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User Manual

ADVANCED CT LASER COLLIMATOR for CASSEGRAIN TELESCOPES

MANUAL VERSION 9.0 WITH =OH= EDITS

User Manual

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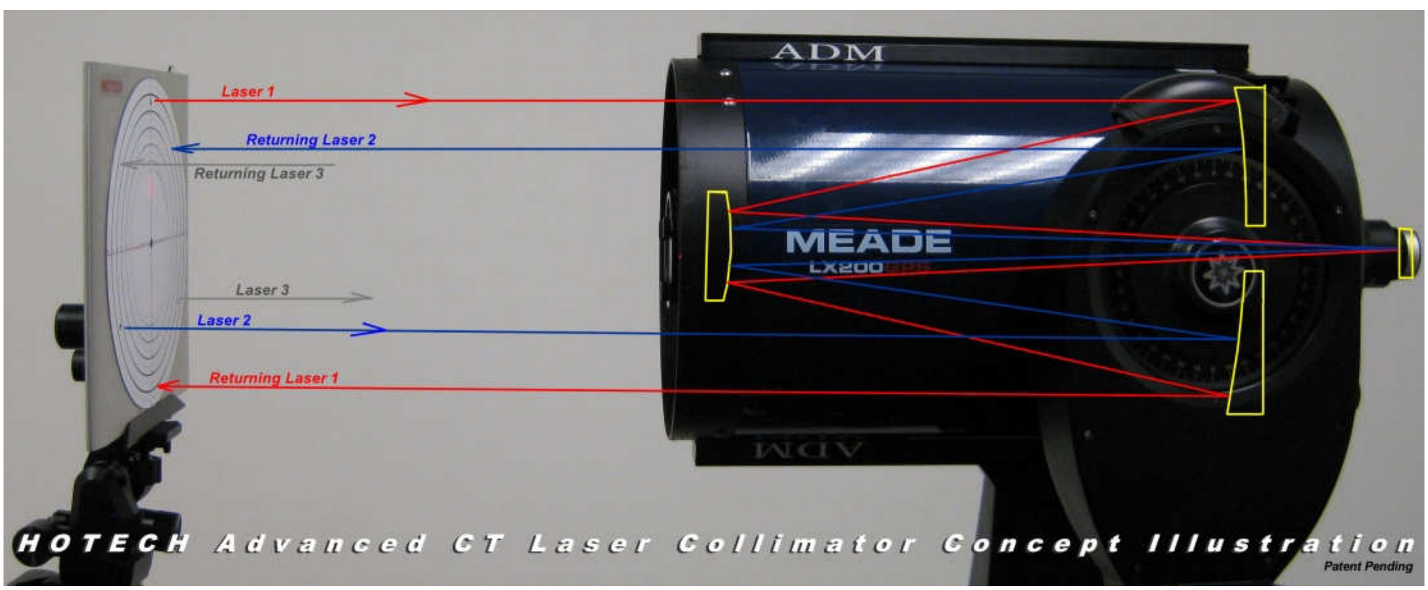


User Manual

ADVANCED CT LASER COLLIMATOR for CASSEGRAIN TELESCOPES

Thank you for purchasing the state-of-the-art HOTECH Advanced CT Laser Collimator. This instrument uses the most advanced laser and optical technology to enable the user to achieve excellent collimation in a very short distance. Collimation is the process of aligning a telescope's optics. The laser collimator makes the collimation process more efficient and increases collimation accuracy. When carefully set up, and each step cross checked, it makes it possible to make fine adjustments to a Cassegrain telescope that cannot be achieved with traditional star collimation. Your telescope is aligned at the factory, but rough handling during shipping can cause misalignment. Some telescopes are not well collimated when shipped. Misaligned collimation causes reduced optical efficiency and results in poor image contrast, astigmatism, and blurry images. The following describes how to collimate your Cassegrain style telescope with the aid of the Advanced CT Laser Collimator.

Please read the entire User Manual before working with your Advanced CT Laser Collimator
CAUTION – Be aware of the following as you use your Laser Collimator:
Only turn ON the laser(s) when you are going to use it. The laser should only be used with adult supervision, and should only be used for collimating a telescope. Never point the laser or the reflection of the laser collimator at anyone's eyes.
NOTE – These instructions cover collimation of Schmidt Cassegrain Telescopes (SCT), but most Cassegrain type instruments are collimated in similar fashion. For telescopes with both adjustable secondary and primary mirrors (e.g. Ritchey-Chretien type telescope), please email or call us for details. All lasers on the collimator are class II (<1mW). For additional information, please visit our website, www.hotechusa.com, or write us at info@hotechusa.com.

Collimation Basics You Must Know Before Starting
What to Adjust:
For a long time (since the introduction of the SCT), traditional star collimation has been the only reasonable adjustment available to the SCT user. Traditional star collimation is done using the three alignment screws on the back side of the secondary mirror. The secondary mirror can be seen in the middle of the clear glass corrector plate that is seen when you look into the front of the telescope (see illustration below). When used with care and precision, the Advanced CT Laser Collimator instrument provides users with the precise measurements that are needed to do collimation and optics alignment beyond just the adjustment of the secondary mirror. However, making precise adjustments requires slow, careful work that involves the iterative processes that were used to originally align your telescope. Be prepared to take notes (know where you started from) and continually recheck and crosscheck all alignment procedures before and after any and all adjustments. If you only use the Advanced CT Laser Collimator to do secondary mirror collimation on your telescope, this adjustment alone can be made with greater precision than previously available. For ease of manual adjustment, we recommend replacing the stock secondary mirror alignment screws with knob headed screws (available from several vendors) to allow easier, finer adjustment.

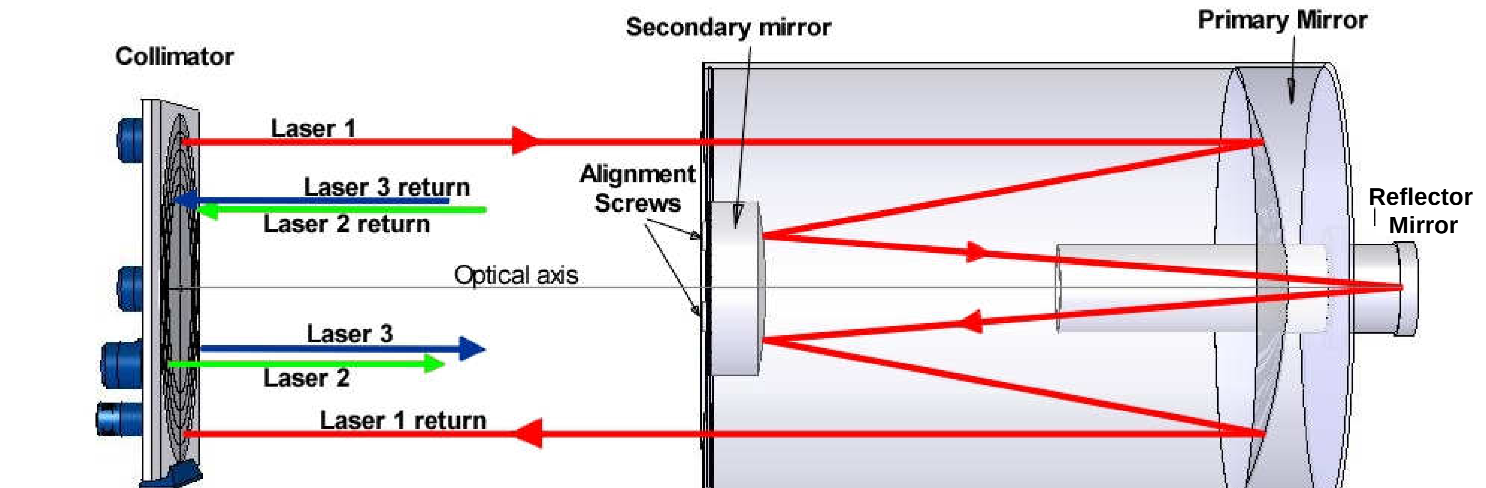


FIG. 1

How the Collimator Works:

The Advanced CT Laser Collimator samples the entire optical system (primary, secondary mirror, and the eyepiece axial position) with a simulated large aperture flat-wavefront light source generated by three parallel lasers positioned behind the target plate. The target plate provides a clear view of the optics' alignment condition when the three lasers are reflected back on the target (FIG. 1). It is extremely critical that the lasers are pointed square-on (co-aligned) to the primary mirror for an accurate reading. It is just like looking at a distant star and centering the star in the eyepiece field of view during a star test, except – regardless of the weather conditions – the star is only about one tube length in front of the telescope and it is stationary.

Basic Co-Alignment of the Telescope & Collimator – Basic Co-Alignment is achieved when the collimator and telescope are centered and squared on the optical axis of the telescope's primary objective mirror and each other. The diffused laser crosshair (diffuser strip in place) is projected from the center of the collimator as a guide to optically aiming the primary mirror back to the center of the collimator target plate. Diffusing the laser crosshair causes it to appear as a circular or donut shaped beam (the crosshair pattern is no longer visible – just the outer crosshair dimension is preserved as a circle). Centering the donut beam, centers the collimator on the telescope optical axis (FIG. 2A, Aim Telescope at Collimator, diffuser strip installed). Then, without the diffuser (crosshair now seen crisp and sharp), center the return laser crosshair reflected from the telescope primary mirror in order to adjust the collimator to be perpendicular (square) to the telescope's optical axis (FIG. 2B, Aim Collimator at Telescope, diffuser strip removed). Most of the time needed to achieve collimation is spent on the initial steps to achieve accurate Basic Co-Alignment of the collimator and telescope. Be patient and careful; the results will be well worth it!

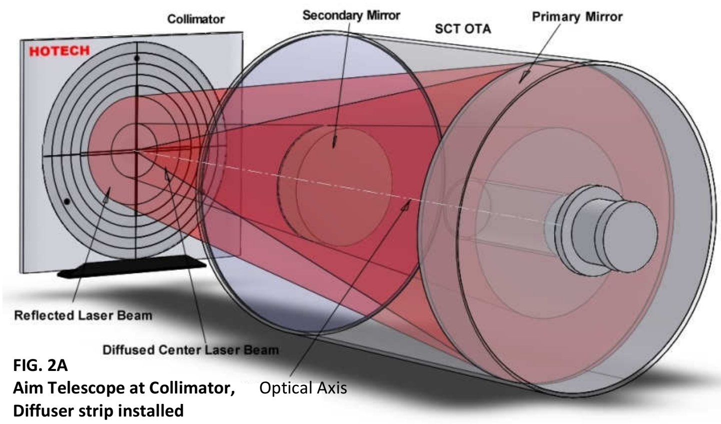


FIG. 2A
Aim Telescope at Collimator, Diffuser strip installed

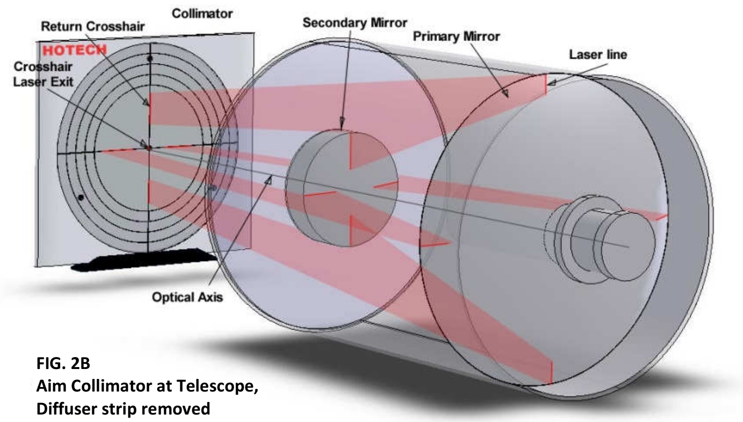
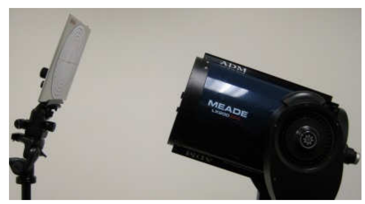


FIG. 2B
Aim Collimator at Telescope, Diffuser strip removed

Overview of the **Basic Co-Alignment Process:**

You can collimate your telescope at almost any position (e.g. telescope 20 deg. up) as long as both the collimator and the telescope are Co-Aligned. Many users find that keeping the telescope optical axis parallel to the floor (level) and keeping the collimator vertical makes it easier to achieve squared-up, accurate Co-alignment. Once the collimator and telescope are Basic Co-aligned, adjust the telescope's three secondary mirror alignment knobs (or screws) carefully by small amounts to move the three projected laser dots to the same collimator target plate ring.



