and replace the batteries. Replace the battery pack cover and gently tighten the screw. Place the foam cushion next to the battery pack and reinsert into the laser body. Replace the cap and secure with the thumbscrew.

DON'T:
Attempt to adjust the collimating screws on the laser body.
If you feel the diode module is not producing a beam parallel with the laser body, simply return the laser to **AstroSystems** with return postage for free factory service.

Do not expose the laser to temperature extremes, especially heat. No dashboards or car windows.

Do not run the laser for extended periods of time (over 30 minutes).
This can overheat the module. Allow to cool if it will be used for an extended time.

Laser Safety

The Laser Collimator will produce up to a 3.5mW beam in the orange-red (635nm). This orange color is easier to see during the day and it makes the return silhouette with the Barlow attachment. Although this is the same power and type produced by laser pointers and grocery scanners, it is advisable to avoid ***any*** accidental eye exposure. This type of laser diode has a fast divergence (spreads out) and is well below the safety threshold of 1mW after traversing 80 feet or more.

Never allow children to operate or play with the laser and keep the laser in a safe place where it cannot be misused by curious family or friends.

Use the laser only for optical collimation of telescopes. Make sure the front of the telescope is covered during the first stages of coarse collimation. If the secondary mirror or primary mirror is misaligned the return beam may miss the secondary mirror and exit the front of the tube. Passing your hand in front of the telescope quickly shows if the beam is exiting the front of the telescope. If this is the case just use your hand as a block while adjusting the secondary until the secondary mirror intercepts the beam. AstroSystems cannot control the use of this laser product. All responsibility for its proper use is assumed by the purchaser.

Laser Characteristics

The laser module used in the Laser Collimator is fully integrated. The module contains the diode laser, power supply, heat sink and collimating lens. The laser is optimized for the smallest spot size at 20 feet (6m). At short or long distances the spot may be slightly elongated. It is a simple matter to interpolate the position of the center of the spot when aligning at extremely short or long distances. The laser spot size is affected by temperature. As the temperature falls below about 50 degrees F the spot size will slowly grow. This will affect telescopes with a focal length over approximately 100 inches. This situation can be remedied by using the laser immediately upon set-up before it has a chance to become cold. It can also be kept in a warm place until needed, such as an inner pocket or warm car.

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