CHARA Technical Report

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Telecope Mirror Removal and Alignment Procedure Notes

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ABSTRACT: Notes taken during the telescope mirror removal process, recoating procedure, and realignment. This document is to be used in addition to TR109 and "Mount Wilson Observatory Aluminizing Procedures" (1999).

1. INTRODUCTION

There are many aspects to the procedures involved with the mirror recoating process for the telescopes and beam train at the CHARA Array. Much of this knowledge is passed on through first-hand experience. This report is a compilation of notes taken during this process, much of which is officially detailed in TR109 and in "Mount Wilson Observatory Aluminizing Procedures" (1999). Hopefully, this report will provide a hands-on reference and also help to distribute and preserve some of the institutional knowledge for the parts of the process that are more art than science.

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2. MIRROR REMOVAL

1. Remove the spy cam from M1.
2. Put the rollers on the side of the M1 cell opposite the finder. This way you can still move the telescope in elevation.
3. Run a lift strap through the holes in the M1 cell truss mounting point and secure it with the short steel bars. Attach chain hoists so these hold the mirror cell to the truss when you unbolt it.
4. Install the dome cylinder extensions that go on the dome pylons. These have a threaded rod and spacer inside.
5. Remove the bottom bolts from the invar rods.
6. Remove M2:
   (a) Tip the telescope over.
   (b) Have the secondary mirror box ready.
   (c) Use an adjustable wrench to remove the secondary mirror. Keeping track of how many spacers there are on the front/back (ex: 2/1). The thinnest plastic ring goes closest to the mirror.
   (d) Put the spacers and the nut back on.
   (e) Safely move M2 to the bunker.
7. Release the central hub from M1 by removing 3x1/4-20 bolts.
8. Tighten the chain falls to support the mirror cell against the truss.
9. Loosen the bolts on M1 cover chain tensioner bracket and move bracket out of way.
10. While the scope is still tipped over, remove the M1 truss bolts, starting with fork sides.
11. Move the scope to vertical and put in the elevation lock bar.
12. Loosen the top bolts of the lower M1 truss (≈1/2in) but don't remove them.
13. Put the roller wheels on the finder side of M1.
14. Remove the M1 truss bolts.
15. Detach the dome upper cylinder limit switch encoders. There are 2 of them. Once detached, you can raise the upper cylinder all of the way.
16. Open the upper cylinder:
    - In the bunker server rack locate the controls for the cylinder.
    - The toggle on the left sets remote/local. Flip this up for local control.
    - The toggle on the right determines the movement direction. Flip it down to open upper cylinder [TR110].
    - You may need to enable the drive in the software:

```
RPI ip: 192.168.3.232
pi\@192.168.3.232 pw:k1sdug0
documents/c/cylinder
sudo ./cyl
commands: di (disable), en (enable), pon (power on), poff (power off),
go $+$X (go up for X seconds), go $-$X (go down for X seconds)
```

17. Use the crane to bring up the rails, saw horses, and the crossbeam.
    (a) Attach the rails to the saw horses.
    (b) Place the crossbeam on cylinder extensions in the notches on top of them.
    (c) Attach the chain fall to the crossbeam.
    (d) Raise upper cylinder to contact the support rails.
    (e) Attach the wood spreaders (two of them).

   (f) Place the wood push bars on the rails so that the grooves are on opposite sides of each other.

18. Unroll carpet under the saw horses.

19. Use the chain falls to lower the M1 cell onto the rails, holding the fork sides of the truss away from the cell and keeping the cell level. Note: the motor side of the cell is heavier and it will tend to tip sideways unless held in check.

20. Raise the two invar rods on the rail side:

   (a) Use blue tape to mark where the bars are currently positioned.
   (b) Loosen the 3/4in bolts at the top of the invar rods.
   (c) Push the rods up and use clamps to hold them.

21. Use the crane to load the M1 box and mirror picker onto the rails.

22. Use the chain falls to lift the mirror picker. Then take the lid off box and set it aside, take the box off of the rails, and take the push bars off of the rails.

