LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Document Type	**LIGO-T000065-05 - D**	9/7/00

COS 4K IFO Alignment Procedure

Michael Smith

Distribution of this draft:

xyz

This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project - MS 51-33
Pasadena CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project - MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

WWW: http://www.ligo.caltech.edu/

1 LIVINGSTON 4K IFO ALIGNMENT

1.1. COS Autocollimator on HAM 2, Behind RM

The ITM, BS, and the RM are not installed during this procedure.

1.1.1. Positioning of COS Autocollimator

Place the IAS theodolite on the optical centerline in the removed spool piece, LBE-1A, location and view along the optical centerline in the -x direction, as shown in figure 1.

Place the Velmex slide mechanism on the optical table in HAM2, and insert the COS autocollimator #1 installed in the x-y tilt mount, as shown in figures 1 and 2. Place the corner cube with a target on the output barrel of the autocollimator and translate the autocollimator in the horizontal and vertical directions, using the Velmex slide, until the target is centered with the cross hairs of the theodolite.

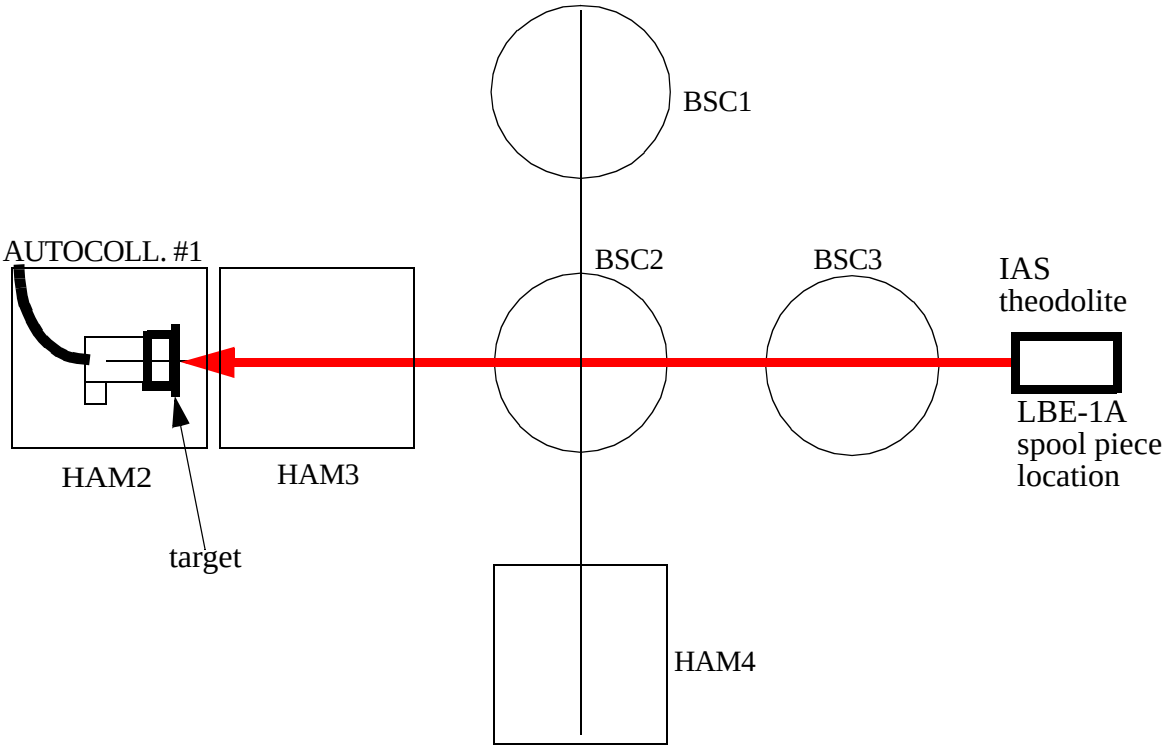

Figure 1: Alignment of Autocollimator #1

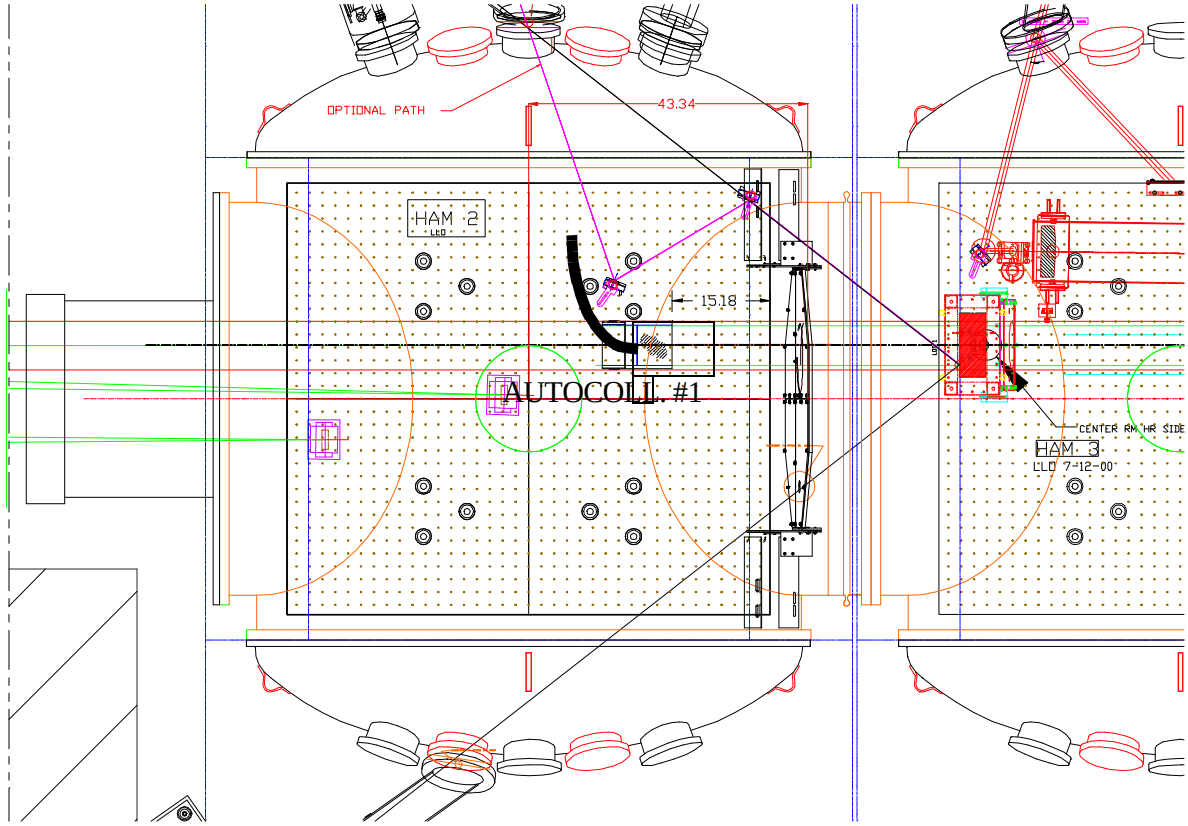

Figure 2: Autocollimator #1 on HAM2, Plan View

1.1.2. Alignment of Autocollimator

1.1.2.1 Pointing angle alignment of autocollimator #1

After the RM has been installed and aligned, turn on the 940 nm laser in autocollimator #1, focus it at infinity (See "Autocollimator Infinity Focus calibration" on page 3.), and adjust the angular alignment of the autocollimator, using the x-y tilt screws, until the retroreflected reticle pattern from the HR surface of the RM is centered on the autocollimator cross hairs.

1.1.2.2 Autocollimator Infinity Focus calibration

Place a corner cube retroreflector on the output barrel of the autocollimator. Set the camera focus at infinity, and adjust the focus of the autocollimator eyepiece until the camera image of the cross-hair pattern is as small as possible. Finally, set the focus of the autocollimator to infinity by turning the autcollimator focus knob until the camera image of the retroreflected reticle is as sharp as possible.

1.2. IO Baffle Alignment

After the IO baffle has been installed in HAM2, as shown in figure 3, place an alignment target in the center of the main beam hole in the IO baffle. Project the reticle pattern from the autocollimator on HAM2 and focus it on the IO target. Position the IO baffle until the center of the target is aligned with the projected reticle pattern. Remove the IO target.

The RM optical lever beam may have to be adjusted so that the beam passes freely through the small hole in the IO baffle.