Basic Co-Alignment Process:

1. Set Collimator distance
2. Install Reflector Mirror in the telescope's visual back (2-inch or 1.25-inch as appropriate).
3. Aim Telescope at the Collimator (FIG. 2A)
4. Aim Collimator at the Telescope (FIG. 2B)
5. Adjust Secondary Mirror to move the three laser dots onto the same circle on the target.

Package Content:

1 x Premium Soft Carrying Case
1 x Advanced CT Laser Collimator
1 x Reflector Mirror (1.25" or 2")
2 x Diffuser strips
1 x Fine-Adjuster (Collimator to Tripod)
1 x 3V, CR123 Lithium Battery
1 x User Manual (in cover pocket)

1.0. Setting Up the Laser Collimator on the Tripod

1.1. Where to setup the telescope and the collimator

Position both collimator and the telescope on solid ground (no carpeted, wooden floor, or other surface that will flex or vibrate). Both telescope and collimator must be on the (same) ground floor.

1.2. Setup the collimator on the tripod

a. Attach the fine-adjuster to your tripod using the tripod's 1/4-20 bolt.
b. Attach the collimator to the fine-adjuster using the threaded knob on the fine-adjuster and the ¼-20 screw hole on the bottom of the collimator.
c. Lock the collimator firmly in place with the lock-knob on the fine-adjuster's 1/4-20 bolt.

2.0. Getting Familiar with the HOTECH Advance CT Collimator

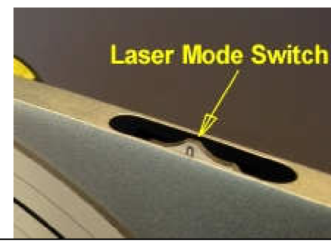
2.1. Installing the battery

Unthread the battery compartment cap and insert the included CR123 lithium battery with the positive side up (+ tip side toward the cap) and replace the battery cap.

2.2. Switching the laser to the proper mode

Position the collimator on a tripod about 4 feet from a white wall with the target side facing the wall. Rotate the rotary knob on the top right corner of the Collimator to activate different laser modes. You will see the projected laser patterns on the wall at various positions.

Mode 0: Unit off.
Mode 1: Crosshair laser ON.
Mode 2: Crosshair laser and three alignment lasers ON.
Mode 3: Crosshair laser, three alignment lasers, and target backlight ON for night use.



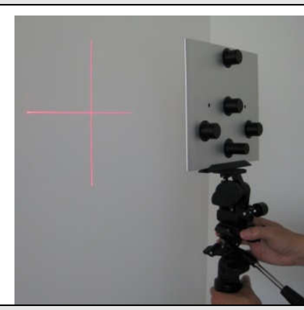
Other modes:

DT: Three alignment lasers ON.	**BL**: Backlight ON.
1L: Crosshair laser and backlight ON.	**CL**: Three alignment lasers and backlight ON.

Please use the recommended mode in each procedure for best result.

2.3. Rough adjustment

Switch the laser to mode 2, lift the tripod and move the collimator and tripod to various distances from the wall to see how the crosshair expands and contracts in size at various distances.



2.4. Using the Fine-Adjuster

With collimator back on the ground, adjust the fine-adjustment stage as follows (In the Figure to the right, the arrows indicate which way the Collimator face moves when the associated knob is adjusted.):

Preparing the Fine-Adjuster:

- The Large Knob on right is for rough adjustment to make the collimator face approximately square to the front of telescope. Loosen the large knob to adjust then tighten to lock the large knob in place so that the forward small knob is ready for use.

Vertical Adjustment:

- The forward small knob is for fine adjustment in the vertical Up/Down (Up/Dn) direction.

Horizontal Adjustment:

- The left side small knob is for fine adjustment in the horizontal Left/Right (L/R) direction.

3.0. Installing the Reflector Mirror:

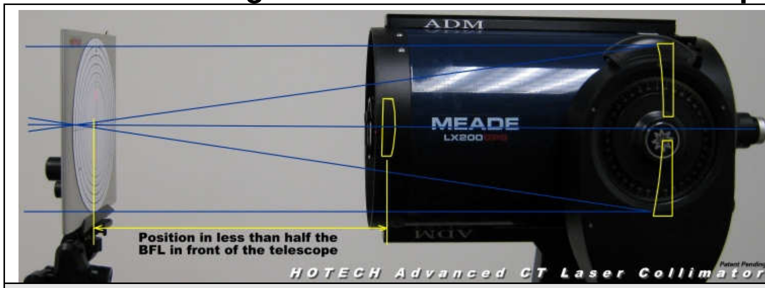
3.1. Installing the Reflector Mirror into your visual back or focuser

If the telescope is to be used mostly for visual observation, collimation can be done with your star diagonal in place. Please note that a poor quality diagonal, one with a misaligned mirror, may cause collimation problems. However, if photography or CCD imaging is planned, it is best to insert the reflector mirror directly into the telescope's visual back or focuser. Use either a 1.25-inch or 2-inch reflector mirror depending on the size of visual back or focuser.

To properly install the reflector mirror, slightly pressure the reflector mirror shoulder against the focuser rim. Rotate the mirror in the focuser and observe movement on any one of the visible laser dots projecting on the collimator target plate. Gently turns the thumbscrew to lock the reflector mirror in place without seeing any laser shifting.

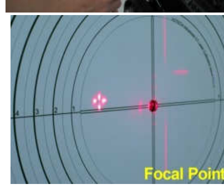
NOTE – For best possible collimation with a diagonal, and if you plan to use a reducer, and/or field flattener, first perform all the steps to collimate the telescope without the accessories, then, refer to Step 10.0 to collimate for use with the accessories installed. (The Celestron Edge series of telescopes already has field flattener lenses installed; this does not change or affect any of the steps or procedures given in this manual.)

4.0. Positioning the Laser Collimator at the Proper Distance



The distance between the laser collimator and your telescope varies depending on the diameter and focal length of your telescope. In general, the greater the distance from the telescope, the higher accuracy you will achieve. In practice, distances just beyond the Back Focal Length (BFL) distance will give larger target patterns with good resolution. Use the following steps to identify a good collimating distance for the telescope.

4.1. Determine the distance between the laser collimator and your telescope



a. Position the collimator one tube length's distance in front of the telescope with the target plate facing the telescope (photo above).
b. Switch the collimator to mode 1 (crosshair laser only).
c. Roughly aim the crosshair toward the telescope.
d. Experiment with the proper distance by lifting the tripod and collimator and moving the collimator slowly toward and away from the telescope while keeping the reflected crosshair on the target plate. Don't worry about getting the crosshair perfectly centered on the target at this point. You will see how the crosshair contracts and expands in size on the target plate in relation to the distance adjustments.
e. Move the collimator to the distance where the crosshair is its smallest. This point is at the Back Focal Length (BFL) of the telescope primary mirror. Now, to position the collimator at a distance with good pattern resolution, move the target away from the telescope until the inner tips of the reflected crosshair are positioned between the target plate's ring 1 and 2.
f. Firmly position the tripod at this distance. This will be your collimating distance.

5.0. Achieving Basic Co-Alignment of the Collimator and Telescope

This is the critical step where you achieve Basic Co-alignment of the Collimator and Telescope for an accurate reading of the Telescope's optics alignment. Step 5.0 is broken down into three linked Sub-Steps 5.1, 5.2, & 5.3 that must be repeated (iterated) to lock-down Basic Co-Alignment. These iterative processes are similar in nature to the processes used to originally align the telescope.

NOTE – DO NOT use the back of the secondary mirror housing as a crosshair centering reference. The secondary mirror might not be perfectly centered on the optical axis of the primary mirror. Referencing the center of the back of the secondary as the pointing axis does not mean the primary mirror is also on the axis. You can use it as a quick rough check for aiming, but not to achieve co-alignment.

(Continued Next Page)

5.1. Center Aim your Telescope to the Collimator

With the collimator switched to mode 1, the laser crosshair (a single-point light source) is emitted from the center of the collimator into the telescope and reflected back to the collimator target plate. With a diffuser strip installed over the crosshair laser, the primary mirror reflects a filled cone-shaped beam back onto the collimator's target plate as a donut shaped beam (the secondary mirror shadow is in the center of the beam). Adjust the donut until it is concentric with an equal-sized printed ring on the target. This step centers the telescope's primary mirror's optical axis to the center of the collimator center crosshair laser and collimator face printed target cross pattern.

a. Place one of the provided diffuser strips (matte-finish tape) over the center crosshair laser (mode 1) in the center of the target plate to diffuse the laser crosshair into a donut shaped beam.
b. Use the telescope's fine adjustment knob or its hand control to center the donut light beam until the donut pattern is concentric with an equal or similar-sized ring on the target plate.
c. Unless you are very familiar with your telescope aiming control, it is recommended that you line up one axis at a time, e.g., adjust telescope for vertical Up/Down (Up/Dn), then horizontal Left/Right (L/R).
   Adjust Up/Dn until the donut moves, and the top and bottom of the donut as the same distance to one of the target rings, then adjust L/R until the light beam L/R sides are equal in distance to the same target ring.
d. Iterate Step 5.1.c until the donut light beam and collimator target plate ring are as concentric and centered as possible.

