Collimating the WIYN Telescope

DRB (dblanco@noao.edu) Last revised 1/30/96

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There are two documented procedures for collimating the WIYN telescope: the first, described below, is the full procedure starting from the installation of the primary mirror; the second is a procedure for making minor routine adjustments to the installed optics. This is described in the section "Routine collimation."

Full Collimation

Overview

This is a summary of the full-up optics installation procedure for the WIYN telescope starting from the initial alignment of the primary mirror cell (PMC) through installation of the secondary, tertiary, and field corrector optics. This procedure was used for the first installation of the telescope optics, and may need to be repeated after major work on the telescope.

Collimation starts with the establishment of an auto-reflecting alignment telescope (AT) on the tertiary rotator. This AT defines the line of sight (LOS) of the primary mirror cell (PMC), and eventually defines the LOS of the telescope. The PMC is initially installed in an arbitrary orientation, and its alignment with respect to the telescope axes is measured. Special shims are then custom made, and the PMC is reinstalled with the new shims to correct the orientation.

Once the PMC has been installed true to the telescope axes, the secondary mirror is trammed onto the LOS. The secondary then becomes the LOS reference and he AT is moved to the one of the Nasmyth instrument rotators (NIR's) where it is used to align the

tertiary mirror. This alignment should be sufficient to acquire a star on an acquisition camera mounted on the NIR. The primary mirror is then tilted within its cell to eliminate coma from the image. Further refinement to the secondary tilt and centration can be done with feedback from the extra-focal images (wavefront sensing).

Goals

The procedure has three major goals; first is to install the primary mirror cell true to the telescope mechanical axes. The second is to align all smaller optics to a common line of sight. The final goal is to tip the primary in its cell so that it, too, is aligned to the common line of sight.

Sine the NIR's are not adjustable it is impossible to achieve simultaneous collimation of both optical branches of the telescope, so compromises are inevitable. The initial installation of the optics favored the MOS port optical path. Since this covers a one degree field compared to the half degree field covered by the WIYN port, the MOS port is more sensitive to image aberrations at the edge of the field. This is only partly mitigated by a larger image error allowance for the MOS optics.

Definitions

We define two vectors which are coincident with the two NIR axes; the "MOS" and the "WIYN" vectors. In a perfect world these vectors would coincide. During fabrication of the mount the rotator axes were machined as accurately as possible, but measurements have shown that the two axes are skewed to each other by an angle of about 12 arcseconds.

A third vector is defined as the LOS of the telescope. This is defined by the tertiary mirror rotator (TMR) axis.

We define a fourth vector, the folded Cassegrain or FC vector, by two points, one on the MOS vector midway between the flanges of the MOS and WIYN NIR's, and a second point on the center of the folded Cassegrain instrument bolt circle.

Acronym list

- AT = alignment telescope (the K&E)
- FC = Folded Cassegrain
- LOS = Line of Sight

- MOS = Multiple Object Spectrograph
- NIR = Nasmyth Instrument Rotator
- PMC = Primary Mirror Cell
- TMR = Tertiary Mirror Rotator

Procedure

The following is a brief description of the steps involved in the procedure. At the start of the procedure the primary and tertiary mirrors have been removed, and the telescope is zenith pointing. Refer to separate documents for instructions on handling the primary, secondary and tertiary mirrors.

1. Mount an AT on the TMR and tram it onto the rotator axis. See the section on Centering.

2. String a scale or between the two NIR flanges. Using the AT, sight on the scale and determine the centration error of the primary mirror cell. [Note: a scale attached to a rigid bar can be used instead of a tape scale].

3. Lower the PMC from the telescope and make adjustments to the flexion bars as necessary. These are bolted to the primary mirror cell with over-sized bolt holes. Moving a flexion is done by loosening the bolts and tapping the flexion. Repeat the measurement and adjustment until the PMC is centered on the telescope axes. Refer to the primary mirror handling document.

