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Transmon Telescope Mirror Test Procedure

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1 Introduction

The purpose of this technical note is to describe an apparatus and a procedure for testing the performance of the off-axis Transmon Suspension (TMS) parabolic reflecting telescope mirrors.

2 Mirror Test Apparatus

The test apparatus consists of a granite table fastened on top of a standard Newport table, as shown in Figure 1.

A reference mirror mounted to a reference angle plate will be placed on top of the granite table against a Secondary reference bar. The Parabolic Telescope Primary mirror mounted to a reference angle plate will be placed against the Primary reference bar.

The autocollimators #1 and #2 will be mounted to the Newport table.

The Telescope Secondary mirror will be mounted to the Newport table.

The Shack-Hartmann apparatus will be mounted to the Newport table.

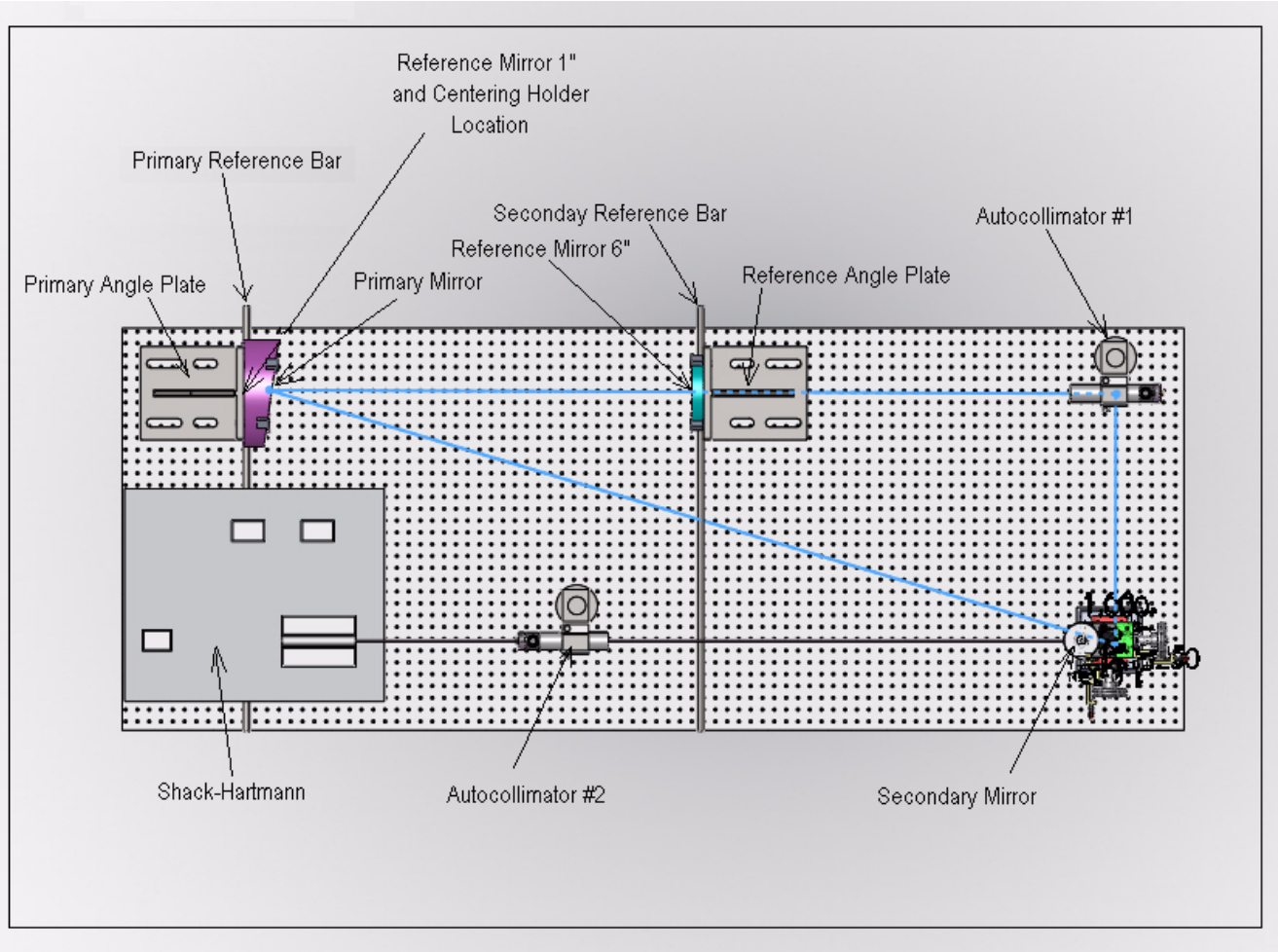


Figure 1: Telescope Mirror Test Apparatus

3 Preliminary Set Up of Test Apparatus

3.1 Vertical Alignment of Reference Mirror 3"

Mount the Reference Mirror 3" to the vertical front face of the Reference Angle Plate using the provided clamps. The wedge of reference mirror is $< 24 \text{ E-6 rad}$, and the vertical face of the angle plate is perpendicular to the base within 33 E-6 rad . Therefore, the reference mirror will be perpendicular to the base of the angle plate within 57 E-6 rad .

Place the Reference Angle Plate on the granite table. The granite table is flat within 5 E-6 rad . The reference mirror will be automatically perpendicular to the table within 62 E-6 rad .

3.2 Alignment of Primary Reference Bar

Place the Primary Reference Bar on top of the granite table in the orientation and position shown in Figure 1 and clamp the reference bar firmly in place using clamps attached to the mounting surface glued to the sides of the granite table; **it must not be moved during the remainder of the telescope alignment procedure.**

3.3 Alignment of Autocollimator #1

Place the Angle Plate with the mounted Reference 3" mirror against the Primary Reference Bar, approximately in the position of the Primary Mirror, with the mirror facing toward Autocollimator #1.