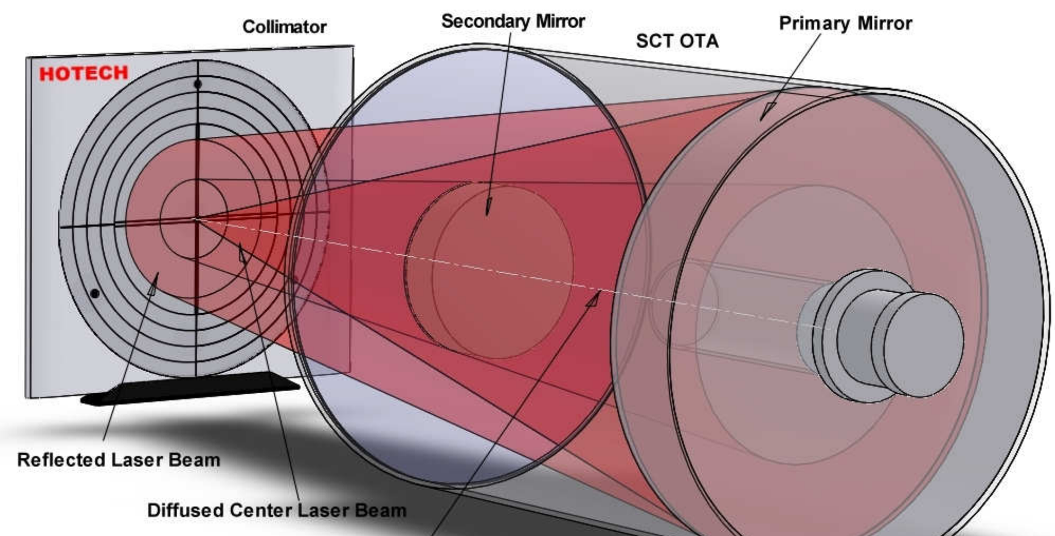
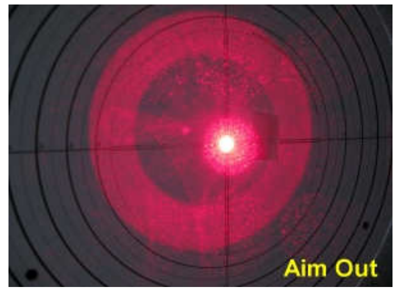
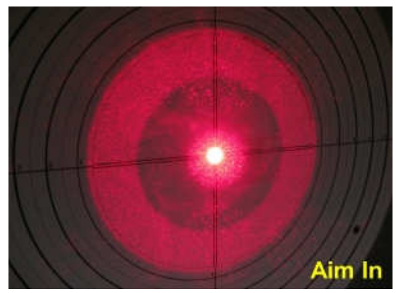


FIG. 2A
Aim Telescope at Collimator,
Diffuser strip installed



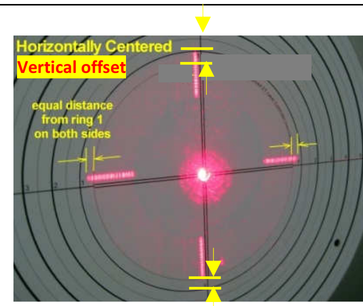
Donut is off from ring 1



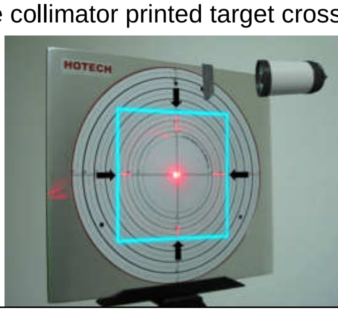
Donut is centered

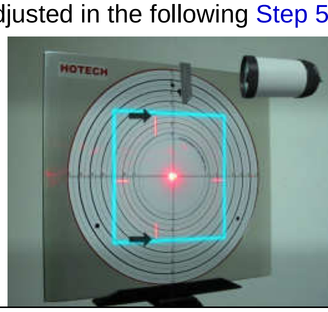
5.1.a. Alternate Method to Achieve Step 5.1, Telescope Alignment - With the diffuser strip removed you can use the *outer edge tips only* of the laser crosshair lines instead of the outer diameter of the donut to line up with an equal-sized (or similar) ring on the target plate. That is using the laser crosshair *tips only* instead of diameter, and move the telescope until the crosshair tips are concentric with a ring on the target plate. (With the diffuser strip in place, the donut beam masks the crosshair itself but not the location of the crosshair *tips* which is of value to prevent confusion with the next Step, 5.2.)

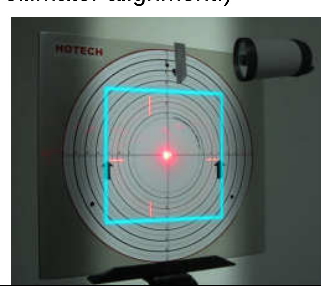
Continue the Alternate Method Step 5.1a by performing Step 5.1.b, .c, & .d above to complete this step.



NOTE – For Alternate Step 5.1.a, telescope alignment, it can help to visualize a box around the crosshair that is perpendicular to and just touching the outer edge *tips* of the laser crosshair lines, then move within this imaginary box with respect to the chosen target plate circle until the target circle is centered inside the box. The crosshair lines need not be centered on the printed target cross, and at this point, they probably are not. See photo illustration. (The exact position of the laser crosshair lines with respect to the center of the collimator printed target cross is adjusted in the following Step 5.2, Collimator alignment.)







5.2. Aim Collimator Square to the Telescope

After the telescope is initially center aimed at the collimator in Step 5.1, in this Step, 5.2, the collimator is adjusted to center the laser crosshair lines in the center of the printed target cross on the collimator target plate. This will adjust the collimator to be perpendicular (squared) to the telescope primary mirror optical axis. When the reflected laser crosshair lines are centered on the printed target cross, this completes the first full iteration cycle necessary to achieve Basic Co-alignment. Usually at least three iterations, at a minimum, of Steps 5.1 & 5.2 are necessary to achieve accurate Basic Co-alignment.

a. Remove the diffuser strip to see the projected laser crosshair.

b. Use the fine-adjustor knobs to line up the laser crosshair with the printed cross on the target plate.

c. Again, line up one axis at a time. Start with collimator vertical Up/Dn adjustment, then horizontal L/R adjustment.

d. Place the diffuser strip back on the center laser to see if the donut light beam is still centered (or without diffuser, the laser crosshair *tips only are still centered*). If not, repeat Step 5.1.

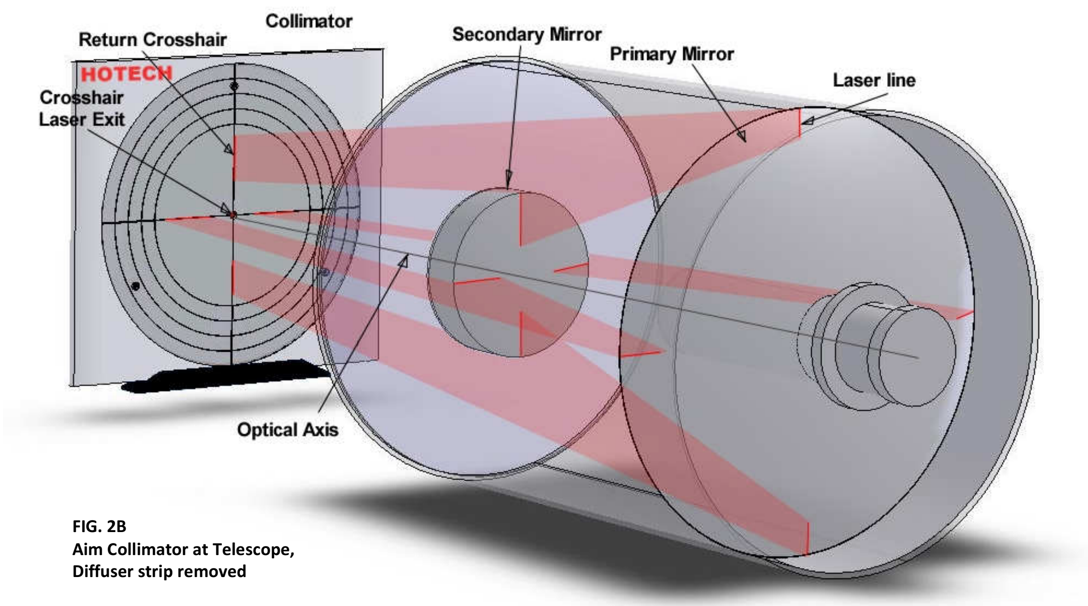
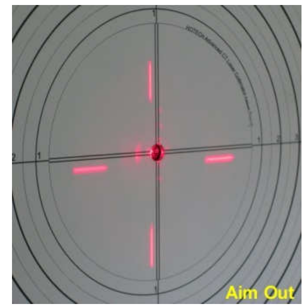
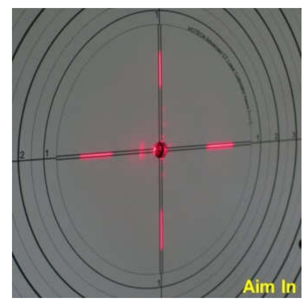


FIG. 2B
Aim Collimator at Telescope, Diffuser strip removed





5.3. Basic Co-Alignment Confirmation

Continue to iterate the procedures in Step 5.1 & 5.2 adjusting the telescope until the donut or laser line tips are centered and concentric with one of the printed target circles, adjusting the collimator until the laser crosshair is centered in the printed target cross. When you achieve this, it means the telescope & collimator are Co-Aligned. For all intents and purposes, it's as if the telescope were pointed at a distant star. You are now ready to diagnose your optics.

6.0. How to Read the Diagnostic Result on the Collimator

With the telescope and collimator Basic Co-Alignment completed (Step 5.0), you can determine collimation errors present in the telescope's optical system by observing the deviation of the three collimating lasers' three reflected dots relative to one of the concentric rings on the collimator target plate.

6.1. Locate the three laser dots

a. Switch to mode 2 or mode 3 (with panel backlight) to turn on the three collimating lasers and the crosshair laser.

b. Verify Basic Co-Alignment (Step 5.0). Check that the crosshair outer tips are concentric on the same target plate ring (Step 5.1), and that the crosshair lines are centered on the printed target plate cross (Step 5.2).

c. Observe the three collimating laser dots on the target plate – ideally they will be close to the same target plate ring.

d. If the three laser dots are visible on the target plate, go to Step 7.0 to collimate the telescope.

e. If the three laser dots are not visible or are only partially visible on the target plate, continue to Steps 6.2 and/or 6.3.

6.2. The Reflector Mirror is not properly installed

a. The reflector mirror reflects the lasers for visual back or focuser axial alignment. You must install the reflector mirror correctly (square in the visual back or focuser drawtube). The axial position of the visual back or focuser drawtube affects the alignment of the entire telescope optical system. Refer to Step 3.0 for correct reflector mirror installation.

b. When you have verified that the reflector mirror is correctly installed, but the three collimating laser dots are still completely or partially invisible, continue to the next step. Otherwise go to Step 7.0.

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6.3. The Reflector Mirror focus position is out of the telescope's normal visual range of focus

a. This can happen if the telescope was last focused with a diagonal in place (and a diagonal is not installed now), or a focal reducer was in the optical train the last time the telescope was focused. The focal plane is too far out, and is not at the normal visual position it would be in if the telescope were focused without a diagonal or focal reducer. If you do not want to use the diagonal during collimation, you will need to adjust the telescope's focus. Continue to Step 6.3.b).

b. Adjust the focus to bring at least two laser dots onto the full view on the target plate. Adjust the focus in one direction first to see if any of the laser dots are moving toward the center direction of the target. If the laser(s) is moving or expanding away from the center of the target, reverse the focusing direction to bring at least two laser dots onto the full view of the target plate. Go to Step 7 to collimate your telescope.

6.4. Your telescope is grossly out of alignment

When your telescope is grossly out of alignment, the collimating laser dots may be reflected completely away from the target plate. If you believe this to be the case, begin the collimation process anyway and see if you can bring the three laser dots onto the target plate.