4. Install the periscope fixture on the TMR and sight on a K&E reflective target mounted on the MOS NIR. Rotate the MOS NIR and tram the target onto the center of the NIR axis. In auto-reflect mode, tram the target normal the NIR axis.

5. Set the TMR index pin to align the target with the AT in azimuth. Adjust the periscope mirror in tilt and height to align the target vertically. Iterate until the target is centered and the AT auto-reflects.

   DO NOT TOUCH THE PERISCOPE ADJUST SCREWS AFTER THIS.

6. Turn the TMR to face the WIYN port. Tram a reflective target onto the center and normal to the NIR bearing axis. Adjust the TMR index stop to line up the AT on the target in azimuth. Measure the vertical angular deviation.

7. Turn the TMR to face the FC port. Sight on wire cross wires strung across the FC

bolt circle. Set the TMR stop to align the AT to the target in azimuth. Measure the vertical angular deviation.

8. Calculate new shim thicknesses based on the measurements. Lower the primary mirror cell and install the new shims.

9. Sight on the MOS port and focus on the target. Measure the horizontal linear displacement of the target.

10. Repeat for the other two targets.

11. Use the measurements to center the cell.

12. Replace and readjust the folding flat height and tilt to auto-reflect off the MOS target. Rotate the TMR to check all measurements.

13. Remove the folding flat, point the telescope at horizon, and sight on the secondary cage. The cage centration and orientation is determined by two points: one is a pin hole drilled into the center of the cage at the top; the second is found by stringing cross wires from the bolt circle at the lower end of the cage.

14. Adjust the spider vane turnbuckles to tram the cage onto the LOS. Simultaneously, these two conditions have to be met:

    - The tension in the spider vanes must be kept equal. To do this, alternately loosen one turnbuckle while tightening another so that there is no net change to the vane tensions. The vane tensions can be checked periodically by "ringing" the vanes (whacking them with a rubber mallet) and listening to the pitch. [This takes someone with a good ear, but turns out to be a very effective technique].

    - The distance from the top of the tertiary rotator flange to the bottom of the secondary cage cross plate must be 179.16 +/- .03". Check this periodically by stringing a tape scale between the two surfaces.

15. Once the cage is aligned, install the secondary mirror. Refer to the secondary mirror handling document.

16. Install the tertiary mirror. Refer to the tertiary mirror handling document.

The procedure for aligning the secondary and tertiary mirrors is described in the next section title Routine Collimation.

Routine Collimation

This is a summary of the collimation procedure for the WIYN telescope. This routine procedure assumes that the primary mirror cell is properly aligned and centered on the telescope. If there is some doubt about the primary mirror cell alignment, then it may be necessary to perform a full-up alignment and telescope collimation.

Overview

Routine collimation involves tramming the smaller optics - secondary and tertiary mirrors - onto the line of sight (LOS) of the zenith-pointing telescope. Once these are aligned, the primary is aligned to the same LOS. In a nutshell the steps are:

1. Establish the line of sight (LOS) of the telescope.
2. Orient the secondary mirror so that the surface at vertex is normal to the LOS.
3. Center the secondary mirror vertex on the LOS.
4. Establish the axis of the instrument rotator.
5. Orient the tertiary mirror to fold the LOS onto the rotator axis.
6. Finally, acquire a star and tip the primary to eliminate coma. ★

Acronym list

- AT = alignment telescope (preferably the K&E)
- LOS = Line of Sight
- MOS = Multiple Object Spectrograph
- NIR = Nasmyth Instrument Rotator
- PMC = Primary Mirror Cell
- TMR = Tertiary Mirror Rotator

Procedure for Routine Collimation.

Establish the line of sight (LOS) of the telescope

The LOS of the telescope is defined to be the tertiary rotator axis. To establish this LOS mount a K&E auto-reflecting telescope on the tertiary rotator axis pointing towards the secondary mirror. To do this, any Cassegrain instrument and reimaging optics must be

removed.