Place a paper target with a 0.5 in diameter hole and cross marks to define the center of the hole against the reference mirror--the horizontal cross marks must be 5.13 in above the surface of the granite table.

Firmly attach the base of the autocollimator mounting post to the Newport table at the desired location that defines the position of the Primary mirror beam line. Move the autocollimator vertically on the post to approximately 5.13 in above the granite table.

Place the corner cube at the output of the autocollimator and adjust the focus until the reticle pattern appears sharp. Remove the corner cube. Tip and tilt the autocollimator in its mount until the reflected reticle pattern from the reference mirror is centered with the cross hairs as seen through the eyepiece. Turn the focus knob of the autocollimator until the projected reticle pattern is sharply focused on the paper target. Move the height of the autocollimator until the projected reticle pattern aligns with the horizontal cross line on the reference mirror target. Iterate these steps until the autocollimator is aligned perpendicular to reference mirror and is 5.13 in height. This completes the alignment of Autocollimator #1; **it must not be moved during the remainder of the telescope alignment procedure.**

3.4 Alignment of Secondary Reference Bar

Place the Secondary Reference Bar on the granite table approximately parallel to the Primary Reference Bar at the desired location.

Place the Angle Plate with the mounted Reference 3" mirror against the Secondary Reference Bar with the mirror facing Autocollimator #1.

Rotate the Secondary Reference Bar within the plane of the granite table until the reflected reticle pattern is centered in Autocollimator #1.

Firmly clamp the Secondary Reference Bar in this position. It is now parallel to the Primary Reference Bar; **it must not be moved during the remainder of the telescope alignment procedure.**

3.5 Alignment of Autocollimator #2

Place Autocollimator #2 approximately at 5.13 in above the granite table, approximately on the nominal beam line exiting the secondary mirror.

Place the Angle Plate with the mounted Reference 3" mirror against the Secondary Reference Bar, with the reference mirror facing Autocollimator #2.