Mechanical Method to get Collimation into Ballpark – Make a preliminary mechanical adjustment of the secondary mirror adjustment knobs or screws to achieve a good rough adjustment of the secondary mirror. If you have not replaced the secondary mirror adjustment screws with knobs, this would be a good time to do so. Since this procedure is essentially the same as the one used to install knobs in place of the screws and greatly expedites secondary mirror adjustment. From this point on, the expression “knobs or screws” will be replaced with “knobs”. To make the ballpark adjustment, remove the knobs turn counterclockwise *one at the time* (DO NOT REMOVE THE KNOBS ALL AT ONCE). Mark the knobs with index marks. While unscrewing *one*, gently pull on it while counting the number of turns and fractions of turns until you see exactly how many turns and fraction of a turn were made until the threads disengaged. Write down the number of turns and the associated knob location (which knob). If you are replacing screws with knobs, do it now. Reinstall each knob – making the noted number of turns so it is back to its original position. Do this, one knob at a time. Now, add up and average the number of turns. And re-adjust all the knobs, *one at the time*, to the average number of turns. Begin with the knob threaded the most turns into the secondary and remove it (CCW). The secondary mirror will be a bit loose at this point, reinstall the knob to the average number of turns. Go to the next longest knob (always *one at the time*) and remove and re-turning it to the average number of turns. Finally set the last knob to the average number of turns. When complete, ensure all the knobs are snug (CW) against the secondary mirror.

Alternate Method for Gross Alignment – A Mirror Reflections Check for a grossly mis-collimated scope can be done by observing the reflections of the telescope mirrors by looking directly down the tube. You will have to stop using the collimator. Turn off the laser before proceeding. Cut a small hole in the center of a white letter size sheet of paper. Holding the paper at a distance of about 7.5 times the diameter of your telescope, look through the hole as straight as you can into the center of your Optical Tube Assembly (OTA). Move back and forth until you see white and black (or dark) rings. The white rings are mirror reflections of the white paper in the primary and secondary mirrors kind of like barbershop mirror reflections where you sit in a chair with a mirror in front of you and a parallel mirror in back of you, and you see reflections of yourself getting smaller and smaller off to infinity. The dark rings are the OTA barrel and secondary housing reflections. Find a distance where you can see three white rings. What you want is to see all the rings, both white and dark to be perfectly concentric. If you are reading this, the rings are not concentric yet. Now, when you begin to adjust the three secondary mirror collimation knobs always remind yourself to work with all rings simultaneously. You can’t get just two rings concentric or you could be off the center optical axis one way or the other. To use this method to achieve gross alignment you must work with all the reflected rings (white and dark) simultaneously, or the optical axis alignment will be skewed to one side.

7.0. Collimating the Secondary Mirror

7.1. Precautions Before Collimating the Secondary Mirror

PRECAUTIONS – Be aware of the following when adjusting the secondary mirror collimation knobs (or screws) located on the back of the secondary mirror housing assembly:

a. Never touch the central screw which holds the secondary mirror (usually only older SCTs will have this central screw).

b. The three knobs must be turned in by very small amounts. No screw being over-tightened or totally unscrewed. When secondary mirror collimation adjustment is complete, all three adjustment knobs must be tight. If collimation knobs are loose, collimation will not be maintained for long! ALWAYS finish adjustment by tightening knobs ONLY. In the process of adjusting the knobs too achieve collimation – when turning a screw would over tighten it – loosen the opposite knob(s) to continue moving the original Knob in the proper direction.

c. As you adjust the collimation knobs, observe the collimating lasers three dots position on the collimator target plate to determine which knob(s) to turn, and by how much. When collimation is close and the three collimation knobs are snug, finishing adjustments will be on the order of 1/32 turn and less.

NOTE – You will need to constantly re-check telescope & collimator Basic Co-Alignment during the adjustment process to make sure proper alignment is maintained.

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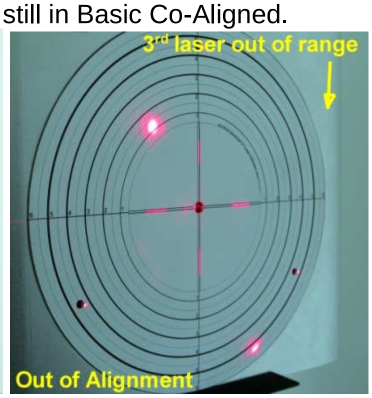
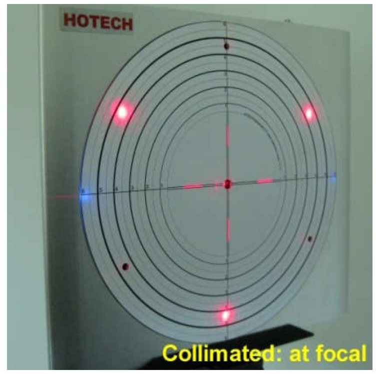
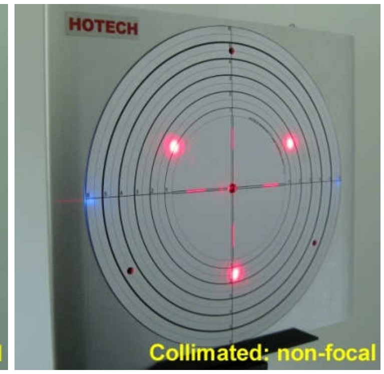
7.2. Secondary Mirror Collimation

The objective of this step, Step 7.2, is to bring the three collimating laser dots onto the same Collimator Target Plate Ring.

a. Adjust the Secondary Mirror Knobs (or screws) to bring the three reflected laser dots onto the same ring on the target.
b. If you cannot bring all three laser dots onto the same target ring because the dots are too far apart, adjust the focus to move the three laser dots closer together.
c. Check Basic Co-Alignment of the Collimator & Telescope (repeat Step 5.0) as necessary.
   The telescope might shift in position when pressure is applied during secondary mirror Knobs adjustment. Double check whether the telescope has been nudged out of Co-Alignment.
d. Iterate Step 7.2.a, .b, & .c until the reflected collimation laser's Three Dots are on the same Target Plate Ring, and the Collimator & Telescope are still in Basic Co-Aligned.





8.0. Fine Tuning Collimation

8.1. Star test to fine tune adjustment

a. On your first observing session, star test the telescope to fine tune the adjustments.
   Minor adjustment can be needed due to temperature variation during a long observing session.
b. Choose a medium bright star – Polaris is good in the Northern Hemisphere. Defocus the scope a little, just until diffraction rings are seen. The star should look like a little bull's eye.
   Carefully center the star and observe the diffraction rings. If they are concentric, collimation is good. If they are skewed (bunched up or squashed) on one side, collimation requires further adjustment.

9.0. Possible Scenarios where the Laser Collimation Does Not Agree with Star Collimation

NOTE – In the field, use star collimation to remove errors introduced with different conditions of focuser or visual back accessory loads such as – changing eyepieces, flatteners, filter wheels, cameras, additional focus motors, or stiff wiring and thermal packs, etc., mirror-flop, or temperature changes.

9.1. Accurate Basic Co-Alignment was Not Achieved or is Insufficient

It is possible that during collimation (Step 7.0), the Basic Co-Alignment of the Collimator & Telescope (Step 5.0) was slightly off causing an incorrect diagnosis. It is critical to ensure that the Collimator & Telescope Basic Co-Alignment is achieved. Do not adjust the secondary mirror knobs. Go to Step 5.0 to verify Basic Co-Alignment and check if the three laser dots still fall on the Same Target Plate Ring. If both conditions are met and star collimation is variably poor and/or better and worse when changing focus, continue to the next step, and consider performing In-Depth Advanced Collimation (Step 11.0).

9.2. "Mirror flop" or "Focus shift" of the primary mirror causing miss-collimation

Due to machining tolerances on the primary mirror focusing mechanism and improper greasing or old dried out grease on the baffle (the column inside the center of the rear cell the primary irror slides on to focus), some telescopes exhibit more mirror-flop then others. A slightly loose tolerance will cause major axial alignment deviation. The Advanced CT Laser Collimator is sensitive enough to pick up any deviations. Prior to changing collimation (before adjusting the secondary mirror knobs), observe the shifting position of the three laser dots on the Collimator target plate by turning the primary mirror focus knob two full turns clockwise, then reverse one half turn. The shifting of the three collimating laser dots during the reverse half turn tells how much focus shift is present in the telescope.

If the displacement is more than two ring scale divisions on the Collimator target plate, we recommend installing an accessory rear cell Crayford focuser on the telescope (these are available from many sources). With the Crayford focuser at the center of its travel, move the telescope built-in focus mechanism to its best in focus position then leave it parked (preferably lock it down) and do all focusing with the Crayford focuser. With a Tilt adjustable Crayford Focuser, it is recommended to perform In-Depth Advanced Collimation (Step 11.0).

(Continued Next Page)

9.3. The eyepiece drawtube or visual back is not square to your primary mirror

We recommend replacing a poor visual back with a higher quality model (2-inch backs are generally better in quality than the 1.25-inch models furnished with SCTs). If the telescope uses a rear-cell focuser, it's possible to replace a poorly aligned one with a new higher grade eyepiece drawtube or a focuser that has tip/tilt adjustment to correct the axial error. For example, a MoonLite CS model shown here, or a MoonLite CHL model 2.5" (see Step 11.2) or special modified focuser available from our website. Please email or call us for availability.

Poor collimation can also result from a focuser or visual back that does not securely hold eyepieces or accessories. Generally, eyepiece holders using a compression ring or more than one thumb screw or more than one thumb screw and a compression ring (as in the figure to the left) do a better job of maintaining alignment. A higher quality focuser with these features can solve these problems as well.

10.0. Diagonals, Reducers, and Field Flatteners

If a diagonal, reducer and/or field flattener accessory is machined square with its mirror or lenses square on the optical axis, and held securely in place, it will not affect collimation. Focus may be in a different position but the collimation will remain unaffected. (The Celestron Edge series of telescopes have non-removable field flattener lenses as part of its basic design; this does not change or affect any of the steps or procedures given in this manual.) To check accessory collimation:

a. Achieve Collimation (Step 7.0 or Step 11.0) *without* the accessory. Then, *one-at-the-time – Install* the component(s), diagonal, reducer and/or field flattener, and perform collimator & telescope Co-Alignment (Step 5.0 or Step 11.0).
b. With the collimator switched to laser mode 2 (or mode 3), check the three collimating lasers' dots on the collimator target plate. You may need to re-focus as described in Step 6.3.
c. Make the checks in Steps 10.1 and/or 10.2 as necessary to isolate problem component(s).