Equipment:

- K&E auto-reflecting alignment scope (AT)
- K&E reticle illuminator
- right angle eye piece
- Scope mounting fixture

1. Set the telescope at zenith, open the mirror covers, and set the tertiary fold to "removed".

2. Install the K&E scope mount fixture on the tertiary rotator (it registers onto three tooling balls pressed into the top plate of the rotator).

3. Install the clamps to hold the fixture in place.

4. Sight through the scope and adjust the scope until the secondary alignment cross mark is in the field of view.

5. Center the K&E scope on the rotator axis. For more detail on this procedure see "Centering".

The K&E scope now defines the telescope LOS.

Orient the secondary mirror so that the surface at vertex is normal to the LOS

For this procedure the control system must be running. For instructions on how to start the control system and tilt the secondary see LTO Documentation.

1. Initialize the secondary.

2. Adjust the focus of the scope to retro-reflect off the secondary mirror.

3. Using the control system, tilt the secondary mirror so that the scope auto-reflects.

4. Focus on the surface of the secondary and note the position of the secondary cross mark using the scope dials.

Translate the secondary mirror to place its vertex on the LOS

1. Move the telescope to horizon pointing.

2. Use a ladder to gain access to the K&E scope.

3. Sight on the secondary mirror cross mark and note the new (X,Y) positions.

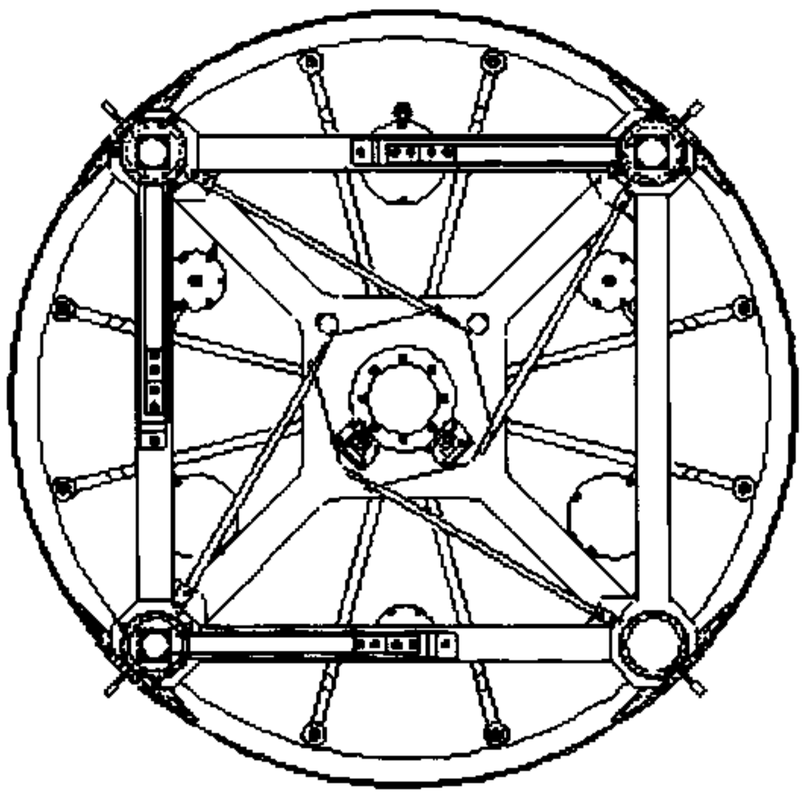
4. calculate new X & Y values from:

   X(new) = X(horizon) - X(zenith) and;
   Y(new) = Y(horizon) - Y(zenith)

5. Set the scope cross hair to the new (X,Y) values. We'll now translate the secondary to place the cross mark on the scope cross hair.

6. Use a 1/4" Allen wrench to loosen the clamp plate at the back of the secondary mirror cell (8 5/16 socket head cap screws). Do not remove.