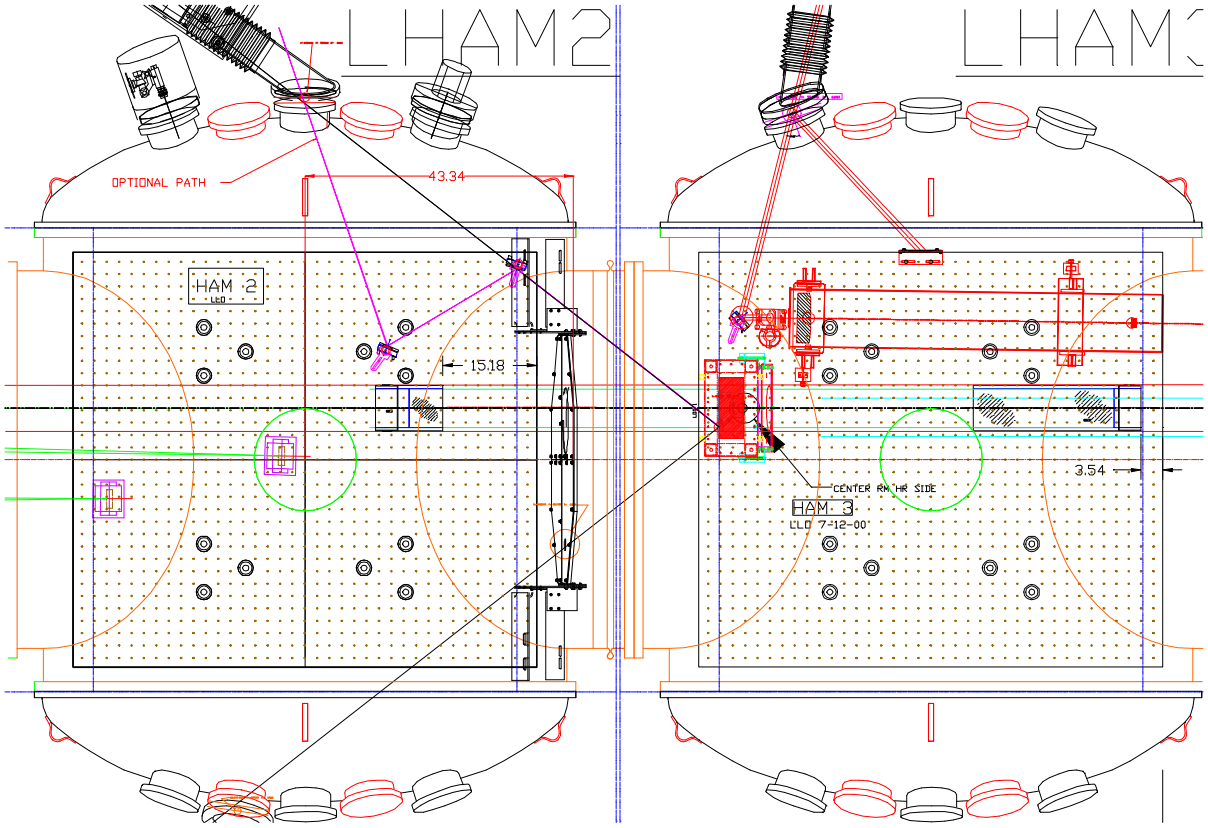

Figure 3: IO baffle, on HAM2

1.3. APS Telescope, Global Alignment

Install and align the APS telescope first, before installing the other PO telescopes on the HAM tables.

Place the APS telescope on HAM 4, as shown in figures 4, and 5, with the front and back ends of the telescope supported by the jack stand alignment fixtures. Adjust the focus of the autocollimator # and project a focussed reticle pattern through the RM, the beam splitter, and reflect from the ITM onto the internal alignment target of the APS telescope. Align the APS telescope as follows:

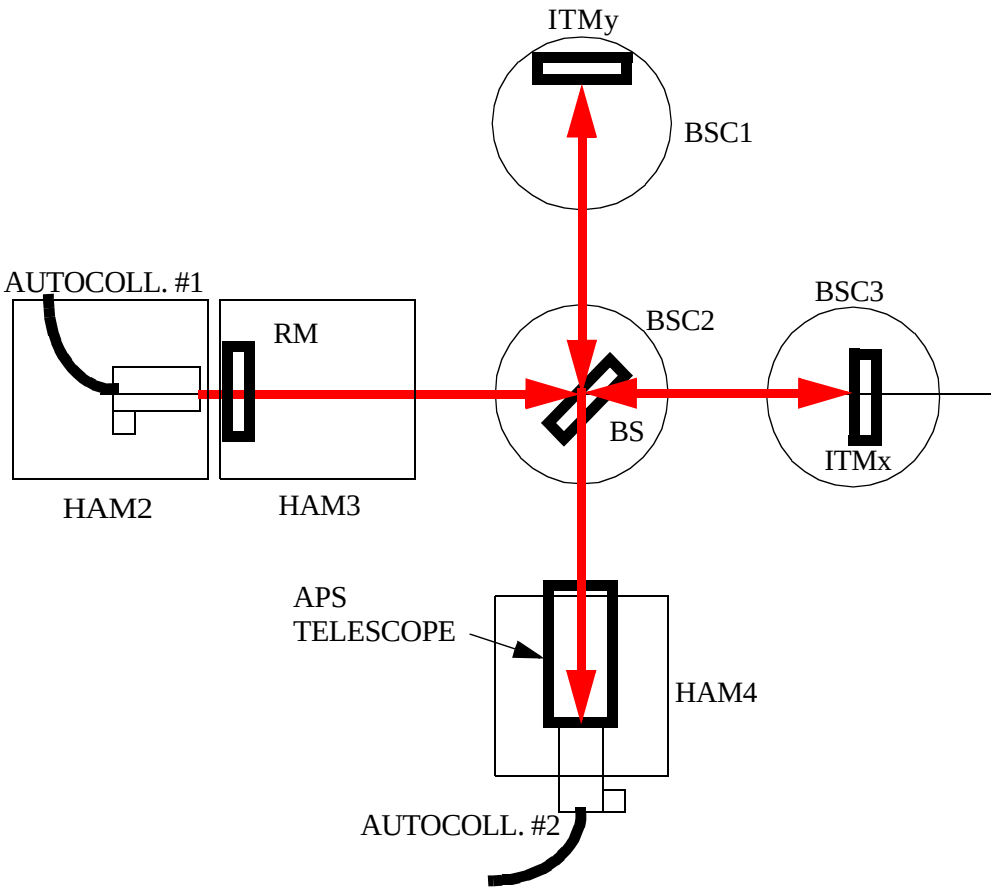

Figure 4: COS Alignment of 4K APS Telescope

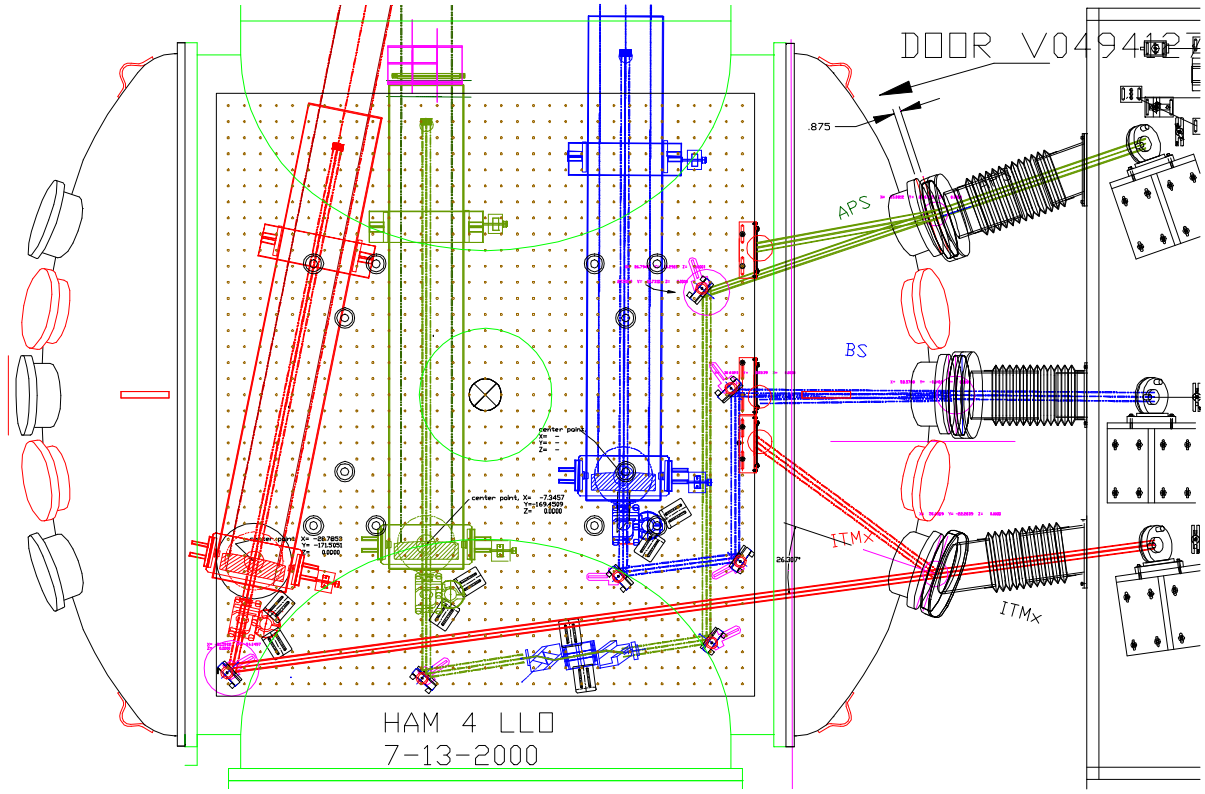

Figure 5: APS telescope, ITMx and BS PO telescopes, on HAM 4

.

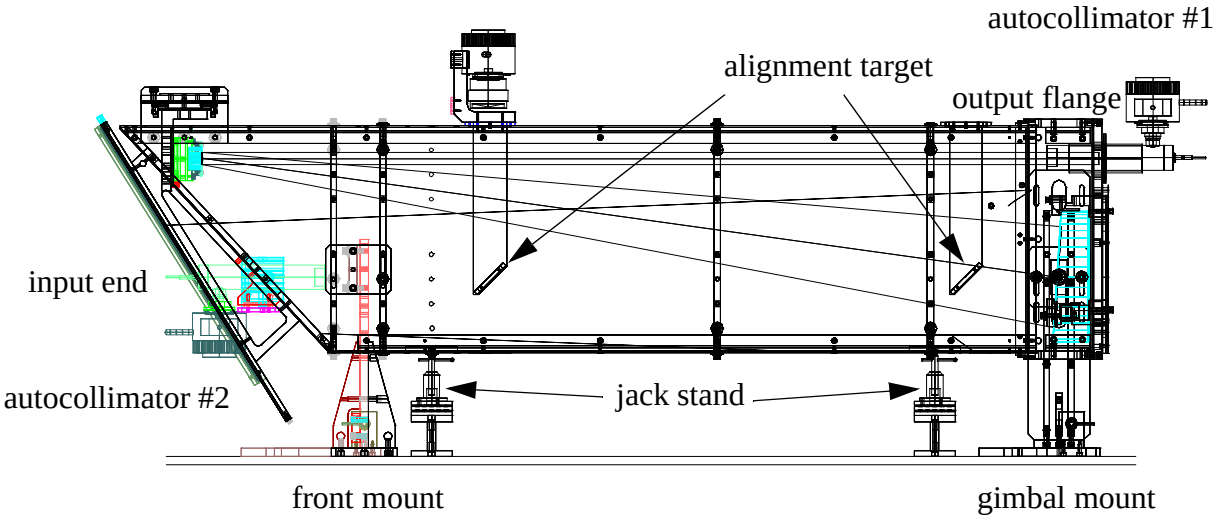

Figure 6: APS Telescope Steering Mirror Alignment Beam

- Place the internal alignment target inside the telescope near the primary mirror, as shown in figure 6. Use the extension spring and push screw to translate the APS telescope gimbal mount (at the primary end of the telescope) horizontally, and turn the jack screw to move

the telescope vertically to center the cross on the target with the projected reticle pattern from autocollimator #1. When this is completed, firmly clamp the primary gimbal mount of the APS telescope to the HAM optical table, leaving the gimbal mount free to rotate in azimuth and elevation.