10.1 Collimation with a Diagonal Accessory Installed

Two types of collimation problems with attendant hardware problems sometimes manifest with diagonals. Achieve (Step 10.0.a) Collimation and Co-Alignment *without* the diagonal installed, then, *with* the diagonal installed – The following two kinds of problems may be detected observing the reflected collimating lasers' three dots on the collimator target plate. Check the following when the diagonal is *rotated* to different positions relative to the telescope rear cell:

a. Three dots wiggle and walk when rotated, and *move* to different positions when retaining thumb screws are tightened.
   Problem: Most common – This indicates that either or both the focuser or visual back hardware that secures and registers the diagonal, or the hardware part of the diagonal that secures and registers the final optic is inadequate (the final optic is the reflector mirror in this case). Tighten and loosen the thumb screws on the focuser or visual back, and the diagonal. Good hardware that secures and registers properly will maintain collimation before and after rotating the diagonal or final optic. Replace or repair the focuser, visual back, or diagonal that is not adequately registering and securing its installed components (for improved focusers see Step 9.3).
b. Three dots are not on the same target plate ping and move smoothly in a well-defined circular pattern without wiggling.
   Problem: Less common – The mirror inside the diagonal is not correctly aligned. The more the three dots are off a single concentric target plate ring – with vs. without the diagonal – the more suspect it is that the diagonal's mirror is out of alignment. Replace or repair the diagonal with the misaligned mirror.

10.2. Collimation with a Reducer, and/or Field Flattener Accessory Lenses Installed

PRECAUTION – DO NOT adjust the telescope Secondary Mirror Knobs (or screws) with a reducer installed. A reducer desensitizes adjustments made with the secondary mirror knobs. Instead, collimate the telescope with Step 11.0 procedures.

To achieve collimation with a reducer or field flattener accessory installed:

a. If the basic collimation is good you will see a good circular pattern of the three collimating laser dots close to the same target plate ring.
b. If the three collimating laser dots are not on the same target plate ring, the tilt of the rear cell optics axis and/or the centering of the corrector plate need to be adjusted. To make these checks and adjustments, remove the accessories, perform Step 11.0, and iterate its sub-steps until no further improvement can be made. Then, reinstall the accessory reducers and field flatteners, and perform Step 11.0 to check collimation with the accessory. If the collimation is not aligned the telescope can be collimated by performing Step 11.0 specifically for the condition of having the accessory installed or not. To have the best possible optical performance under each of the two conditions (accessory lenses installed or not installed), the telescope will have to be collimated separately for each condition. If photography is the primary goal, use Step 11.0 to collimate most accurately for this setup. This may still allow sufficient optical performance to enjoy eyepiece viewing without having to perform Step 11.0 collimation specifically for eyepiece use. Because the viewing eye is the final optical element (eyeball cornea & auto-focus lens), and the ability to move around over the eyepiece to collectively stacking the best view over different viewing position, this can have the effect of allowing some dynamic fine tuning collimation, as opposed to camera imaging where the final imaging sensor is fixed.

11.0. In-Depth Collimation Procedures

Step 11.0 requires removing and replacing the secondary mirror and working with other hardware items. Thoroughly read and familiarize yourself with all of the Step 11.0 In-Depth Procedures, and Tools & Equipment requirements for tilt axis and corrector plate adjustments (Step 11.2 & .3), and Co-Alignment (Step 11.1.c, .d, & 11.4.a) before performing Step 11.0. The scope of the Step 11.0 mechanical procedures is usually within the scope of normal telescope maintenance and intended design as described in telescope user manuals (i.e. removing the secondary mirror for Hyper-Star equipment, or using provided Setscrews to center the corrector plate). The skills needed to perform Step 11.0 are certainly within the capabilities of advanced amateur astronomers. After familiarization, if you are uncomfortable with performing Step 11.0 seek the guidance of an advanced amateur or astronomy club for assistance. If your telescope is new and still under the manufacturer's warranty – so that you will know where you stand with the telescope manufacturer, read the Warranty details carefully to know if the Step 11.0 procedures you intend to use conflict with or violate the Warranty.

Telescope Hardware Used to Perform Adjustments – Performing Step 11.0 collimates all the optical axes of the telescope's lens and mirror elements to be squared (made perpendicular) & centered on the optics axis of the primary mirror. The centering & squaring is accomplished with adjustment of the secondary mirror optical axis, and the final optics optical axis (e.g., visual back, or focuser). The following hardware is used to make the adjustments:

Secondary Mirror Optical Axis Centering & Squaring Hardware:

- Secondary Mirror Centering – Corrector plate is moved in lateral directions to adjust the secondary mirror axis (Step 11.1.g) to center on the final optics axis.
- Secondary Mirror Squaring (Aiming) – Secondary mirror collimating knobs (or screws) are adjusted – with a procedure referred to as Zeroing-Out the Knobs (Step 11.1.a) – so that the Secondary's optical axis is aimed to be perpendicular (square) to the glass corrector plate in the front of the telescope.

Final Optics Optical Axis Centering & Squaring Hardware:

- Final Optics Axis Centering – Focuser or visual back is installed onto the telescope baffle rear flange – centering is dependent on the telescope's rear cell baffle (primary mirror center focusing column) being installed into the center of the primary mirror. (Will be introduced in Advanced Collimator & Telescope Z-Axes Co-Alignment procedures Steps 11.1.c, .d, .g, & .h to achieve the best alignment possible within the limits of the telescope's construction.)
- Final Optics Axis Squaring (Tilt) – Focuser Flange Tilt or Drawtube Tilt, Visual Back Tilt by Shimming, or Tilt Adjustable Reflector Mirror, Tilt axis is adjusted (Step 11.1.d & .h).

KEY POINTS of the Step 11.0 In-Depth Collimation Procedure:

- ➢ Zero-out the knobs to make the secondary mirror axis square to the corrector plate glass (Step 11.1.a).
- ➢ Remove the secondary mirror.
- ➢ Perform Basic Co-Alignment (Step 11.1.c.1 & .2) of the collimator & telescope so that the crosshair outer tips (or diffused donut) are on the same ring and the crosshair is centered on the printed target cross.
- ➢ Perform In-Depth Co-Alignment (Step 11.1.d.1 & .2) Adjust the final optical tilt axis (adjust with focuser tilt, visual back shimming, or tilt adjustable reflector mirror) – Select collimator mode 1 to simultaneously accomplish both:
  1) Observing the Collimator Target Plate – center and overlap the reflected crosshairs from the primary mirror and the reflector mirror, and
  2) Observing the Reflector Mirror installed into the Visual Back or Focuser – center the crosshair laser onto the center of the reflector mirror target.
- ➢ In-Depth Collimator & Telescope Z-axes Co-Alignment is achieved when Basic Co-Alignment (X & Y dimensions) is achieved, and all three Z-axes dimension crosshairs – Two (double pass) reflected crosshairs on the collimator target plate printed cross, and One direct (single path) crosshair on the reflector mirror target – are all centered as well as possible within the limits of telescope construction. This prepares Z-axes alignment so that fewer remaining adjustments are necessary when the secondary mirror is re-installed.
- ➢ Install the secondary mirror with zeroed-out knobs into the corrector plate, and select collimator mode 2.
- ➢ Adjust the Corrector Plate (Step 11.1.g) so that the primary mirror optical axis centerline *reflected* from the secondary mirror is aligned with the final optical axis centerline. Observe the reflector mirror target (mounted in the focuser or visual back) – Adjust the corrector plate to center the single laser dot (the focal point of the three collimating lasers) onto the center of the reflector mirror target.
  - ❖ De-Focus the single laser dot on the reflector mirror target into its three incoming (single path) collimating lasers' three dots (this is corollary to traditional Star Collimation). Observing the reflector mirror target at any given de-focus position, Fine adjust the corrector plate to place the three de-focused dots onto the same reflector mirror concentric ring. When the focus knob is rotated so that the dots converged and expanded, they should cross the same concentric

ring at the same time.

- Adjust the Final Optics Tilt Axis (Step 11.1.h) – Observe the Collimator Target Plate – Adjust tilt of the final optical axis (focuser, visual back, or tilt adjustable reflector mirror) to place the reflected collimating laser's three dots onto the same collimator target plate ting. The three *outgoing* reflected collimating laser dots on the same ring display that the path of light (laser or star light) that comes *into* the primary mirror is also parallel to the primary mirror optical axis.

Step 11.0 Preparations:

a. Mirror Flop – If primary mirror flop was a significant problem that negates focusing with the primary mirror, i.e. moving it, then pre-focus the telescope on a distant object such as a star; get the best focus you can while minimizing mirror flop. If you are using an accessory focuser set it to the middle of its travel before focusing with and locking down the primary mirror focus knob.

   Mirror Flop and the focused Single Laser Dot – When using an accessory focuser and the telescope primary focus knob is locked down, and a procedure (e.g. Steps 11.1.a & .g) requires focusing the three collimating lasers into a focused single laser dot on the reflector mirror target, then use the accessory focuser to focus the three laser dots as tight as you can and *visualize* the center of the three laser dots on the reflector mirror target as the reference point in lieu of the focused single dot.

b. Tripod for Advanced In-Depth Collimation – When collimating, many users need to keep the telescope in one convenient position, also the Right Ascension (RA) & Declination (DEC) movement control of telescope mounts are often relatively far apart making precise centering of the telescope to the collimator challenging. In Basic Co-Alignment, Step 5.1, whenever the step directs to *move the telescope* to center on the collimator, the *whole Collimator can be moved* instead to achieve the same centering of the telescope on the collimator X & Y dimensions. To do this a tripod is needed that provides both elevation and lateral movement.

   The tripod hardware solutions (see Step 11.4.a) are a tripod with a worm geared elevating center column, and a camera quick release adaptor with a screw clamp that accepts a sliding plate or rail as is used with a macro-camera lens. The fine-adjuster is mounted atop the plate or rail, and the collimator atop the fine adjuster as it normally done.

c. Accessory Diagonals, Reducers and Field Flatteners – Remove these accessories when performing Step 11.0. Then, reinstall the accessories, and perform Step 11.0 to check collimation. If the collimation is not ideal with diagonals refer to Step 10.1.a & .b to determine the problem; if not ideal with a reducer and/or field flattener installed, refer to Step 10.2.b to choose the best collimation alternative.

PRECAUTION – Collimation and optical alignment beyond the traditional adjustment of the secondary mirror requires slow, careful work that involves the iterative processes that were originally used for telescope alignment. When proceeding with the following steps, take notes (know where you started from) and before and after any and all adjustments continually recheck and crosscheck collimator & telescope In-Depth Co-Alignment, and the details of the step to be performed. It is a good idea to mark the heads of screws and knobs and note where they were positioned before they are turned or removed. In many cases it is of value to count the number of turns (or fraction of a turn) a screw is backed out so that it can be returned to its former position if needed.

11.1. Collimation by Final Optics Tilt with Zeroed-Out Secondary Knobs

a. Zero-Out the Knobs - Aim the secondary mirror axis so it is perpendicular to the corrector plate.
   1. Perform basic Co-Alignment of the collimator and the telescope (Step 5.0).
   2. Remove the secondary mirror.
   3. Remove the locator (timing) pin or setscrew (if one was installed) that orients the Secondary Mirror to one specific rotational position. (Save the pin or setscrew in a safe place for later re-installment. Some setscrews can be turned in (CW) deep enough to allow mirror rotation then backed out later to hold position.)
   4. Reinstall the Secondary Mirror – Secure it sufficiently to hold it in the middle of its housing mount, but it is still free to "spin-around".
   5. One laser dot - with the collimator crosshair and collimating lasers turned on (mode 2), observe the reflector mirror and adjust telescope focus until the three collimating laser dots converge into one single laser dot. (If an accessory focuser is installed due to mirror flop, only focus with it. (Also see Step 11.0.a above.)
   6. Zeroing-out the knobs - This will make the secondary mirror square (perpendicular) to its mount and the corrector plate. Observe the position of the single laser dot on the reflector mirror. When the secondary mirror knobs are zeroed out, the single laser dot will not move (will not walk, wiggle or gyrate) when the secondary mirror is rotated. (It is fine if the dot is not centered at this time, but it should not move when the secondary mirror is rotated – the dot will be centered in a later step.) Rotate the secondary mirror 180 degrees and adjust the secondary collimation knobs to move the single laser dot half way back toward the location it was in before rotation. Rotate 90 degrees and note the position of the dot, then rotate 180 degrees and again move the dot half way back toward the last position. Keep iterating this process until the single laser dot no longer moves when the secondary is rotated. (To ensure the Secondary is laterally

centered in the middle of its housing, after each knobs adjustment and rotation, it may be necessary to gently secure the secondary enough to know it is in its normal seated position so the position of the single laser dot can be accurately checked.)