23. Pull up the M1 wood cover.

24. Roll the M1 cell out onto the rails.

25. Remove the pucks, which are held by 36 bolts in total.

26. Open the M1 cover slightly.

27. Unscrew the M1 hub from top and remove it.

28. Remove the anti-rotation devices from the side of primary. There are two of them.

29. Remove the mirror retainer brackets from the outer edge. There are two on the fork sides below the mirror and two above the mirror at 90° from the others.

30. Remove the black inner semi-rings from the hub. This is held by five bolts.

31. Remove the hex head bold on that is on the hub. This is the taper bolt that tensions the hub to the mirror.

32. Fully open the M1 cover.

33. Place the wood cover on M1.

34. Lift M1 with the mirror picker. Remove two arms of the picker on the same side so that it will clear the mirror. Note: the side of M1 has a scribed mark and on the cell there is a fiducial mark to line it up with during re-install. Place the picker so that the forks miss all of the pucks and hold the hub from the bottom while lifting the mirror.

35. While the mirror is lifted roll the mirror cell back on the rails.

36. Lower the mirror into its crate, put the lid on, and lower it down with crane.

37. Take the extensions off of the rails.

38. Close the cylinder.

39. Remove M5:

   (a) Loosen the three spring plungers.
   (b) Remove the mirror mount.
   (c) There are three metal pads on the front and three metal pads on the side. The ones on the sides are ground to match the curve of the mirror and must be reinstalled so this lines up. Note: be careful not to let the pads fall and hit the mirror surface.

40. Remove M4: Leave it in its box, just remove the three spring bolts.

41. Remove M3: Take the back screws and washers off. Back out two of the alignment set screws (ex. top & right) but leave the other two alone to preserve the alignment. Carefully pry the crown out with a flat-head screwdriver. For this and all other mirrors, place them in a plastic box and label it with the telescope, mirror name, and serial number.

42. Remove M6:
    (a) Make sure the M7 cover is closed, so nothing could fall and damage M7.
    (b) Remove the sheet metal panel.
    (c) Mark the position of the four bolts on the holder with a marker.
    (d) Remove the four bolts, being very careful not to let the spacers drop.
    (e) Carefully remove the mirror and the mount by angling it away from AOB as you lift, as it will not clear otherwise.
    (f) Remove the three bolts that hold the mirror to the mount.
    (g) Remove the mirror and then replace the bolts.
    (h) Use a flat-head screwdriver to remove the crown.
    (i) Put the mount back in the stove-pipe.
43. Place the empty M1 cell back over the center.
44. Take the M3 and M6 crowns to the shop.
45. The rest of the mirrors are in the coudé box below the telescope.
46. Remove M7:
    (a) Loosen the brackets at the front of M7 and remove them.
    (b) Loosen the top side spring plunger and remove M7.
    (c) Replace the brackets and keep the metal pads in place by their respective mounts. Note: be careful with spacers and don't lose them or mix them up.
47. Remove M8: remove this next so you can reach M9. Remove the whole base (black mount), then replace the brackets.
48. Remove M9: remove the whole black mount and remove the top bracket.

3. MIRROR CLEANING & STRIPPING

[See also Larry Webster's "Mount Wilson Observatory Aluminizing Procedures" manual from 1999.]

1. Set up the dolly, "kiddy" pool, and the mirror table.
2. Use the 100in crane to lift M1 out of its crate.
3. While it's lifted, clean the bottom of the mirror.
4. Set M1 on the table which is in the pool, which is on the dolly. Be careful to miss the pucks.
5. Wrap the bottom edge and bottom of the inner hole of the mirror with duct tape to prevent acid running underneath.
6. Rinse the mirror.
7. Wash the mirror with Orvis and water by hand - carefully feeling for grit. Then dab with a sponge and feel by hand again.
8. Clean any residue with acetone - DON'T use Kimwipes, use Technicloth.
9. Use cotton pads with 37% HCL acid to strip the mirror coating. Repeat as needed. Then repeat it again.
10. Rinse with distilled water.
11. Sprinkle with calcium carbonate, polish with cotton pads, rinse with distilled water. Repeat as needed. Then repeat it again.
12. Dry with Technicloth, folding the corners up and only using the center of the cloth
13. Inspect with a flashlight for streaks.
14. Put Technicloth towels on top to completely cover the mirror and protect it.
15. Put the lid on the mirror.