- Move the internal alignment target to the entrance of the APS telescope, and translate the front telescope mount horizontally with the push screw and vertically with the jack screw to clamp it to the HAM optical table. Clamp the gimbal structure so that it will not rotate in the azimuthal direction.
- coarsely center the cross on the target with the projected reticle pattern from autocollimator #1.
- Place autocollimator #2 in the output flange of the telescope.
- LEVEL THE HAM TABLE.
- Remove the internal alignment target and tilt the input end of the APS telescope in elevation and azimuth, using the push screw and the jack screw the until the cross-hair of autocollimator #2 is aligned with the projected reticle pattern from autocollimator #1. When this procedure is accomplished, lock the front mount of the APS telescope and firmly

1.4. PO Mirror Alignment

Place the ITMx, ITMy an BS PO telescope external primary mirror alignment targets at the position of the PO telescope primary mirrors on the HAM tables, as shown in figures 5 and 9. Focus the COS autocollimator to project a sharp image of the reticle pattern at each target. Steer the corresponding PO mirrors located on BSC1 and BSC2, as shown in figures 7 and 8, until the projected reticle pattern is centered with the cross on the target. After steering is completed, permanently lock the tilt mechanism of the PO mirror.

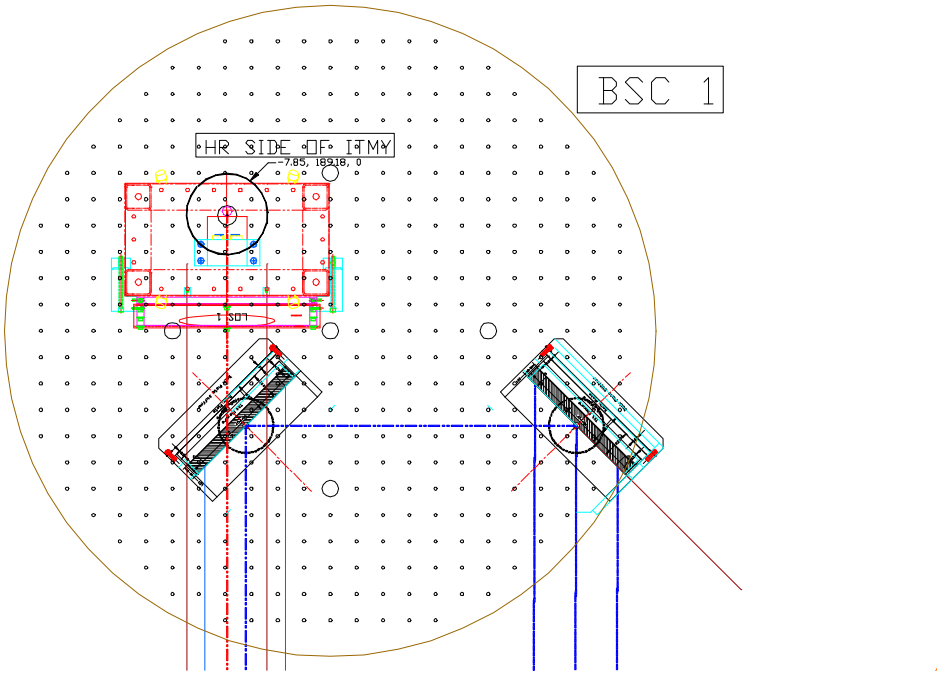

Figure 7: BS PO mirrors, on BSC1

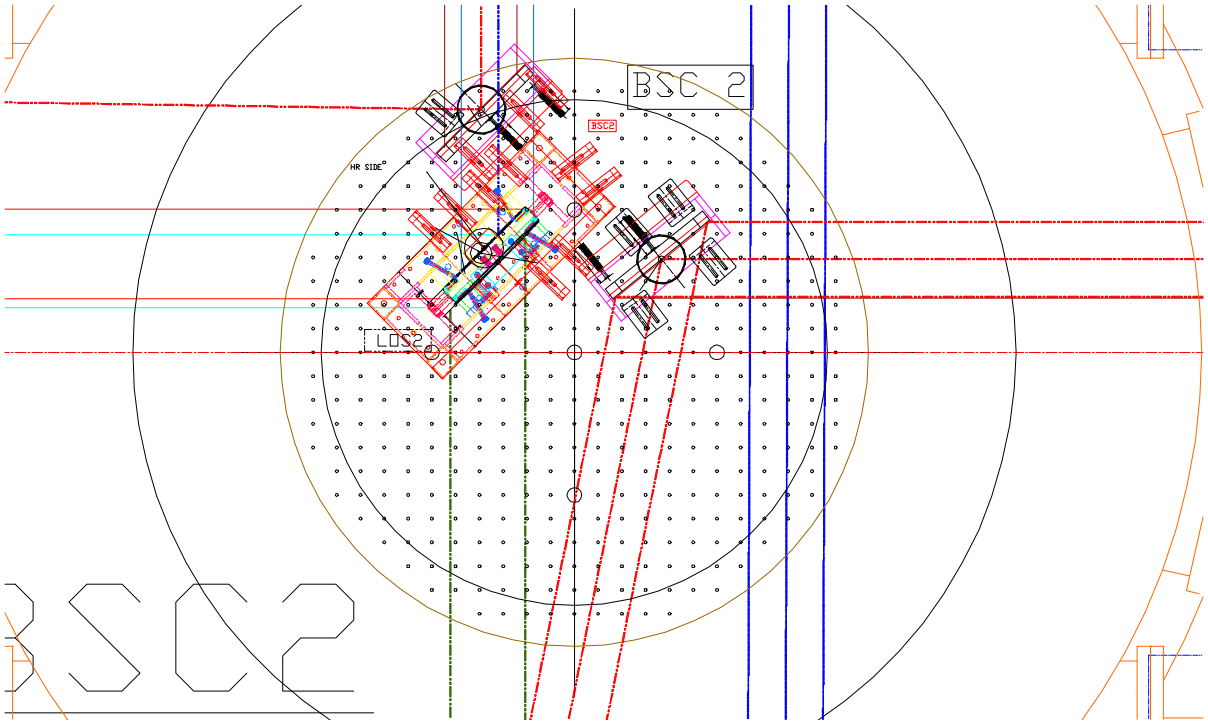

Figure 8: ITMx and ITMy PO mirrors, on BSC2

1.5. PO Telescope Alignment

1.5.1. PO Telescope Centering Alignment

Remove the external primary mirror alignment targets. Place the PO telescopes in their proper positions on the HAM tables, as shown in figures 5 and 9. The height of the primary mirror for the PO telescopes is pre-set at 16 inches above the HAM table. Support the front and back of each PO telescope in turn with the jack stand alignment fixtures. Proceed to center the front and back of the PO telescope with the projected reticle pattern, as was done for the APS telescope. When the front and the back of the PO telescope is aligned with the reticle pattern, attach permanently the primary gimbal mount to the HAM table, leaving it free to rotate in the azimuthal direction.

1.5.2. PO Telescope Pointing Alignment

Insert the autocollimator #1 into the output flange of the telescope.

LEVEL THE HAM TABLE.

Align the PO telescope by tilting the front end in azimuth and elevation, as was done for the APS telescope. When the alignment is completed, permanently attach the telescope mounting structures to the HAM table