When rotating the secondary, and getting close by observing the single laser dot on the reflector mirror, and you see the dot is barely wiggling. When you get this close, direct your attention to the collimator target plate and notice that the three collimating laser dots – while not necessarily on the same target plate ring (which is fine for this step) – are, also, almost not wiggling either. The return reflections of the three collimating laser dots on the target plate are formed by a double pass and provide more resolution than the single laser dot on the reflector mirror. Detecting the last bit of wiggle to remove can easily be seen on the collimator target plate looking at any one of the three collimating laser dots. This is handy because your hand on the secondary knobs may cover up a dot or two and it's not a problem. When the single laser dot and the three collimating laser dots (or any one that is visible) no longer move when the secondary is rotated, then – Zeroing-out the secondary mirror knobs has been achieved.

7. Reinstall (or re-position) the locator (timing) pin that orients the secondary mirror to one specific rotational position.

b. Remove and set aside the secondary mirror with zeroed-out knobs.

c. Perform Basic Co-Alignment of the Collimator & Telescope (select collimator mode 1):

1. Corollary to Step 5.1, move the *whole Collimator* in elevation and azimuth (use a tripod capable of X (L/R) & Y (Up/Dn) dimensions adjustment) – Center the crosshair outer tips (or diffused crosshair donut) on the same ring of the collimator target plate. (When Step 5.1 calls for moving the telescope Up/Dn use the tripod elevation adjustment. When Step 5.1 calls for L/R movement use the tripod lateral sliding side-to-side adjuster.)

2. Unchanged Step 5.2, move fine-adjuster (atop the tripod) to aim the collimator in the Z-axis dimension – Center crosshair lines in the printed cross on the collimator target plate. (Step 5.2 is unchanged with In-depth collimation.)

d. Perform In-Depth Co-Alignment – Adjust tilt (Step 11.2) of the final optical axis (focuser tilt, visual back shimming, or tilt adjustable reflector mirror) to *simultaneously* accomplish both:

1. Observing the collimator target plate – Center and overlap the reflected crosshairs from the primary mirror and the reflector mirror. (Note: An un-centered reflector mirror crosshair is easily seen as the off-center crosshair.)

2. Observing the reflector mirror installed into the visual back or focuser – Center the crosshair laser onto the center of the reflector mirror target.

i. If all three crosshairs cannot be perfectly centered, then – observing the collimator target plate – center the two reflected crosshairs (from the primary mirror and reflector mirror), and center the crosshair on the reflector mirror target in the visual back or focuser as well as possible. (Also see Step 11.4.b regarding peripheral focusing issues.)

ii. In-depth collimator & telescope Z-axes Co-Alignment is achieved when basic Co-Alignment (X & Y dimensions) is achieved, and all three Z-axes dimension crosshairs – Two (double pass) reflected crosshairs on the collimator target plate printed cross, and one direct (single pass) crosshair on the reflector mirror target – are all centered as well as they can be within the limits of telescope construction. Performing Step 11.1.d.1 & .2 prepares the Z-axes alignment so fewer remaining adjustments are necessary when the secondary mirror is re-installed.

3. Iterate Step 11.1.c & .d. The adjustments made in Steps 11.1.c.1 & .2 & d.1, & .2 affect each other and are interactive. Iterate these steps until no further improvement can be achieved.

e. Select the collimator lasers mode 2, and use mode 2 for the remaining steps.

f. Install the secondary mirror with zeroed-out knobs into its mount on the corrector plate.

g. Adjust the corrector plate to align the primary mirror optical axis centerline *reflected* from the secondary mirror with the final optical axis centerline – Observe the reflector mirror target (mounted in the focuser or visual back) – Adjust the corrector plate (Step 11.3) to center the single laser dot (at the focal point of the three collimating lasers) onto the center of the reflector mirror target.

1. De-focus the single laser dot on the reflector mirror target into its three incoming (single path) collimating lasers' three dots (this is analogous to traditional Star Collimation) – Observing the reflector mirror target – at any given de-focus position, fine adjust the corrector plate to place the three de-focused dots onto the same concentric ring.

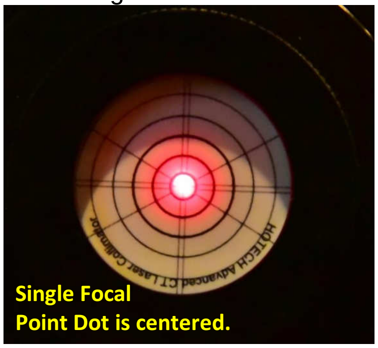
2. When the focus knob is rotated so that the dots converge and expand, they should cross the same concentric ring at the same time on either side of the centered single dot focal point. This traces the path of the final optical axis, and illustrates that the centerlines of the final optical axis and the primary mirror axis are aligned.

h. Adjust the final optical tilt axis – Observe the collimator target plate – Adjust tilt (Step 11.2) of the final optical axis (focuser tilt, visual back shimming, or tilt adjustable reflector mirror) to place the three reflected collimating laser dots onto the same collimator target plate ring. The path of the three reflected *outgoing* collimating lasers, seen as the three dots on the same ring, displays that the path of light (laser or star light) that comes *into* the primary mirror is parallel to the primary mirror's optical axis.

i. The adjustments made with Steps 11.1.c, .d, .g & .h affect each other and are interactive. To achieve the best possible collimation of the telescope (within the limits of the telescope's construction) It is important to iterate Steps 11.1.c, .g, & .h until no further improvement can be achieved. The following Figures illustrate good alignment of a representative SCT.

Figure 11.1.i – Alignments seen After Completing Step 11.1.i

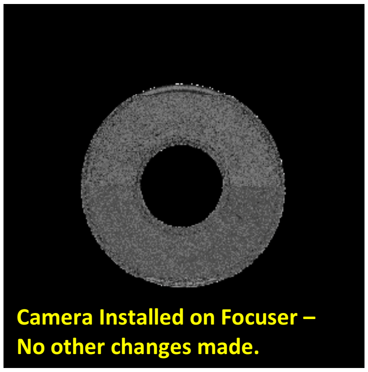
1. **Corrector Plate Centering** – Observing the Reflector Mirror



2. **Corrector Plate Centering** – Observing the Reflector Mirror

3. **Final Optics Tilt Adjustment** – Observing the Collimator Target Plate

4. **Star De-Focused Telescope Photo –** Star Collimation Check Only



5. **A Look Inside After Step 11.1.i** – Secondary Mirror is Removed

6. **A Look Inside After Step 11.1.i** – Secondary Mirror is Removed

11.2. Mechanical Systems Used for Final Optics Axis Tilt Aiming Adjustment

This step presents the mechanical systems and their use to adjust the final optical (focuser, visual back, or tilt adjustable reflector mirror) tilt axis. The necessary checks and observations that must be made using the Advanced CT Laser Collimator to observe the status of the final optical tilt axis alignment – regardless of the mechanical system employed to control tilt – are presented in Step 11.1.d. & .h. Use one of the following mechanical systems to adjust the final optical tilt axis:

a. Accessory Focuser Flange Tilt Setscrews (used in many Crayford focusers) – Some brands of Crayford accessory focusers have tandem flanges that allow the "top" flange (closest to the eyepiece or camera) to rotate (or spin around) separately from the flange closest to the telescope. This allows a convenient means of maintaining the relationship between the camera or eyepiece and the focuser knobs or focus motor. Focusers with this feature often have tilt adjust setscrews built into the top (rotating) flange. See the figure included in Step 9.3 above. Note that the tilt adjustment setscrews in this type focuser are set parallel to the optical axis. When the setscrews are adjusted they do a good job of adjusting tilt within a somewhat limited range, but after tilt is adjusted the rotating feature of the "top" flange is lost, and it can no longer be rotated and still maintain tilt alignment.

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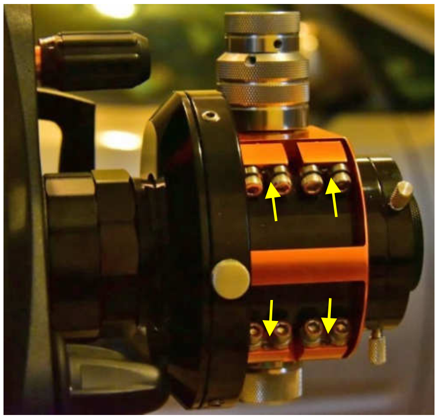
b. Accessory Focuser DrawTube Tilt Setscrews – MoonLite telescope accessories CHL MODEL 2.5" Focusers with draw tube tilt adjustment setscrews. These focusers are available for all Celestron Edge telescopes for use with and without the dedicated Celestron reducers installed, and for other telescope brands. The CHL focuser draw tube tilt adjustment has greater tilt adjustment range and maintains the rotational feature between the telescope-side fixed flange and the top flange (eyepiece/camera) side flange. The draw tube tilt setscrews are set cross-wise to the optical axis. The CHL focuser has both older style flange tilt setscrews, and draw tube tilt setscrews. This is necessary because the flange tilt setscrews have special self-lubricating delrin bearing tip material that allows the rotational feature to function.

When the draw tube tilt is adjusted to accomplish Step 11.1.d & .h the focuser must maintain the same orientation on the telescope rear cell when it is removed and installed – the tilt adjustment will be incorrect in any other orientation. However, leave the flange rotational feature functional, and when installing accessory reducers or flatteners rotate the focuser to the orientation where tilt adjustment is correct and lock it down again in the correct orientation when using the accessories. When not using the accessories, again, rotate the focuser to the correct orientation.

(To re-square the flanges after inadvertent flange tilt setscrew adjustment: use a feeler gauge set to check the gap between the flanges and adjust the gap with the flange tilt setscrews until the gap is the same all the way around, and rotation is free with no play between the flanges.)