16. Remove the duct tape.
17. Clean the leftover adhesive with acetone.
18. Lift the mirror, clean the underside, and place it into the vacuum chamber on the Delrin pucks.

4. MIRROR REINSTALL

Basically the same as the removal process but in reverse. Reinstall order:

1. M1
2. M9, M8, M7
3. Align M9 and M7.
4. M5
5. M4
6. M6
7. Align M6.
8. Align EAM.
9. M3
10. Align to EAM.
11. Align finder scope.
12. M2

5. ALIGNMENT

[See TR 109]
For our process we used the telescope WFS instead of TAS or TAS2. Final tuning notes:

1. Use the two knobs that can be attached to the M1 wiffle tree support.
2. AT on the optical axis between M4 and M5.
3. Use the finder to mark the optical axis after you have to remove the AT.
4. Use the M2 mercury's (mercurygtk S2_SECONDARY) to control the trio of PI M-224.20 actuators.
5. Use the finder origin (which is now marking the optical axis) to keep star centered by moving the telescope.
6. Tip/tilt M1 using the two knobs on M1 (on opposite side of the bars as the motors).
7. Tip/tilt M2 with mercurygtk.
8. Center a star on acquisition camera.
9. Use USB WFS to judge and minimize the Zernicke's.

6. FINE-TUNING THE COUDÉ

6.1. M4/M5

To check the alignment:

1. Fully align the lab, including the engineering beam, and using pop 5.
2. Align the beacon with the IR dichroic.

3. Switch to the bare dichroic.
4. Set M7 to DFT.
5. Do an M10 alignment.
6. Put the red laser in place of the beacon. To do this you need to open up the box inside on the AOB that houses the beacon LED.
7. Place the thin metal cover over ACQ camera to protect it.
8. Use the engineering beam and check the red & green laser alignment with a piece of paper over the top of the dichroic. The two beams should overlap there with little to no shear.
9. Remove the red laser, metal cover, and the engineering beam. Put IR dichroic back in.

To fix the alignment:

1. Go to a bright star and center it on the finder origin, as long as the finder has been set to the optical axis of M2/M1.
2. Adjust M5 to center the engineering beam on the target in front of M4, while adjusting M4 and the dichroic to keep the star in ACQ.
3. Check that the starlight is hitting the telescope WFS and reaching the lab WFS.
4. Check that the laser beam remains well-centered through elevation slews on the M2 target.

6.2. Elevation Axis - M3/M4

If there is beam shear at M3 or if the telescope WFS is not illuminated so all of the boxes have light, there may be beam shear between M3 and M4.

To fix this:

1. Attach a fold mirror to the M2 center nut to use as a retro (this is in the lab, it's an M6 screw with two posts and a 2in fold mirror on a mount). Note: this method has been replaced by a mount that instead attached to the M2 spider.
2. Use the engineering beam (after a full lab alignment, on pop5, and with M7 to default if it's not been done already), and observe the reflected beam on ACQ. This may take some work to get the beam auto-collimated but once you have it in the ACQ camera you want to observe the brightest spot at the end of the chain of spots.
3. Adjust M3 and M4, respectively, so that you keep the laser spot very close to the hole in ACQ and you center the beam on M3. You can see the shadow of the M4 spider on M3 and center it on the M3 center hole. Note: there is now a 3d-printed target for use on M3.
4. Slew the telescope in elevation and track how the spot moves on ACQ.
5. Adjust M4 to center the beam on M3.
6. Slew the telescope, checking the position of the laser on ACQ.
7. Record the position (in pixels) of the laser spot, it should make a circle. Use the python code, circle2b.py, to determine the center and radius of the circle. (`https://gitlab.chara.gsu.edu/scott/circle-fitter`)
8. Adjust M3 and M4 to minimize the circle and get it centered on ACQ, use the cursor on ACQ to mark the center of circle from this code, and move to that spot.
9. Adjust M4 to move circle, move the spot halfway towards where you want it to be and check the circle again, aiming to get it in ACQ.
10. Move M3 to change the radius, adjusting to bring the spot the rest of the way into ACQ. Recheck the circle by recording spot positions at different points in elevation again.