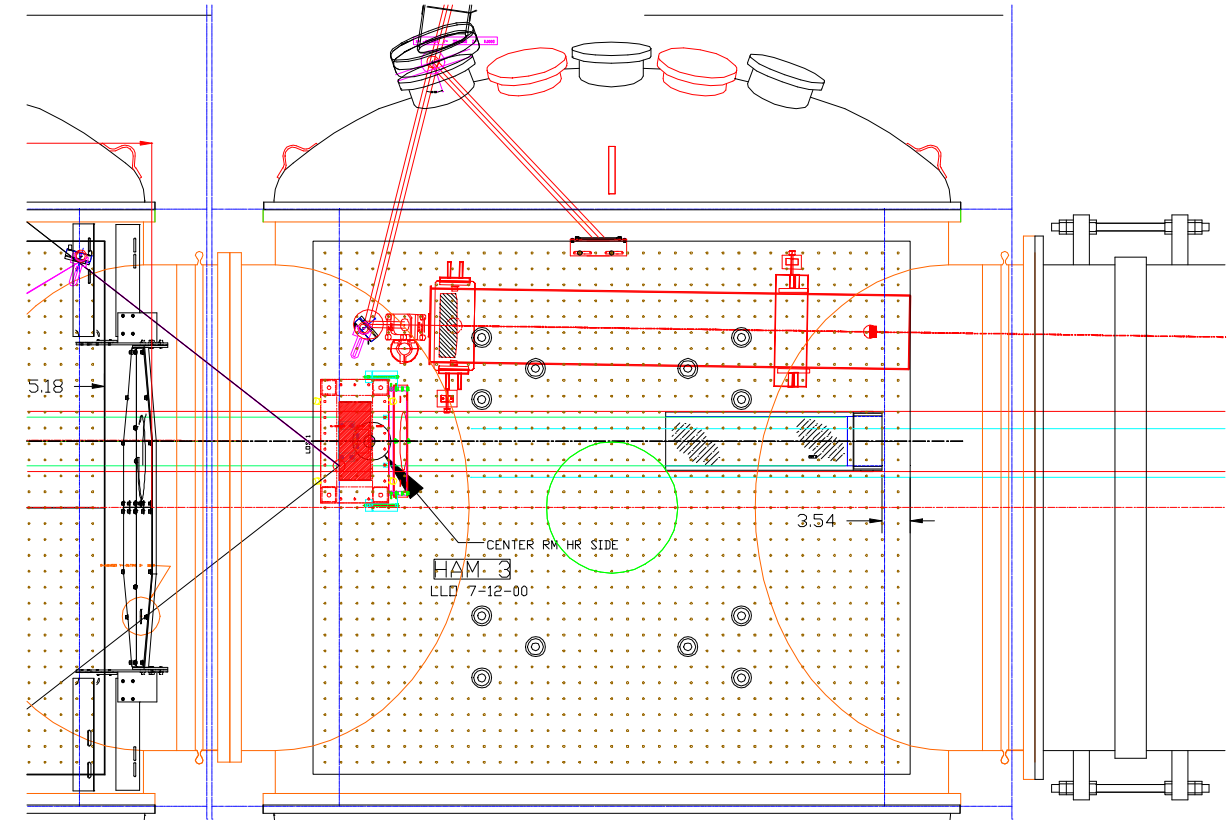

Figure 9: PO Telescopes 4K ITMy, on HAM3

1.6. APS/PO Telescope Optical train Alignment

Attach the mounting bracket at the input end of the telescope, and insert autocollimator #2, with a 990 nm laser illuminator source, into the x-y mount; insert autocollimator #1 into the output flange of the telescope, as shown in figure 6. Focus both autocollimators at infinity. Turn on autocollimator #2 and adjust its elevation and azimuth, with the x-y mount, until the projected reticle is aligned with the cross-hair of autocollimator #1 at the output of the APS/PO telescope. Autocollimator #1 will now be removed from the output of the APS/PO telescope. The reticle pattern from autocollimator #2, projected through the back end of the telescope, will be progressively focussed on targets placed on each steering mirror and aperture along the optical train, as shown in figures 5 and 9, and each succeeding steering mirror will be centered on the reticle pattern and pointed toward the next mirror to define the desired beam path on the HAM optical table. The last steering mirror will be pointed to project the output reticle pattern onto a target placed on the HAM viewport window alignment fixture, which marks the desired position of the output beam at the viewport window.

1.7. Arm Cavity Baffle Alignment

After the arm cavity baffles have been installed in the LB1-A and lB1-C spool pieces, place an alignment target in the center of the main beam hole. Project the reticle pattern from the autocolli-

mator on HAM2 and focus it on the arm cavity target. Position the arm cavity baffle until the center of the target is aligned with the projected reticle pattern. Remove the arm cavity baffle target.

The ITMx and ITMy optical lever beams may have to be adjusted so that the beams pass freely through the hole in the arm cavity baffle.

1.7.1. Temporary Removal of Arm Cavity Baffle.

The arm cavity baffle glass support can be removed temporarily from the outer support frame as follows. Measure the height of the glass support assembly above the lower horizontal cross members of the outer support assembly. Unfasten the top and bottom connector plates, D990379, from the glass support assembly and from the mounting angle plates, and slide the glass support assembly away from the outer support assembly.

Reverse the procedure to re-install the glass support assembly, and use the measured height to replace it in its original position.

2 HANFORD 4K IFO ALIGNMENT

Place an iris on HAM 2 and center it on the optical centerline by means of the IAS theodolite, as shown in figure 10.

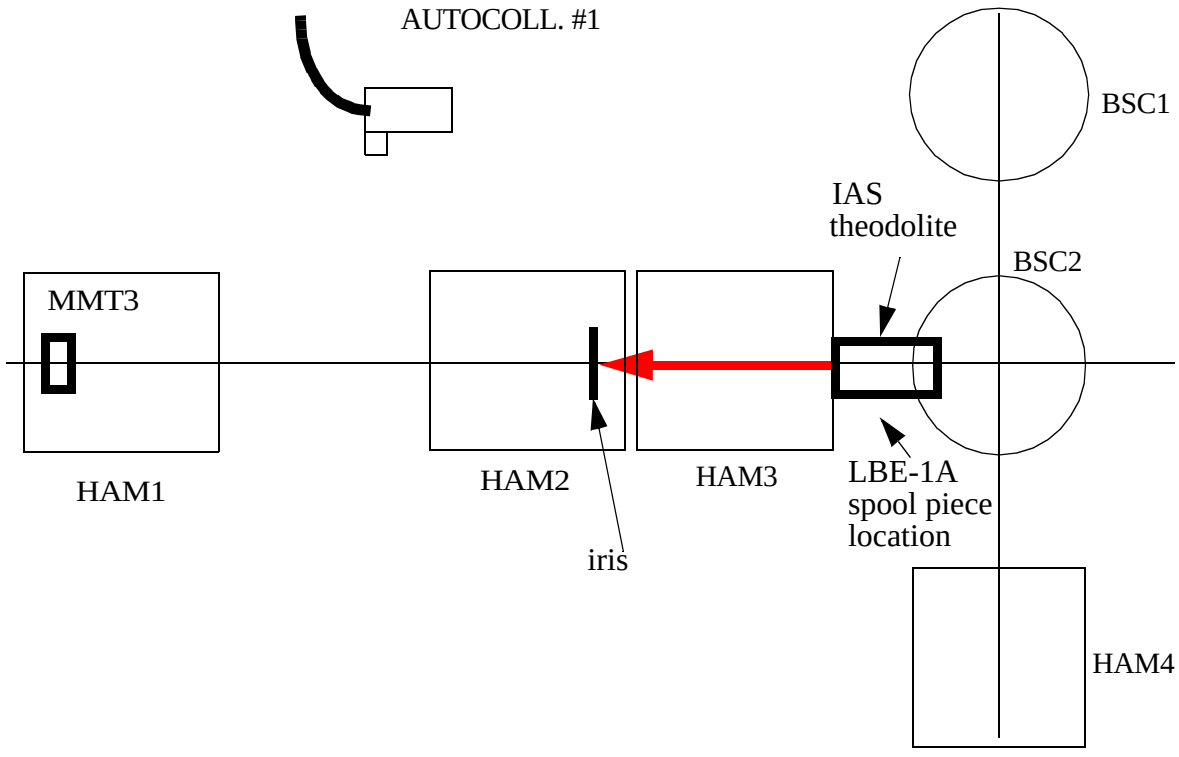

Figure 10: Alignment of iris on HAM 2

2.1. IO Baffle Alignment

After the IO baffle has been installed in HAM2, as shown in figure 11, place an alignment target in the center of the main beam hole in the IO baffle which can be viewed from the RM side. View the target with the theodolite placed in the spool piece location WBE-3A1 on the optical center-line. Position the IO baffle so that the center of the target is aligned with the cross-hairs of the the-odolite. Remove the IO target.

The RM optical lever beam may have to be re-adjusted so that the beam passes freely through the small hole in the IO baffle.

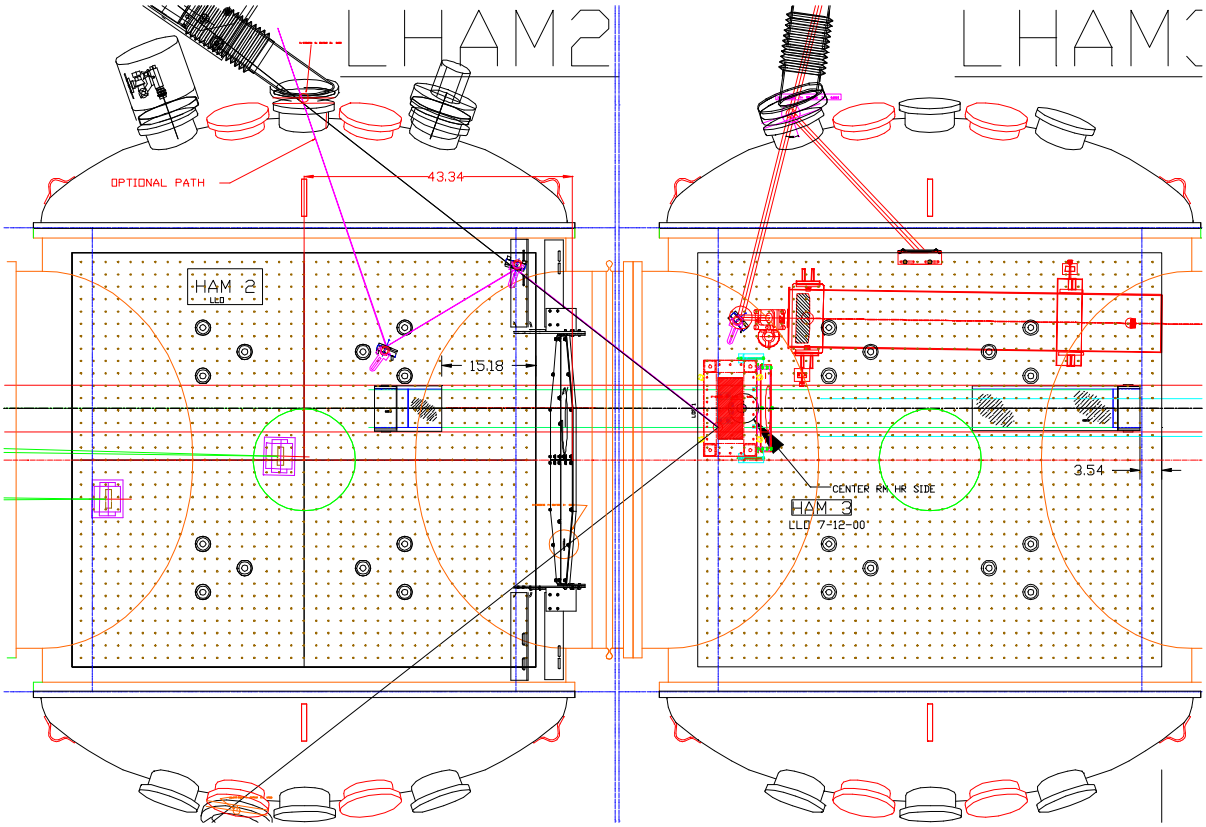

Figure 11: IO baffle, on HAM2

2.2. COS Autocollimator on HAM 2, Behind RM

The ITM, BS, and the RM are installed during this procedure.