Adjusting tilt using the MoonLite CHL focuser draw tube setscrews:

CHL focuser draw tube tilt setscrews



1. Maximum CHL DrawTube setscrew adjustments will be on the order of less than one-half turn, and most adjustment will be small increments of a turn.
2. Determining which of the four setscrews to adjust first is strictly trial and error. Get the feel of how much torque is on each of the setscrews. Put the 5/64" allen wrench into any setscrew and note its position, then turn it in (CW) a bit while noting how much torque is on the setscrew; also observe if Tilt alignment is better or worse, then return it to the start position. Do this for all four setscrews getting a feel for a normal range of torque values that can be expected. (Torque on a setscrew represents force to hold metal into a position; it does not represent load applied to a bearing.)
3. When the tilt is completely adjusted the setscrews will have varying torque and this is OK and expected. However, all setscrews should have some minimum torque. If backing out a setscrew (CCW) improves tilt alignment to the point that all torque is lost, turn it back in (CW) until the first movement of tilt alignment is observed and stop – this is the minimum torque required. Then proceed using the other setscrews to continue adjusting the tilt alignment. More adjustment will be available using the other setscrews. The CHL 2.5" Focuser allows more Tilt adjustment than was available with previous focusers.
4. When Tilt adjustment is complete, some setscrews will require much more torque than others to bring everything into alignment.

c. Visual Back Shim – Final optical tilt axis adjustment with a visual back is typically done with wedge shims between the telescope rear cell threaded mounting flange (rear surface) and the mating surface of the visual back where it butts up against the rear cell flange. (Some telescope accessory makers offer specialized visual backs with a tilt adjustment.) To create a wedge shim for the tilt adjustment, Mylar tape (like Scotch 3M #600 transparent tape), can be placed on the visual back - rear flange mating surface (a single piece or in layers as needed), and trimmed to size with a No. 11 Exacto blade. After applying the tape, when installing the visual back on the rear cell, hold it up against the telescope rear flange and do not let the visual back turn when tightening the large nut (B-nut) that secures the visual back to the rear cell. By applying the Mylar tape to the visual back flange the tilt shim can be rotated to different positions. However, to prevent tape peeling problems, it is recommended to loosen the B-nut sufficiently to lift the visual back away from of the rear cell flange before rotating it to a new position.

d. Tilt Adjustable Reflector Mirror – Use the instructions supplied with the accessory to adjust Tilt.

11.3. Mechanical Systems Used for Corrector Plate Adjustment

This step will cover the mechanics of moving the corrector plate in lateral directions to achieve adjustment. The necessary checks and observations that must be made to achieve centering are presented in Step 11.1.g.

PRECAUTION – Use care working around the corrector plate. Work so as not to touch it or get finger prints on it. Use a lens blower and/or a soft camel hair lens brush to remove any dust, pollen, and debris before starting. If an aerosol blower is used, do not tip it on its side so much that liquid propellant is discharged on the telescope parts. Use care to prevent debris from falling into the telescope tube.

a. Direction to move the corrector plate for adjustment – The *push* or *pull* direction is the same when observing either the collimator target plate or the reflector mirror target: Visualize the center of the collimating lasers' three dots or focused single laser dot – the dot or dots move toward the direction from which the corrector plate is pushed, or conversely away from the direction the corrector plate is pulled. (To move the dots – push to fetch or pull to repel.)

b. The Corrector plate adjustments that are available fall under two types of SCTs:
   1. Retainer ring screws (see Step 11.3.c below): All types have a corrector plate retaining ring that runs around the outer circumference of the corrector plate. This ring has "Retainer Ring Screws" that hold the corrector plate in place after adjustment, and these screws must be loosened to move the corrector plate. Some types only have the retaining ring and no special provision for corrector plate adjustment. The screws securing the retainer ring go in parallel to the optical axis.
   2. Adjustment setscrews (see Step 11.3.d below): In addition to the retainer ring screws, some types (like the Celestron Edge series) also have "adjustment setscrews" around the front cell of the telescope that go in perpendicular to the optical axis, and are used specifically for shifting the corrector plate to adjust its centering positon.

c. Retainer Ring Screws – To make adjustments, loosen (CCW) the retainer ring sScrews. Note the amount of torque on each retainer ring screw to get a baseline for how much toque (CW tightening) will be needed on the retainer ring screws when finished and adjustments are complete – the "final torque". Loosen the screws sufficiently to be able to move the corrector plate. It would be ideal if the screws could be loose enough to move the corrector plate for fine adjustment, but still provided enough friction to hold the corrector plate in place after moving it. Make the necessary adjustments per Step 11.1.g, and finish by torqueing all the retainer ring screws to the "final torque".

   When things are not ideal, prepare the telescope before setting up with the Collimator:
   1. If the corrector plate stuck in place (from not having been removed for long period, usually) it may be necessary to completely remove the retaining ring to break the "set" so the corrector plate can be moved for adjustment. Shore up the telescope in a vertical position (corrector plate up) on soft padding.
   2. Remove the retaining ring but do not move the corrector plate. Carefully use a sharp pencil or other marker to go around the outer circumference of the corrector plate to mark its starting position before adjustment. Clean any debris as you go to prevent it from entering the tube.
   3. With its position marked you are free to work with the corrector plate and its retaining ring to adjust the retainer ring screws to just the right torque to facilitate fine adjustments. Replace the retaining ring and work with the torque on the retaining ring screws to find just the right torque on the screws to allow adjustment – "screw adjustment torque".
   4. Plan to use two opposed screws to temporarily apply additional "holding torque" to hold the corrector plate from moving. You will need to apply and remove a little torque from these two screws before and after each adjustment. Mark & note their position to quickly find them.
   5. Remove the retaining ring and re-center the corrector plate to its marked starting position.
   6. Replace the retaining ring and install all but two of the retainer ring screws to the "screw adjustment torque" setting. Then install the final two screws set to the necessary "holding torque".
   7. Moving the corrector plate – The "draw-string" method can be a useful way to make fine movements. Loop a string around the secondary mirror housing and pull it off to the side of the front of the telescope in the adjustment direction (Step 11.3.a). On one side of the front of the scope, hold down one end of the string with one hand, then right next to it, hold the other end of the string between thumb and index finger. Place the index finger against the side of the front of the scope and rotate the hand – roll the index finger to lever a tiny bit of string over the edge of the front of the scope to pull the corrector plate making a small incremental adjustment.
   8. Set up the telescope and collimator and perform all the steps necessary to return to and continue at the beginning of this Step 11.3. corrector plate centering is complete when "final torque" is applied to the retainer ring screws.

d. Adjustment Setscrews – For telescopes that also have "adjustment setscrews," use the following precautions, and preparations to adjust the corrector plate when using the adjustment setscrews:

   CAUTION – Torquing down an adjustment setscrew on a locked down corrector plate can crack the glass. Always provide for movement of the corrector plate (loosen retainer ring screws and appropriate adjustment setscrews) before torquing (CW) an adjustment setscrew to move the corrector plate.
   1. The adjustment setscrews have some mild locking compound on them that can interfere with getting the feel for the increased torque encountered when a setscrew is turned in (CW) to touch the corrector plate. Note the allen wrench position you started from, and turn the setscrews out (CCW), then, very carefully turn them back in (CW) to their original position to free them up. You need to be confident that you can tell just when a setscrew is touching the corrector plate. You want to work the setscrews (about 3-turns) out (CCW) and in (CW) a half dozen times till they free up and you can feel just when a setscrew touches the corrector plate glass and torque starts to increase. The setscrews have Delrin tips that makes a bit of drag even when they are turning (CCW). When you turn in (CW) any increased torque you feel over the CCW direction is probably the feel of just beginning to push on the corrector plate. End this step with all four setscrews just touching the corrector plate to hold it in its pre-adjustment start position.
   2. As with telescopes that do not have adjustment setscrews, the retainer ring screws will have to be loosened (CCW) to allow movement of the corrector plate. Note the amount of torque on each retainer ring screw to get a baseline for how much toque (CW tightening) will be needed on the retainer ring screws when finished and adjustments are complete – the "final torque". Back-out (CCW) the retainer ring screws till they are loose, then turn them back in (CW) till they just

touch, but the corrector plate is free to move.

3. There are four corrector plate adjustment setscrews installed 90º apart in a cross pattern. This means you can slide or move the corrector plate on one crossbeam by moving the two setscrews that are 180º apart (turn one out (CCW) to make room, then turn the other one in (CW) to push the Plate). Only turn one setscrew in (CW) by the amount you turned its opposing partner out (CCW). The plate will slide through the other two setscrews on the other crossbeam that should be adjusted to be just touching the corrector plate and act as guides.
4. To get the feel of moving the corrector plate and to free it up from taking a set, pick two opposed setscrews to be guide setscrews to slide between. Ensure the guide setscrews are torqued to be just touching the corrector plate. On the crossbeam to the guide setscrews beam, move the corrector plate by backing out a setscrew two turns (CCW) noting the position of the allen wrench to know the number of turns exactly. Go to its opposed partner and note its starting wrench position, (this will be the end position for this exercise), then turn it in two turns (CW) to move the corrector plate. Now back out (CCW) the same setscrew two turns to its noted starting position. Then go to its opposed partner and turn it in (CW) two turns to put the corrector plate back to its starting position. This (two turns movement) was a substantial movement; final adjustments will be 1/8 turn and less. Use this system to go around the corrector plate and move it back and forth, Noting where you started from and returning to that position. Do this till the corrector plate is freed up and you feel confident.
5. Use the method presented in Step 11.3.a to determine which way the corrector plate will need to be moved for an adjustment. To start making an adjustment back out a setscrew closest to the go to direction. Back it out by an amount you guess you will need to move the corrector plate (start with ¼ turn CCW). Now go to its opposed partner and turn it in ¼ turn CW to push the corrector plate in the adjustment direction. By working in increments after each adjustment all setscrews are set to be guide setscrews before the next movement. Always start an adjustment by backing out the setscrew (CCW) in the chosen go-to direction.
6. When the corrector plate is observed to be centered per Step 11.1.g, torque (CW) all the retainer ring screws to the "final torque", and re-check that the corrector plate is centered.
7. Re-check corrector plate adjustment. Iterate Steps 11.3.d.5 & .6 as necessary to end with a well-adjusted and secure corrector plate.

11.4. Addendum

a. Tripod Equipment Solutions for Performing In-Depth Co-Alignment:

1. Tripod with a worm geared elevating center column:

   Example website found for this type item – http://www.adorama.com/SLMCL.html?gclid=CJbAks2x4sUCFZA8gQodFbMAqQ

2. Tripod quick release assembly with fine-sliding rail movement:

   Example website found for this type item – http://www.bhphotovideo.com/c/product/318567-REG/Giottos_MH621_M621_Quick_Release_Assembly.html/prm/alsVwDtl

3. The tripod quick release adapter "Red Button" camera safety catch can be removed by removing its retaining screw that allows removing the Red Button and its spring. This removes the center "detent" so that the fine-sliding rail can slide totally free for its entire length. (The center detent is not desired when adjusting the collimator in the L/R (X-dimension.) This makes this inexpensive item ideal for collimator fine lateral adjustment, but care must be taken not to slide the collimator too far so that the rail disengages from the adapter tracks. At extra expense a longer rail plate is available from the example website (see the Accessories Tab). The rail in the figure has ~ 1.18" total adjustment (when the tripod is close – 0.5" is plenty); the Long Rail has ample adjustment on either side of the center detent (Red Button left in place), and the long slot for the collimator attachment screw allows centering the collimator over the tripod head. The Long Rail overhangs the adaptor offering easier handling for the lateral sliding adjustment. A little graphite powder lubricant makes the sliding rail movement very smooth. (The Red Button and its associated hardware can be saved and reinstalled if it is also desired to use the adapter with a DSLR camera and macro lens.)
4. When performing the Corollary Step 5.1, in lieu of moving the telescope, reach for the tripod elevation crank to adjust the Up/Dn (Y dimension), and reach for the fine-sliding rail to adjust the L/R (X-dimension). Be exacting and methodical when using these controls in lieu of moving the telescope.
5. The equipment stacks from the ground up: 1) Tripod with geared elevating center column, 2) Quick release adaptor with fine-sliding rail, 3) supplied fine-adjuster, and 4) on top – the collimator.