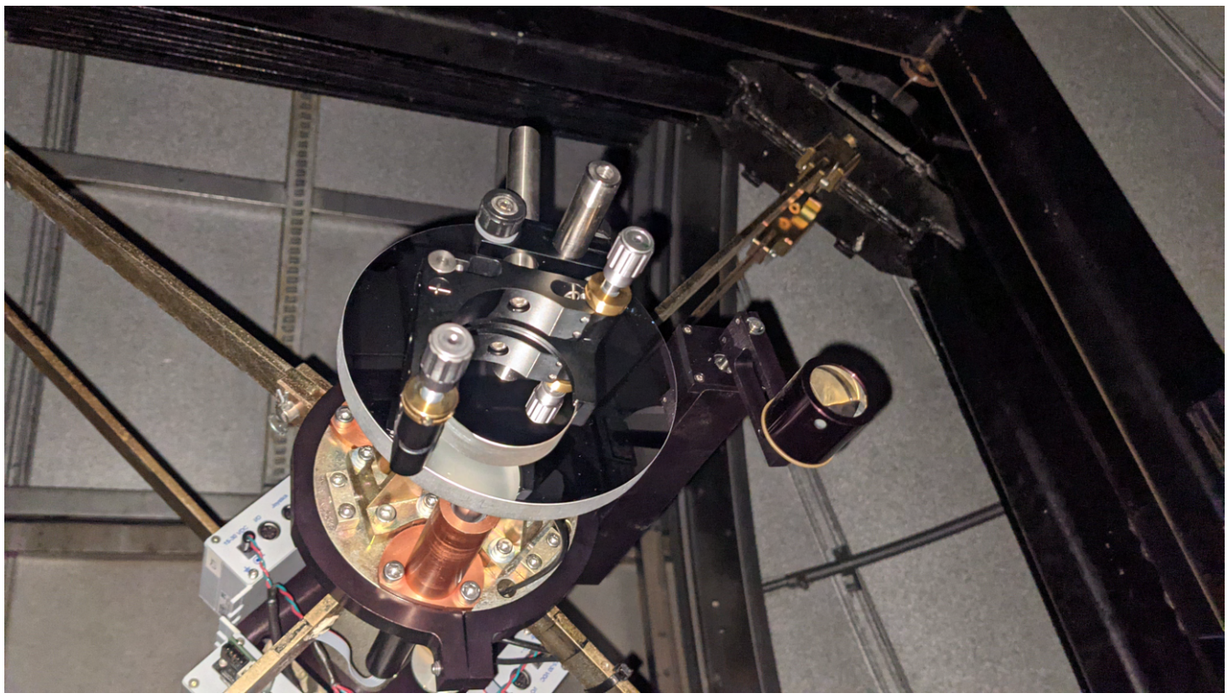

FIGURE 1. M2 with the retro mirror mounted.

11. Iterate until this converges and you have a very small circle centered on ACQ.
12. Adjusting M4 moves the center of the circle more, adjusting M3 changes the radius more.
13. Check with starlight how the telescope WFS and labAO look. Do a fiber explorer as well to verify that everything looks good.

Once this is done, you may need to retune and focus M2 and can now realign the finder, confident that the telescope optical axis and elevation axis are aligned.

7. SUMMARY

This Technical Report is not a replacement for the hands-on training with experienced CHARA staff nor the other technical reports, but it could be a useful guide for some of the finer details and the order of operations necessary during this complicated but routine maintenance.

8. REFERENCES

L. Sturmann & J. Sturmann, Telescope and Coude Path Alignment: Procedures after mirror recoating, TR109, 2021

Webster, L. "Mount Wilson Observatory Aluminizing Procedures", 1999