2.2.1. Positioning of COS Autocollimator

Place the Velmex slide mechanism on the optical axis and at the center of the optical table in HAM2, and insert the COS autocollimator #1 installed in the x-y tilt mount, as shown in figures 12. Align the autocollimator #1 with the ITMx. Project the reticle pattern from the autocollimator

through the center of the iris by translating the autocollimator in the horizontal and vertical directions, using the Velmex slide.

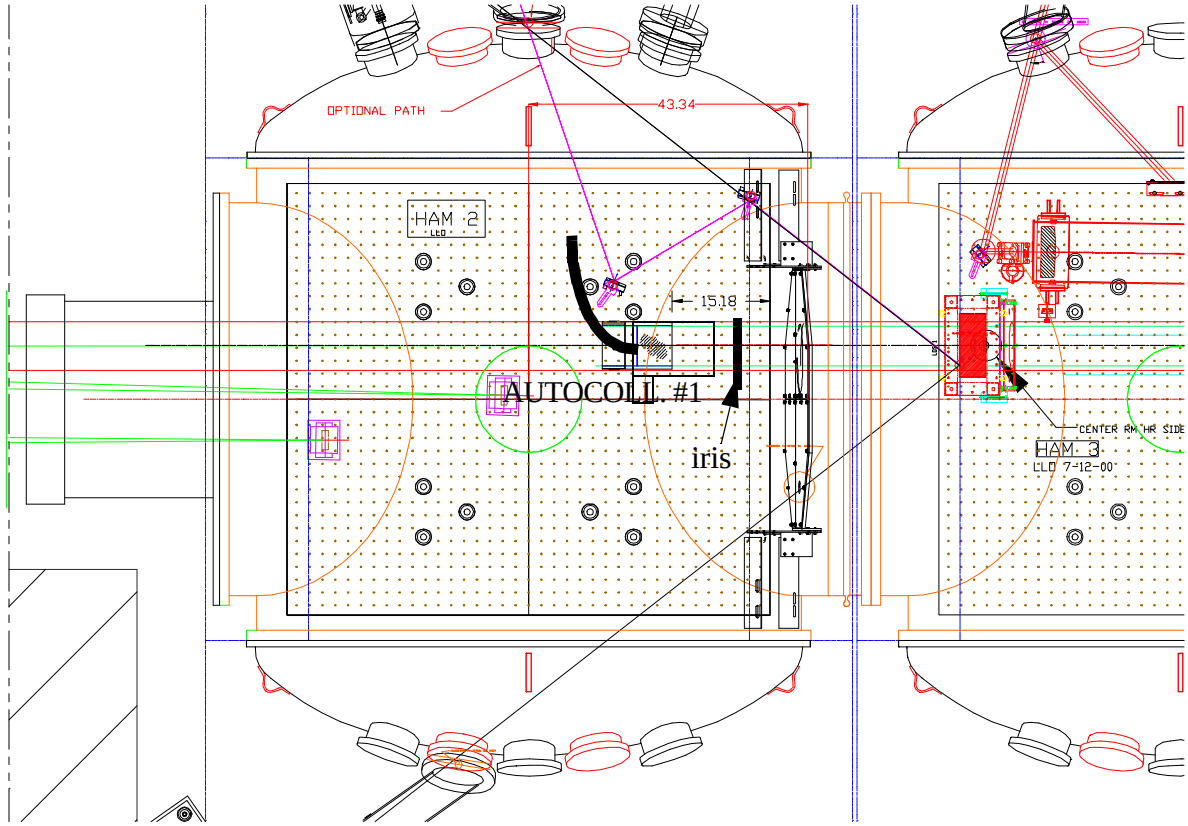

Figure 12: Autocollimator #1 on HAM2, Plan View

2.2.2. Alignment of Autocollimator

2.2.2.1 Pointing angle alignment of autocollimator #1

After the RM has been installed and aligned, turn on the 940 nm laser in autocollimator #1, focus it at infinity (See “Autocollimator Infinity Focus calibration” on page 3.), and adjust the angular alignment of the autocollimator, using the x-y tilt screws, until the retroreflected reticle pattern from the HR surface of the RM is centered on the autocollimator cross hairs.

2.2.2.2 Autocollimator Infinity Focus calibration

Place a corner cube retroreflector on the output barrel of the autocollimator. Set the camera focus at infinity, and adjust the focus of the autocollimator eyepiece until the camera image of the cross-hair pattern is as small as possible. Finally, set the focus of the autocollimator to infinity by turning the autcollimator focus knob until the camera image of the retroreflected reticle is as sharp as possible.

2.3. COS Check of BS Alignment

The relative alignment of the ITMx, ITMy, and BS mirrors will be checked with the COS autocollimator, as shown in figure 13. Place the RM on its stops and move its retroreflection out of the field of view. Align the COS autocollimator with the ITMx, and check the coincidence of the ITMy retroreflection. Adjust the BS tilt, if necessary, to make the two ITM retroreflections coincident.

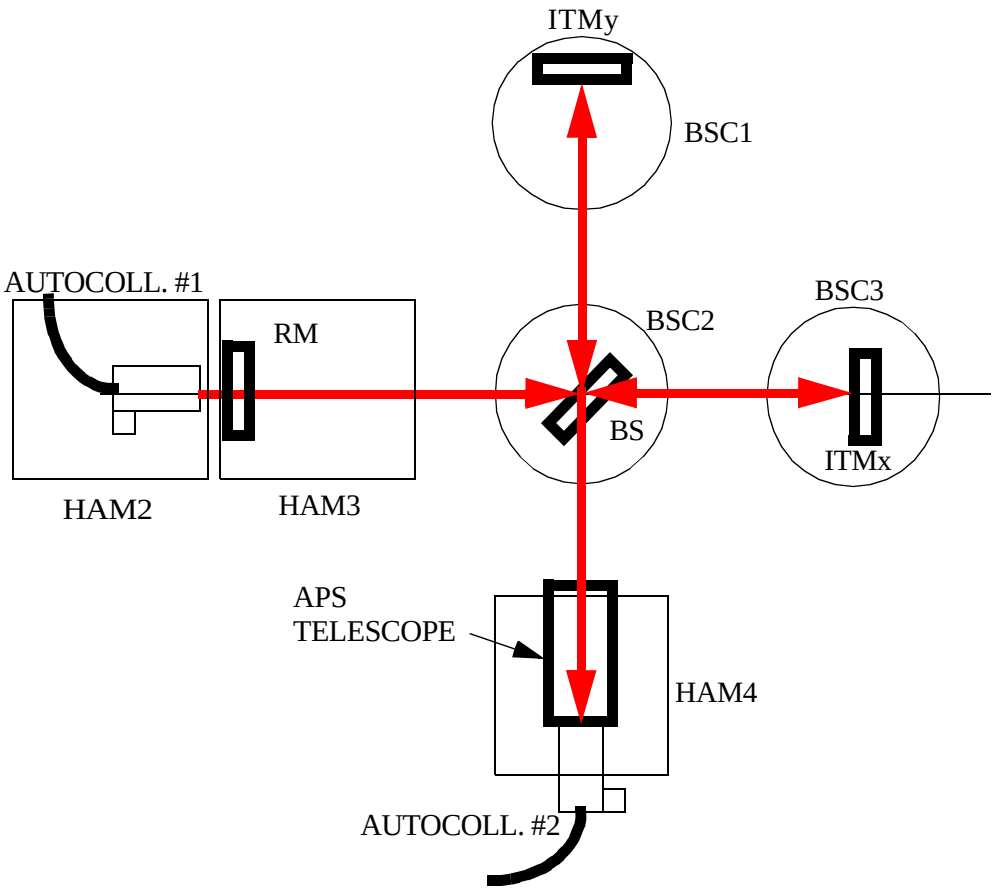

Figure 13: COS Alignment of 4K APS Telescope

2.4. APS Telescope, Global Alignment

Install and align the APS telescope first, before installing the other PO telescopes on the HAM tables.