7. Loosen the cam side-clamps (3/16" Allen) and adjust two centration cams located near the hub at the center of the cell (use a 1/2" open end wrench). Opposite the cams are two dial indicators to measure the centration. Be sure to mark down the positions recorded on the indicators before and after moving the secondary.



View of secondary mirror cell from the back. The lateral adjust cams are just below the center hub; the dial indicators are just above the center hub.

8. Once the secondary has been centered, tighten the clamp plate and the cam clamp screws.

   The secondary mirror is now centered on the LOS, however the tilts required in the next stage of collimation may decenter the secondary slightly making it necessary to iterate this procedure.

9. Point the telescope to zenith, set the scope cross hair to zero, and check the secondary centration.

10. Set the focus to auto-reflect and adjust the secondary tilt as needed. Iterate the centration and tilt until all converges.

Establish the axis of the instrument rotator

In this procedure we'll move the K&E scope to a mounting fixture on the WIYN Nasmyth Instrument Rotator (NIR). The centering procedure is identical to that used for establishing the LOS. See "Centering".

Once the scope is centered on the NIR axis, we move on to...

Orient the tertiary mirror to fold the LOS onto the NIR axis

The tertiary mirror is held onto the telescope in a kinematic style mounting. At the back of the mirror are three screws fitted with jam bolts. These provide a three point adjustment for the tertiary mirror.

1. Turn the tertiary rotator to the WIYN position, and point the telescope so to horizon with the WIYN port over the lift.

2. Adjust the focus of the scope until it auto-reflects.

3. Adjust the tertiary mirror tilt until to center the scope reflection.

While adjusting the orientation of the tertiary, it's best to iteratively advance one screw while backing out another to keep the surface of the mirror from advancing or retracting.

PRECAUTION: the tertiary assembly weighs about 300 lbs and is held in place by only three screws! KEEP TWO SCREWS TIGHT AT ALL TIMES.

This completes the small optics alignment. In the next section we will use star light to align the primary mirror to the same LOS established in the previous sections.

Tilting the Primary Mirror

1. Point to a wavefront star as high as possible in elevation. At least 80 degrees, 85 if possible.

2. Measure the wavefront. Look at the coma terms Z7 and Z8. The command to remove the terms is "active set axial X1 X2 X3" where X1 X2 and X3 are computed the following way:

   - Record the current LVDT values from the wiyn_page.
   - Adding 0x0100 to X3 increases Z7 by 0.12 wave.
   - Adding 0x0100 to X2 decreases Z8 by 0.12 wave.
   - Once the new X2 and X3 are obtained, check they are within the range (0x0300 < X < 0x0A00). If they are not add a constant to X1, X2 and X3 to bring them all within the range.
   - Once this is done, command "active set axial X1 X2 X3".

3. Iterate until the wavefront measurements of Z7 and Z8 are less than about 0.1 wave.

4. The new values for the LVDTs can be set as default by entering them in the file actGlobal.c.

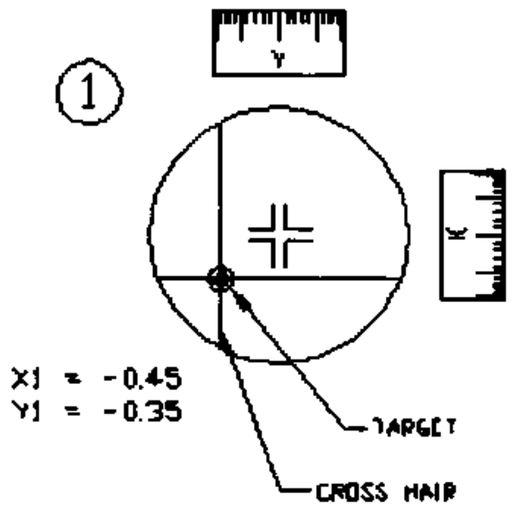
5. Recompile and reboot the system.