(Continued Next Page)

b. Peripheral Star Focusing Issues – With astrophotography imaging sensors, depending on how much of the peripheral edges of the field of view the sensor uses, if after completing Step 11.1.i and testing the telescope in the field, the sharpness of focus of stars in the peripheral edges of the field of view are not sufficiently sharp (especially on one side of the field), significant improvement can be achieved by finer centering of the three crosshairs (Step 11.1.d) to remove residual misalignment inherent in the telescope's construction. Full centering of the three crosshairs can be achieved with a focuser with lateral (X, Y axes) adjustment as well as tilt (Z axis) adjustment. Consider using a MoonLite 3-Axis (X/Y/C) Focuser (please email or call us for availability). (Focuser manufacturers sometimes referred to the Z-axis as the "C-axis" – it's the same thing.) Due to the extra thickness of the lateral adjustment mechanism the camera focal plane distance from the telescope rear cell may be an issue with some smaller telescopes. However, new focusers are continually added to the line, so check for availability.

c. Differential Diagnosis – Tilt Axis Misalignment versus Corrector Plate Centering Misalignment:
   1. Co-Align collimator & telescope. Then, Before & After performing Step 11.0, make the following checks for diagnostic comparison:
      i. Check how close the three crosshairs (Step 11.1.d) are to all being centered (secondary temporarily removed). Two crosshairs on the collimator target plate and one on the reflector mirror target.
      ii. Check the inner crosshair tips (or diffused donut inner circle) for closeness to being centered on the same collimator target plate ring (Step 11.1.c).
   2. If during the Before check, the three crosshairs were more misaligned than After – tilt was out.
   3. If during the Before check, the corrector plate centering was more misaligned than After – corrector plate centering was out.
   4. The item requiring the most adjustment to correct is regarded as most misaligned.

d. Ability to Make the Differential Diagnosis – The ability to sort this out demonstrates the incredible value of the Advanced CT Laser Collimator as the tool of choice for achieving seminal advances in collimation accuracy. After performing Step 11.1.d.3, the closeness of centering of the three laser crosshairs shows the limits the telescope's original construction alignment. Step 11.4.b and working with the ACT Laser Collimator makes it possible to even surpass this limit.

e. Alternate Mechanical Procedure for Zeroing-Out the Knobs (in lieu of Step 11.1.a.6) – With some older telescopes, the secondary mirror has collimation knobs, but is potted-in (can't be removed from) the corrector plate, so it can't be spun around on its centerline axis (i.e. in its mount). The following information is of value if you have one of these – if not, unless you are a history buff or cowboy, proceed to the next bullet item.

   The alternate method to Zero-Out the Knobs is strictly mechanical, but if done with care it can be very accurate (mechanical measurement is all the old-timers had). Use the Step 6.4 Mechanical Method to achieve a good rough centering of the Knobs. Next, remove the Corrector plate; perform Step 11.3.a through .c – ensure carefully Steps 11.3.c.1, .2, & .3. Looking at the Secondary Mirror installation, note the positions of the three collimation knobs (or screws). Take accurate measurements of the distance between the back of the Secondary Mirror and its supporting structure at the three screw positions. This can be accomplished with a feeler gauge set or better still – with a machinist quality "inside caliper" to take the dimension, then measure the dimension with a digital caliper or precision micrometer. Get the average of the three dimensions, and adjust the knobs to the average dimension ("just keep measuring, just keep measuring"). Then iterate this process until no further Zeroing of the Knobs can be achieved ("just keep measuring, just keep measuring"). This will get close to the Zeroing-Out the knobs process that can be achieved with lasers with far less time and iteration of a procedure to get dialed-in; and, welcome to the iterative processes of the old world. But – hay, why not go fully to the "old-timer cowboy way" – a digital caliper is suggested, why not go fully old school with the tedium of a Vernier caliper or a Vernier micrometer.

f. Previously Unachievable – When In-Depth Co-Alignment and Tilt Adjustments are performed in Steps 11.1.c, & .d, the telescope Secondary Mirror is completely removed. Star collimation provides no corollary for this in depth level of specific Tilt axis alignment. Also, star collimation offers no corollary to centering the Corrector Plate with Steps 11.1.a & .g.

   Value of Zeroing-Out the Knobs (Step 11.1.g) – Because the Secondary Mirror is spherical, only movements of its spherical surface from side-to-side change the angle of reflections bounced off its face (i.e., if a polished perfect sphere was being spun about its fixed center axis, and you bounced a laser off its surface it would bounce in the same direction whether it was spinning or not.) The piece of the Secondary Mirror that is spherical only bounces light in different directions by being moved from side-to-side whether swung from side-to-side by swinging from a short radius pivot point (i.e., its center pivot that it swivels on behind its polished face), or by sliding it from side to side by moving the Corrector Plate. Zeroing-Out the Knobs (Step 11.1.a) removes all arbitrary aiming of the Secondary Mirror and very accurately Centers the Corrector Plate to align the Primary Mirror Optical Axis Centerline *reflected* from the Secondary Mirror with the Final Optics Axis Centerline.

g. Facts – The facts illustrate that the HOTECH Advanced CT Laser Collimator has made historically significant seminal advancement to the tools available for amateur telescope collimation, adjustment, and optics alignment. The detailed sensitive measurements that can be made with the ACT Laser Collimator simply cannot be made with star collimation or traditional tools that were previously available to the amateur telescope owner. It is with pride that HOTECH Corp. presents the Advanced CT Laser Collimator so that users can enjoy the maximum performance available with their telescopes and integrated systems equipment.

12.0. Glossary:

Aim (& forms: Secondary Mirror Aiming, Secondary Mirror Alignment, Secondary Mirror Collimation, Collimating) –

Secondary Mirror aiming (tilting) process that is done with the Secondary Mirror Knobs (or screws). The optical axis of the Secondary is aimed at the optical axis of the Primary with its Collimating Knobs (Step 7.0). This is not called "tilt" because of conflict with Focuser manufacturers wide spread use of the use of the word "tilt" in reference to hardware and its use in aligning an accessory focuser optical axis with the optical axis of a telescope's Primary Mirror.

Co-Align (& forms: Basic Co-Alignment, In-Depth Co-Alignment, Co-Alignment, Co-Aligned, Co-Aligning) –

The Collimator & Telescope are Co-Aligned with Basic Co-Alignment Procedures (Step 5.0), or In-Depth Advanced Z-axes Co-Alignment Procedures (Step 11.0) that require removing and replacing the Secondary Mirror.

Collimated –

The optical axis of each element of a system of mirrors and lenses is centered on and aligned to the same axis. The telescope is collimated using the Secondary Mirror Collimating Knobs (or screws) (Step 7.0). This is the level achieved with traditional star collimation, but a fully collimated telescope will have the corrector plate centered and the final optics tilt axis collimated as well (Step 11.0).

Collimating Lasers (& forms: Alignment Lasers, Collimating Laser Dots, Three Laser Dots) –

The three collimating lasers and their three dots as seen when the lasers are reflected onto the Collimator Target Plate (Mode 2 selects three laser dots in addition to the Crosshair).

Corrector Plate –

The glass plate in the front of the telescope that holds the telescope Secondary Mirror. Moving the Corrector plate in side-to-side lateral directions allows for *centering* the Secondary Mirror on the optical axis of the Primary Mirror. (The optical axis of the Secondary is *aimed* with its Collimating Knobs.)

Crosshair –

The reflected pattern of the Collimator center crosshair laser (Mode 1) that is double pass reflected onto the Collimator target plate, or seen single path directly on the Reflector Mirror Target in the eyepiece (Final Optics) location when the Secondary Mirror is removed.

CW & CCW –

Clockwise and Counter-Clockwise. In this manual these terms most often refer to the direction needed to turn a screw fastener:
CW - tightening (increasing torque). CCW – loosening (decreasing torque).

Final Optics Axis (& forms: Final Optics Tilt Axis, Tilt Axis, Final Optics Adjustment, Tilt Adjustment, Tilt Aligned) –

The optical axis centerline of a focuser drawtube, visual back, or tilt adjustable reflector mirror that is aimed by Tilt adjustment.

Primary –

The Telescope Primary Mirror.

Reflector Mirror (& forms: Reflector Mirror Target, Final Optics Mirror, Tilt Mirror, Tilt Axis Mirror, Eyepiece Mirror) –

The Reflector Mirror is a Collimator Part; it is a Semi-Transparent Target Reflector Mirror that is a Two-Way Mirror with a Target Screen that is installed at the Final Optics location, i.e. where an eyepiece (or camera) is installed. The Reflector Mirror reflects laser beams back to the Collimator target plate, and also passes laser beams for viewing onto its target screen. (Also, see Tilt Adjustable Reflector Mirror below.)

Secondary –

The Telescope Secondary Mirror. The traditional collimating Knobs (or screws) are on the back of the Secondary Mirror housing in the front of the telescope in the middle of the Corrector Plate glass.

Secondary Collimated (& forms: Secondary Mirror Aiming Achieved, Secondary Mirror Aligned) –

When the ACT Laser Collimator is used to collimate the telescope, the Three Collimating Laser Dots (Mode 2) will be centered on Same Ring of the Collimator Target Plate. This can be done with Basic Co-Alignment procedures (Steps 5.0 & 7.0), or if necessary with more In-Depth Co-Alignment Procedures (Step 11.0)

Single Laser Dot –

The pattern seen on the Reflector Mirror Target when the three collimating lasers are focused to a single point or dot.

Target plate (& forms: Collimator Target Plate, Collimator Target Plate Face, Target Plate Screen) –

The Collimator Target Plate.

Tilt –

Final Optics Axis alignment relative to the Primary Mirror optical axis, alignment process, or adjustment hardware (Step 11.2). Tilt Axes Alignment is achieved by adjustments with visual back shimming, focuser tilt adjustment, or an accessory tilt adjustable reflector mirror.

Tilt Adjustable Reflector Mirror –

The Tilt Adjustable Reflector Mirror is an Accessory Collimator Part; its capabilities are the same as the Reflector Mirror (see Reflector Mirror above) with the addition of Tilt Axis Aiming Adjustment capability. Final Optics Axis Tilt capability is required when accomplishing In-Depth Collimation Procedures (Step 11.0). It is primarily used when the telescope is exclusively used for direct viewing with an eyepiece, and it is not desired to use an Accessory Focuser with Tilt adjustment, or to shim the Visual Back to adjust Tilt (Step 11.2.c).

Tilt Aligned –

The adjustment of the Final Optics Axis (visual back, focuser, or tilt adjustable reflector mirror) to align it with the Primary Mirror optical axis (Step 11.1.i achieved).

Zeroing-Out the Knobs (& forms: Zeroed-Out Secondary Mirror Knobs, Zeroed-Out Secondary, Zeroed Knobs) –

Adjusting the Secondary Mirror Knobs (or screws) to make the Secondary optical axis centerline perpendicular (square) to the plane of the front glass Corrector plate (this involves rotating the Secondary Mirror to achieve it) (Step 11.1.a).