Place the APS telescope on HAM 4, as shown in figures 13, and 15, with the front and back ends of the telescope supported by the jack stand alignment fixtures. Adjust the focus of the autocollimator # and project a focussed reticle pattern through the RM, the beam splitter, and reflect from the ITM onto the internal alignment target of the APS telescope. Align the APS telescope as follows:

Figure 14:

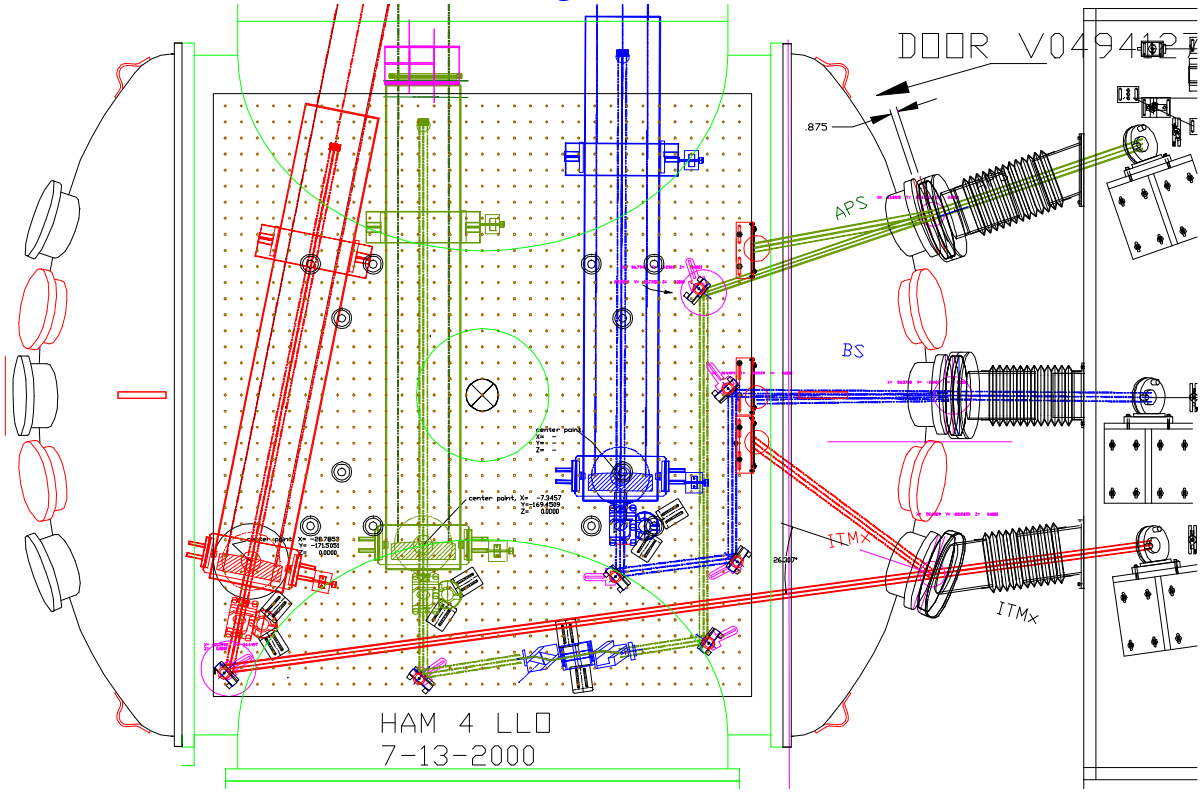

Figure 15: APS telescope, ITMx and BS PO telescopes, on HAM 4

.

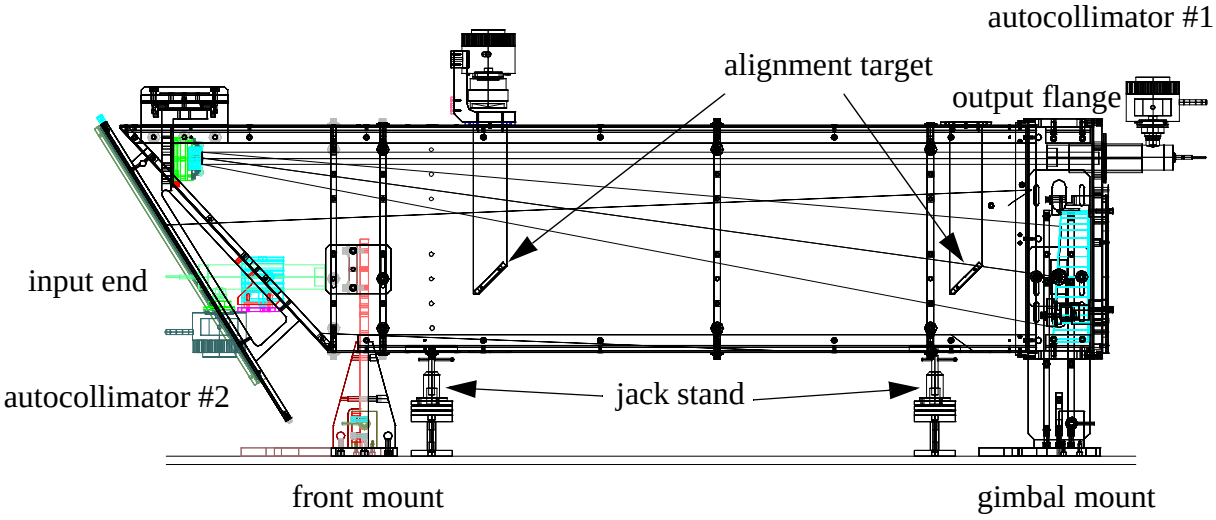

Figure 16: APS Telescope Steering Mirror Alignment Beam

- Place the internal alignment target inside the telescope near the primary mirror, as shown in figure 6. Use the extension spring and push screw to translate the APS telescope gimbal

mount (at the primary end of the telescope) horizontally, and turn the jack screw to move the telescope vertically to center the cross on the target with the projected reticle pattern from autocollimator #1. When this is completed, firmly clamp the primary gimbal mount of the APS telescope to the HAM optical table, leaving the gimbal mount free to rotate in azimuth and elevation.

- Move the internal alignment target to the entrance of the APS telescope, and translate the front telescope mount horizontally with the push screw and vertically with the jack screw to clamp it to the HAM optical table. Clamp the gimbal structure so that it will not rotate in the azimuthal direction.
- coarsely center the cross on the target with the projected reticle pattern from autocollimator #1.
- Place autocollimator #2 in the output flange of the telescope.
- LEVEL THE HAM TABLE.
- Remove the internal alignment target and tilt the input end of the APS telescope in elevation and azimuth, using the push screw and the jack screw the until the cross-hair of autocollimator #2 is aligned with the projected reticle pattern from autocollimator #1. When this procedure is accomplished, lock the front mount of the APS telescope and firmly

2.5. PO Mirror Alignment

Place the ITMx, ITMy an BS PO telescope external primary mirror alignment targets at the position of the PO telescope primary mirrors on the HAM tables, as shown in figures 5 and 9. Focus the COS autocollimator to project a sharp image of the reticle pattern at each target. Steer the corresponding PO mirrors located on BSC1 and BSC2, as shown in figures 17 and 18, until the projected reticle pattern is centered with the cross on the target. After steering is completed, permanently lock the tilt mechanism of the PO mirror.