Centering an alignment telescope

Tramming an alignment telescope (AT) onto a rotating axis is a five step process shown in these illustrations. At the start the scope is mounted on the rotating axis and mechanically centered by indicating on the scope barrel. There also must be a target of some type in the field of view of the scope. This can be any thing that provides a sharp point for positioning the cross hairs. The target need not be on the rotation axis.

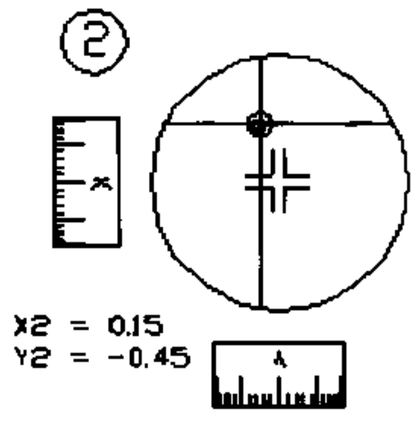
Step 1

With the rotator set to 0°, sight on the target and measure its position with the scope X-Y dials. Note the position. In this example X1 = -0.45 and Y1 = -0.35.



Step 2

Rotate the axis one half turn (180°) and measure the target position again. In this example X2 = 0.15 and Y2=-0.45.



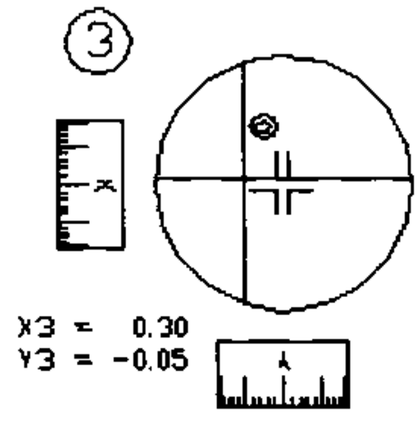
Step 3

Set the cross hair dials to half the difference of the first two readings:

$$X = (X2-X1)/2$$
$$Y = (Y2-Y1)/2$$

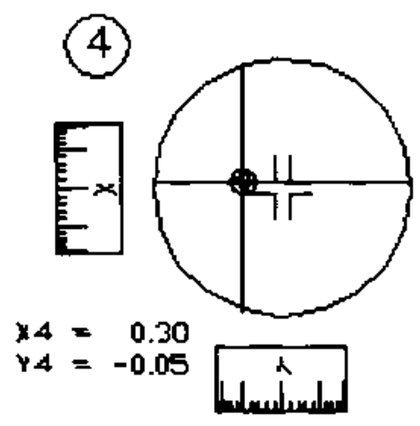
In this example:

$$X = (-0.45 - 0.15)/2 = -0.30$$
$$Y = (-0.35 + 0.45)/2 = +0.05$$



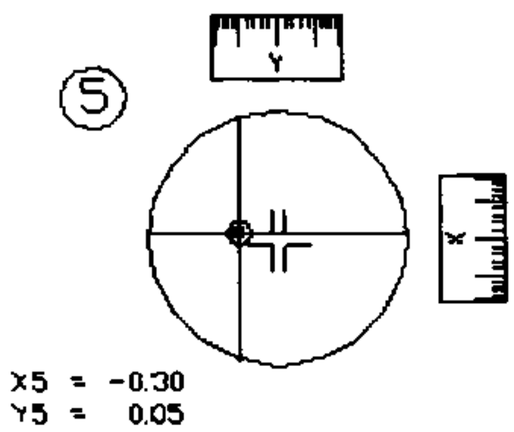
Step 4

Tip or tilt the scope to move the target onto the cross hair.



Step 5

Turn the rotator back to 0° and check the reading. When the scope is centered the target position measured with the rotator at 0° has the same value *but opposite sign* the position at 180°. This is because the target is not on the rotator axis.



Repeat the steps to check the centration; correct as needed until the scope is centered.