Use the same procedure used in Sec. 3.3 to align the autocollimator perpendicular to the reference mirror and at 5.13 height above the granite table; **it must not be moved during the remainder of the telescope alignment procedure.**

3.6 Alignment of Primary Mirror

Place the Primary Angle plate, with the mounted Primary Mirror, against the Primary Reference Bar--the center of the primary mirror should be 5.13 inches above the granite table.

Place a paper target in front of the Primary Mirror with a cross pattern referenced to the center of the Primary Mirror. Turn the focus knob of the autocollimator until the projected reticle pattern is sharply focused on the paper target. Move the Primary mirror laterally along the surface of the granite table until the reticle pattern aligns with the vertical cross line on the Primary Mirror target. Also, check that the reticle pattern aligns with the horizontal cross line on the Primary Mirror target--if not, the height of the Primary Mirror must be adjusted accordingly.

3.7 Alignment of Telescope Secondary Mirror

Set the focus of Autocollimator #1 to infinity focus by using the corner cube, and project the beam toward Telescope Primary Mirror.

Place the Telescope Secondary Mirror at the approximate focal position by observing the focused spot of the projected autocollimator beam.

3.7.1 Spherical Secondary Mirror

Tip and tilt the secondary mirror until the reflected reticle pattern from Autocollimator #1 is centered in Autocollimator #2

Move the secondary mirror along the beam path from the primary mirror until the reticle pattern appears sharp in autocollimator #2.

Iterate the tilting and focusing of the secondary mirror until the reticle pattern is both sharp and centered in autocollimator #2.

3.7.2 Parabolic Secondary Mirror--One Pass

Place Reference Mirror 1" against the mounting surface where the back of the Secondary Mirror will be placed.

Turn on Autocollimator #2, and Tip and tilt the secondary mount until the reflected reticle pattern is centered in Autocollimator #2.

Focus the projected autocollimator reticle pattern onto a target in front of and centered with the secondary mirror barrel. Adjust the height of the secondary mirror mount until the horizontal cross mark on the target is aligned with the reticle pattern.

Focus the Autocollimator #2 at infinity by using the corner cube, and turn off the projection lamp.

Insert the Telescope Secondary Mirror against the back mounting surface of the mirror mount.

Turn on Autocollimator #1. Translate the Secondary Mirror horizontally and vertically until the projected reticle pattern from Autocollimator #1 is centered in Autocollimator #2. Focus the Secondary Mirror by moving the mirror parallel to the primary input beam line until the reticle pattern appears sharp. Iterate these steps until the reticle pattern is both sharp and centered in the Autocollimator #2.

During the Autocollimator alignment procedure of the Secondary Mirror, the secondary mirror mount must not be tilted!

3.8 Final Alignment Using the Autocollimator #2--Double Pass

Place the Reference Mirror 3" against the Secondary Reference Bar on the primary mirror beam line, facing toward the Primary Mirror.

The projected beam from Autocollimator #2 will reflect from the Reference Mirror 3" and make a double pass through the telescope. Repeat the Secondary Mirror adjustments described in section 3.7.2. **During the Autocollimator alignment procedure of the Secondary Mirror, the secondary mirror mount must not be tilted!**

4 Shack Hartmann Alignment

Place the Shack Hartmann beam line 5.13 in above the granite table, approximately on the same beam line of Autocollimator #2.

Remove the Autocollimator #2 from its holder.

Place the Reference Angle Plate with the Reference Mirror 3" against the Secondary Reference Bar, with the mirror facing toward the Shack Hartmann.

Tip and tilt the Shack Hartmann beam until it retro-reflects from Reference Mirror 3" upon itself. **Do not move the Shack Hartmann beam from this position during the remainder of the telescope alignment procedure.**

4.1 Final Alignment of the Transmon Telescope Using the Shack Hartmann Beam

Adjust all degrees of freedom of the Secondary Mirror--horizontal and vertical translation, focus, tip and tilt--to minimize the astigmatic wave front error of the secondary beam, using the wave front map generated by the Shack Hartmann sensor.