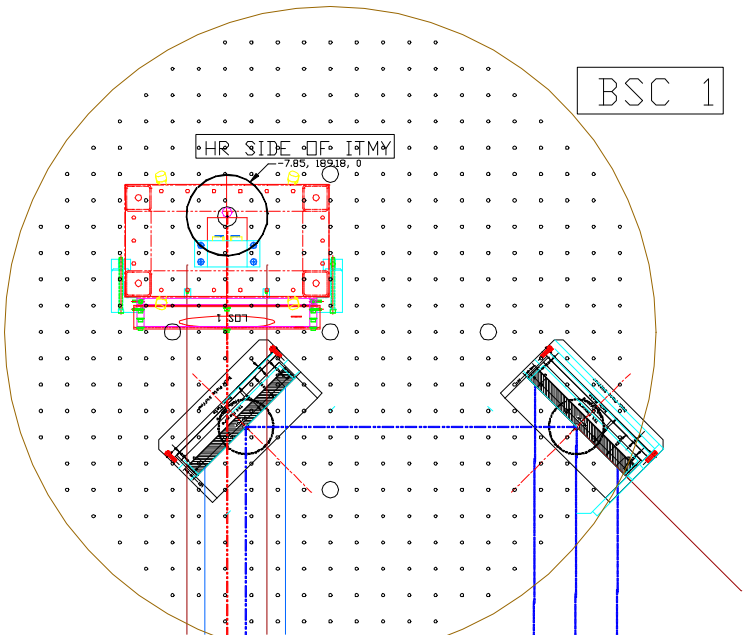

Figure 17: BS PO mirrors, on BSC1

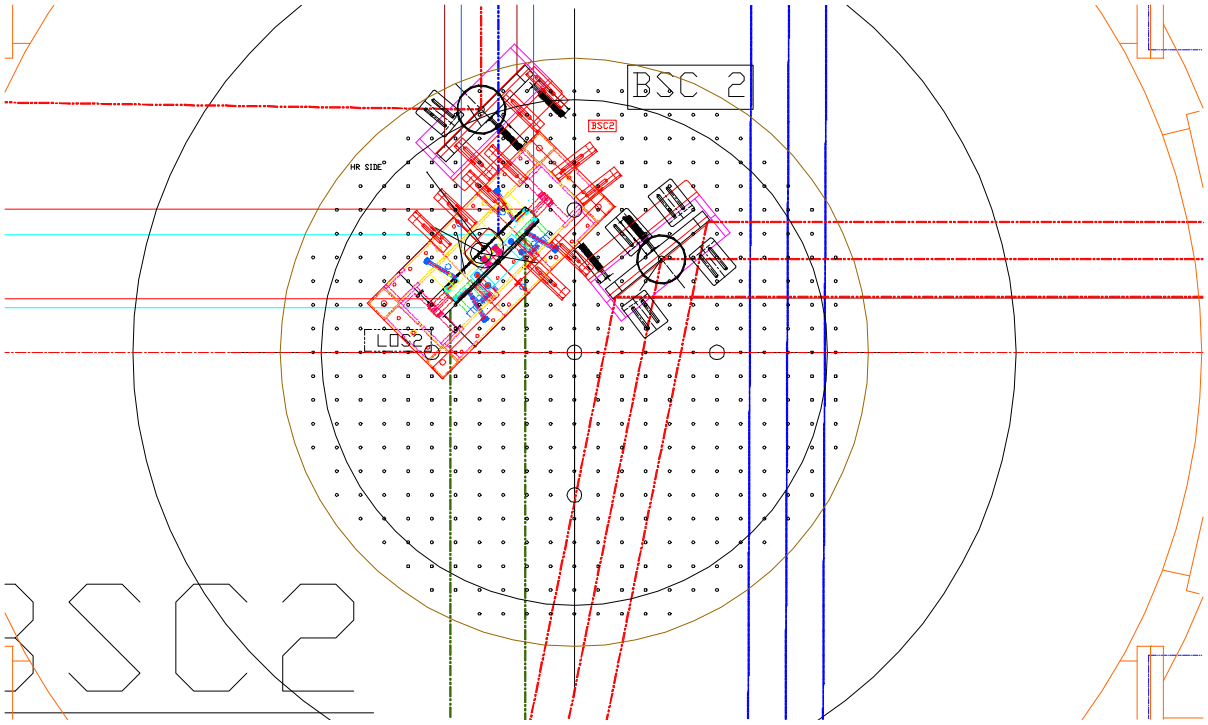

Figure 18: ITMx and ITMy PO mirrors, on BSC2

2.6. PO Telescope Alignment

2.6.1. PO Telescope Centering Alignment

Remove the external primary mirror alignment targets. Place the PO telescopes in their proper positions on the HAM tables, as shown in figures 5 and 9. The height of the primary mirror for the PO telescopes is pre-set at 16 inches above the HAM table. Support the front and back of each PO telescope in turn with the jack stand alignment fixtures. Proceed to center the front and back of the PO telescope with the projected reticle pattern, as was done for the APS telescope. When the front and the back of the PO telescope is aligned with the reticle pattern, attach permanently the primary gimbal mount to the HAM table, leaving it free to rotate in the azimuthal direction.

2.6.2. PO Telescope Pointing Alignment

Insert the autocollimator #1 into the output flange of the telescope.

LEVEL THE HAM TABLE.

Align the PO telescope by tilting the front end in azimuth and elevation, as was done for the APS telescope. When the alignment is completed, permanently attach the telescope mounting structures to the HAM table

.

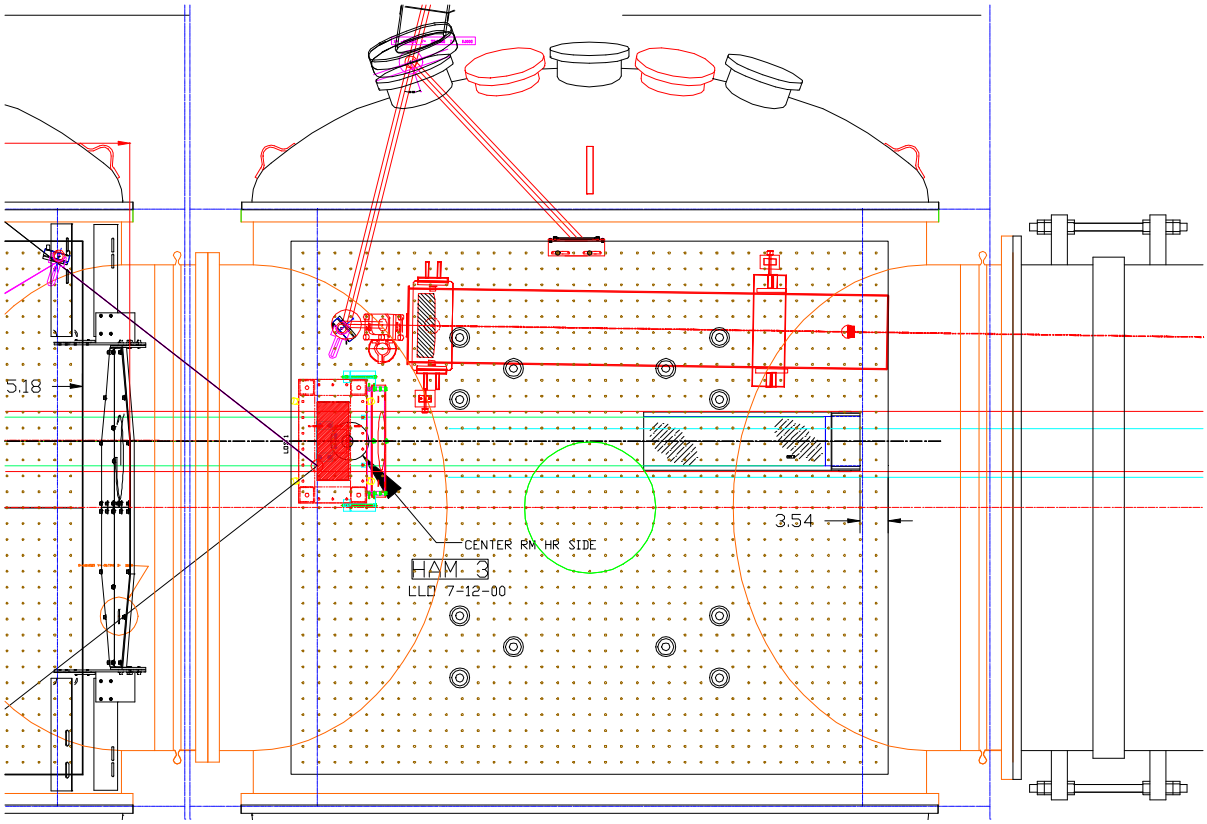

Figure 19: PO Telescopes 4K ITMy, on HAM3

2.7. APS/PO Telescope Optical train Alignment

Attach the mounting bracket at the input end of the telescope, and insert autocollimator #2, with a 990 nm laser illuminator source, into the x-y mount; insert autocollimator #1 into the output flange of the telescope, as shown in figure 6. Focus both autocollimators at infinity. Turn on autocollimator #2 and adjust its elevation and azimuth, with the x-y mount, until the projected reticle is aligned with the cross-hair of autocollimator #1 at the output of the APS/PO telescope. Autocollimator #1 will now be removed from the output of the APS/PO telescope. The reticle pattern from autocollimator #2, projected through the back end of the telescope, will be progressively focussed on targets placed on each steering mirror and aperture along the optical train, as shown in figures 5 and 9, and each succeeding steering mirror will be centered on the reticle pattern and pointed toward the next mirror to define the desired beam path on the HAM optical table. The last steering mirror will be pointed to project the output reticle pattern onto a target placed on the HAM viewport window alignment fixture, which marks the desired position of the output beam at the viewport window.

2.8. MMT3 Alignment

Move the COS autocollimator #1 from HAM 2 and place it on the optical centerline on the total station in the spool piece WBE-3A1 location, as shown in figure 20. Place an alignment target on

the MMT3 LOS structure on the optical centerline in front of the MMT3 mirror. Check the lateral position of MMT3 by projecting the reticle pattern from autocollimator #1 onto the alignment target.

Remove the center of the alignment target. Place an alignment target on the MMT2 LOS structure on the optical centerline in front of the MMT2 mirror. Reflect the projected reticle pattern from autocollimator #1 off of MMT3 and onto the alignment target at MMT2. Adjust the MMT3 mirror azimuth and elevation tilt angles with the PAM magnets until the projected reticle pattern is centered on the MMT2 mirror target.

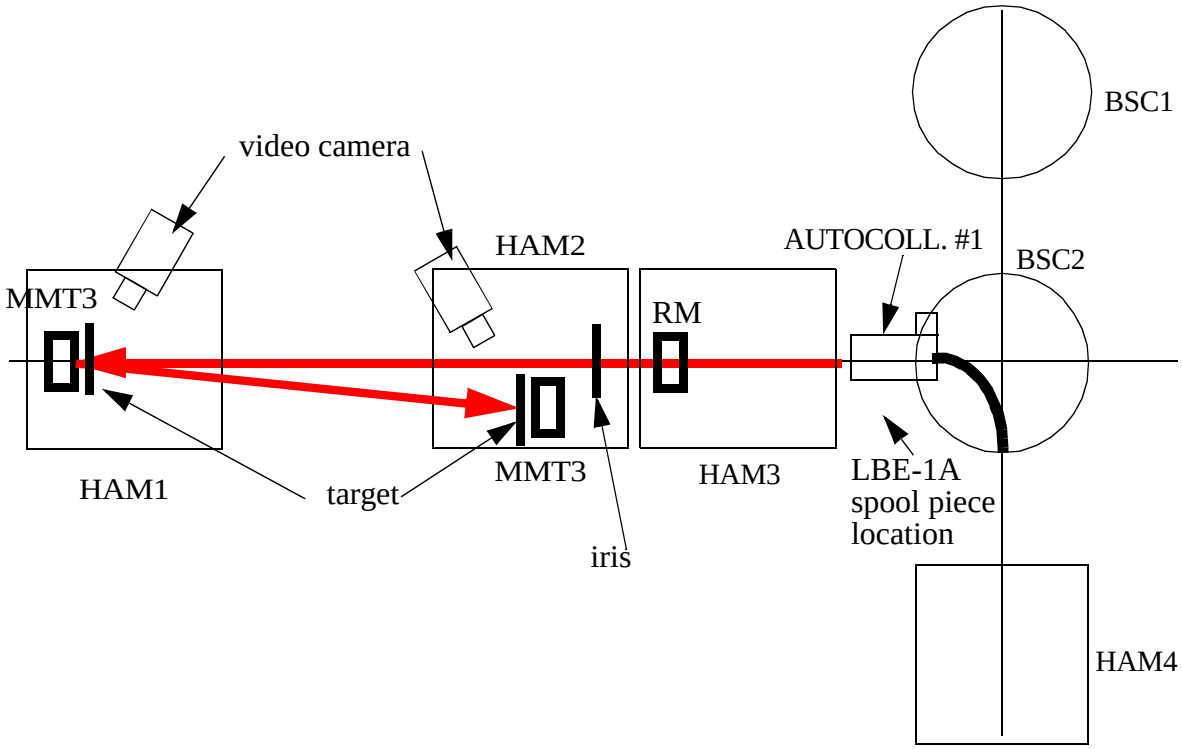

Figure 20: Alignment of MMT3 and MMT2

2.9. MMT2 Alignment

Align the PSL beam through the modecleaner to hit the center of the target at MMT2.

Remove the target at MMT2. Replace the center of the target at MMT3. Tilt MMT2 until the PSL beam is centered on the target at MMT3.

When the alignment of the MMT3 is complete, remove the targets at MMT2 and MMT3.

2.10. Arm Cavity Baffle Alignment

After the arm cavity baffles have been installed in the LB1-A and lB1-C spool pieces, place an alignment target in the center of the main beam hole. Project the reticle pattern from the autocollimator on HAM2 and focus it on the arm cavity target. Position the arm cavity baffle until the center of the target is aligned with the projected reticle pattern. Remove the arm cavity baffle target.

The ITMx and ITMy optical lever beams may have to be adjusted so that the beams pass freely through the hole in the arm cavity baffle.

2.10.1. Temporary Removal of Arm Cavity Baffle.

The arm cavity baffle glass support can be removed temporarily from the outer support frame as follows. Measure the height of the glass support assembly above the lower horizontal cross members of the outer support assembly. Unfasten the top and bottom connector plates, D990379, from the glass support assembly and from the mounting angle plates, and slide the glass support assembly away from the outer support assembly.

Reverse the procedure to re-install the glass support assembly, and use the measured height to replace it in its original position.

3 4K ETM TELESCOPE ALIGNMENT

3.1. Pre-alignment of ETM Telescope

3.1.1. Focus of ETM Telescope

With the steering mirror removed, insert the COS 940 nm laser autocollimator into the sleeve at the output end of the telescope. Project the reticle pattern out the large input end of the telescope, and place a corner cube retroreflector on the beam centerline to retroreflect the beam back into the telescope. Set the camera zoom lens at 75 mm. Translate the focus barrel until the retroreflected reticle pattern, as imaged by the video camera viewing through the eyepiece of the autocollimator, is in sharp focus.

Measure the distance that the focus barrel is protruding from the end of the large housing and increase the separation between the primary lens and the focus barrel by an additional 0.091 inches, to compensate for the longer focal length at 1064 nm wavelength.

3.1.1.1 Height and Coarse Elevation Adjustment of ETM Telescope

The height of the telescope will be preset to the nominal height by adjusting the length of the vertical mounting post of the telescope with the slotted height adjustment. The elevation angle will be coarsely set by measuring the height offset of the front and back of the telescope with a suitable measuring device

3.1.2. On-site Alignment of the ETM Telescope in the IFO

3.1.2.1 2K ETM Telescope Alignment Apparatus

A schematic of the IR autocollimator set up for alignment of the ETM telescope is shown in figure 21.

3.1.2.2 Initial Installation and lateral Alignment of ETM Telescope in the BSC Chamber

The ETM telescope will be mounted on the optical platform inside the BSC chamber and loosely clamped with the table clamps.

Place the IAS theodolite on the interferometer centerline in the removed spool piece located adjacent to the gate valve at the y-end station of the IFO. View the target, with a central cross at the entrance aperture of the ETM telescope, with the aligned theodolite, and move the front of the ETM telescope until the target cross is centered with the theodolite. Similarly, view a target placed at the exit aperture of ETM telescope, by looking through the telescope with the theodolite, and move the back of the ETM telescope until the target cross is centered with the theodolite. The telescope mount can be moved with the table clamps to achieve a coarse lateral alignment of the telescope, after which the table clamps should be securely fastened. Use the lateral adjustment screws near the telescope body to achieve a fine lateral alignment.

3.1.2.3 Fine Adjustment of Tilt Angle of ETM Telescope

The COS IR autocollimator #1 will be mounted on the IAS tripod at the optical center line by using a bayonet mount and height adapter with a two-axis tilt mount. A 940 nm diode laser source will be used to illuminate the reticle of the autocollimator. Set the autocollimator focus at infinity, and the camera zoom lens at 75 mm. Tilt the autocollimator #1 until the retroreflected reticle pattern from the HR surface of the ETM mirror is centered with the cross hairs of the autocollimator.

Remove the steering mirror at the output end of the telescope and insert autocollimator #2 into the output sleeve. Set the autocollimator #2 focus at infinity, and the camera zoom lens at 12.5 mm.

Project the reticle pattern from autocollimator #1 through the ETM mirror and through the ETM telescope to autocollimator #2. Tilt the ETM telescope in azimuth and elevation, by means of the fine adjustment screws on the output side of the telescope mounting structure, until the cross hair of autocollimator #2 is centered with the projected reticle pattern from autocollimator #1.

3.1.3. Alignment of ETM Telescope Steering Mirror

Remove autocollimator #2 from the output of the ETM telescope and install the steering mirror. Place a translucent target at the output window of the BSC chamber.

Rotate the steering mirror within its mounting base to achieve a coarse pointing alignment. Adjust the x-y mirror tilt screws until the projected reticle pattern from autocollimator #1 is centered on the cross of the alignment target. The target will be viewed with an IR video camera from outside the BSC chamber

3.1.4. Alignment of ETM PO Beam Dump

The projected reticle pattern from autocollimator #1 will pass through the ETM telescope and will reflect from the output window toward the ETM PO beam dump. An IR video camera will be placed inside BSC to observe the reflected pattern on a target placed at the ETM PO beam dump. The ETM PO beam dump will be positioned on the BSC6 optical table so that the reflected reticle pattern from the output window will hit the center of the beam dump.

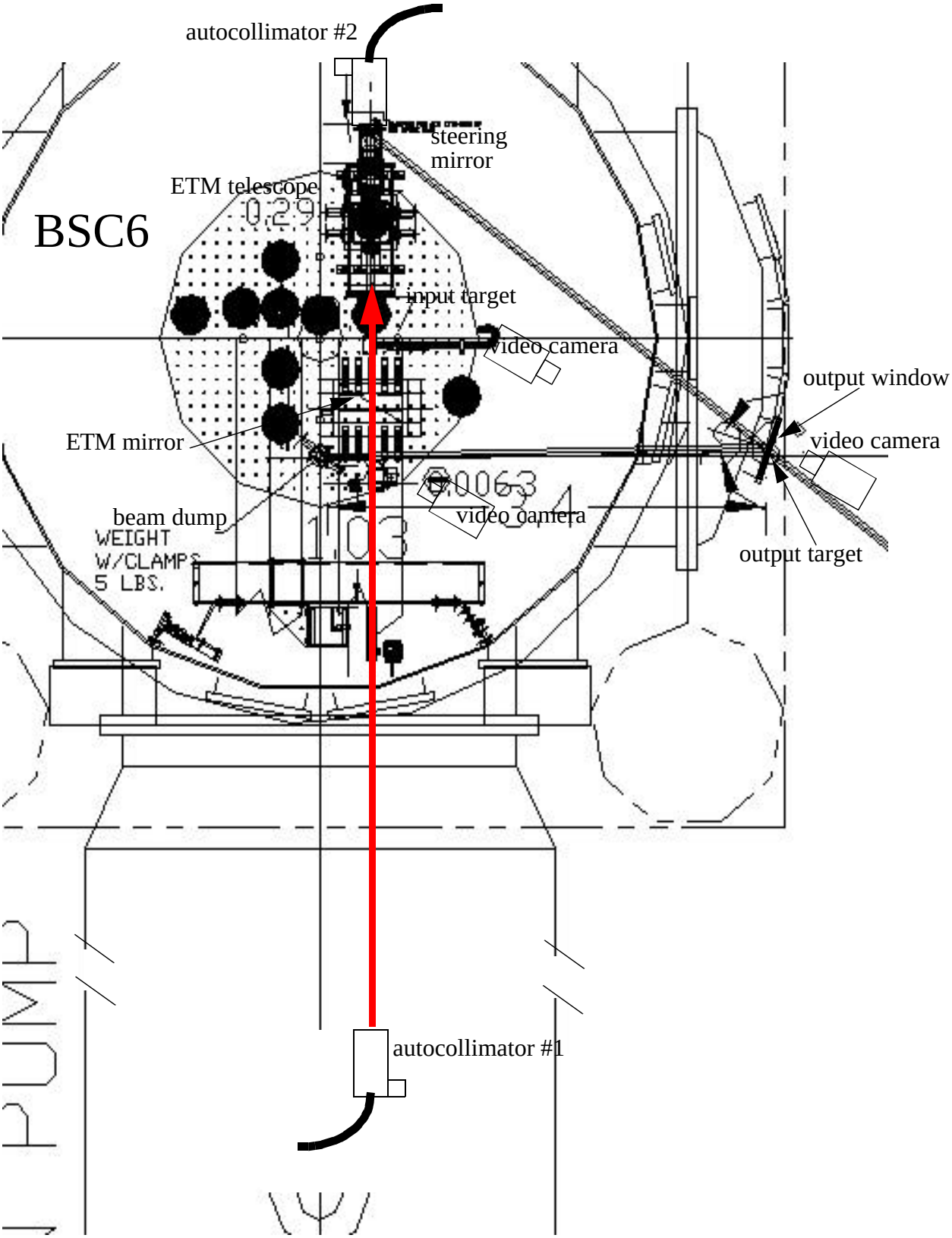

Figure 21: Alignment Apparatus for the ETM Telescope