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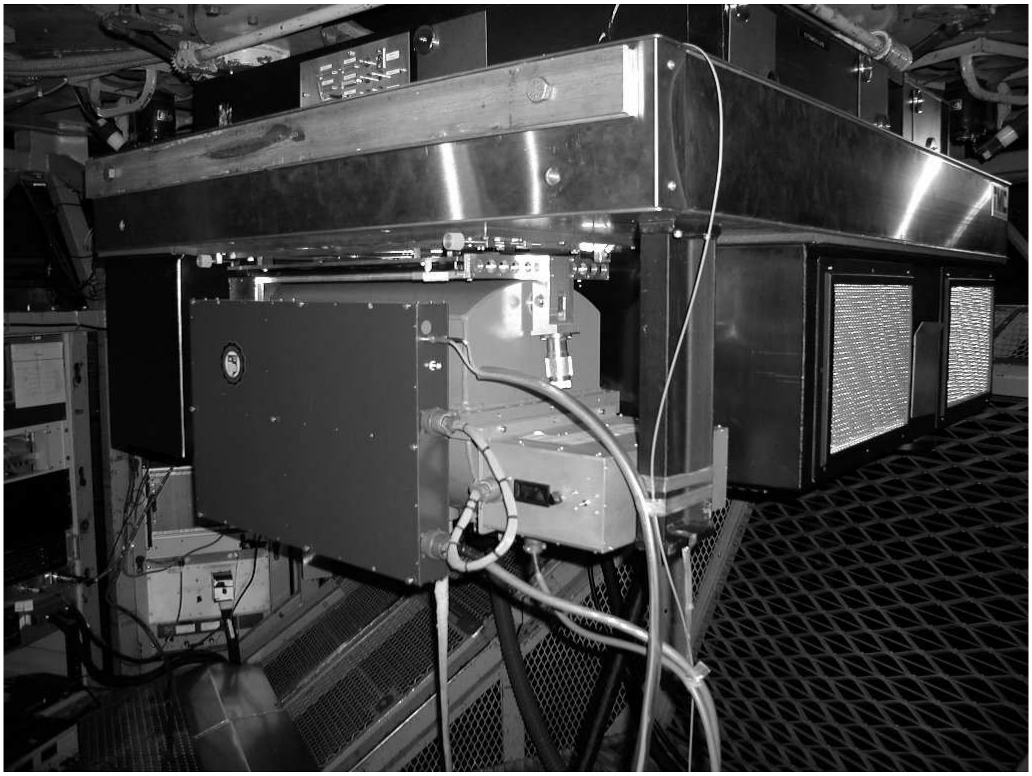

PHARO

Palomar High Angular Resolution Observer

User's Manual
Volume 2: Instrument Setup

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Change Log:

2002 Feb 05 (TLH): Revised pumpdown section to describe use of turbopump instead of diffusion pump.

Added Chapter 3 describing tuning of detector and stepper motor electronics.

Chapter 1. Introduction

PHARO (short for Palomar High Angular Resolution Observer) is a near-infrared camera built by members of the infrared astronomy group at Cornell University especially for the Palomar Adaptive Optics (AO) system. The AO system itself was built for the 200-inch Hale Telescope by members of the Spatial Interferometry Systems Group at NASA/JPL.

The PHARO manual is split into two volumes. This one, Volume 2, describes the setup and maintenance of the instrument. For general information and operating procedures, see Volume 1.

For further information on PHARO, see the world-wide web site http://www.astro.cornell.edu/PHARO/pharo.html. The site may contain more up-to-date data on currently installed filters, recent sensitivity measurements, etc., that are difficult to maintain in a printed manual. Information on PHARO's design is contained in "PHARO – A Dedicated Near-Infrared Camera for the Palomar Adaptive Optics System," PASP 113, 105 (January 2001). Questions may be directed to one of the PHARO team members at the following addresses.

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Chapter 2. PHARO Setup

2.1 PHARO Cooldown

2.1.1 Introduction

A PHARO cooldown should begin about 30 hours before the start of instrument testing or observing. This allows 4-6 hours for vacuum pumping and LN_2 filling, and 24 hours for the internal components to cool to their final operating temperature (~ 77 K).

PHARO may be pumped and cooled while mounted on the AO bench or on its own handling cart. It is highly desirable NOT to remove PHARO from the bench for a cooldown, in the interests of preserving optical alignment and minimizing the amount of labor needed for the procedure.

To cool down PHARO, the following items are needed:

- PHARO itself
- Pumpout valve w/ elbow extension
- Appropriate vacuum fittings, O-rings, etc. (should be w/ dewar).
- Hose
- Thermocouple vacuum gauge (from SC-10)
- Nutdrivers, screwdrivers, etc. for hose clamps
- The orange hydraulic lift (from SC-10) if PHARO isn't mounted on the AO bench
- LN_2 neck insert tubes (usually left in necks)
- T handle tool
- Fill tube with 90 degree elbow at end
- Full 50 liter LN_2 storage dewar and N_2 cylinder.

Use the Palomar "Key" pump station with the diffusion pump, or the new Palomar turbopump, to pump the getters in PHARO down to sufficiently low pressure. The turbopump is simpler to operate and cleaner (no oil) so it is preferable over the diffusion pump. The basic procedure is similar to pumping down other Palomar LN_2 dewars. *If you're not familiar with pump operation, please get proper training before proceeding with the following checklist.*

To minimize contamination, PHARO, like any dewar, should not be exposed to pump station pressures higher than its internal pressure during pumping. Always check appropriate vacuum gauges before opening valves to avoid exposing the dewar to high pressures unnecessarily.

If there's a **POWER FAILURE** or some other problem during pumping:

1. Close the DEWAR VALVE as quickly as possible to protect the dewar.
2. Close all pump station valves to protect the pumps.
3. When the power comes back on, turn on the pump first and ensure that it's working properly and that all hoses are pumped out thoroughly before opening the dewar valve.

4. GET HELP if you're not sure what to do!

2.1.2 Vacuum Pumping Checklist (assumes the turbopump)

1. Mount the pumpout valve on the dewar. Connect the turbopump hose to the fitting on the dewar valve.
2. Make sure the pump station valve is closed.
3. Turn on rough pump. The turbopump will also start spinning up.
4. Open the the pump station valve to pump out the hose.
5. Check dewar pressure w/ thermocouple gauge, being careful that the gauge makes a good connection (it often does not).
6. When the pump station gauge is less than the dewar pressure, open the dewar valve.
7. If the dewar begins at atmospheric pressure and requires significant rough pumping, the turbopump may spin up too fast, before the pressure is low enough for it to operate. In this case, the power switch will turn red. If this happens, close the dewar and pump stations valves, then briefly switch off the pump power to let the turbo spin down. Finally, turn the power back on and open the valves. Even when the dewar starts at 1 atmosphere, one of these cycles should be enough to rough pump the dewar to the point where the turbopump can reach its maximum speed.
8. Once the turbopump is at operating speed, pump until the dewar pressure <~ 15-30 mTorr. This usually takes ~3 – 4 hours. Longer times may be required if the dewar was open to 1 atm. and/or the getters are dirty.
9. When pumping is complete, close dewar valve.
10. Close the pump station valve and turn off the pump.

2.1.1 Cooldown Checklist

PHARO is cooled with liquid nitrogen only, much like other LN_2 instruments such as PFIRCAM. The dewar has two LN_2 tanks, and the necks extend down from the bottom of the dewar instead of up from the top.

Temperature Sensors: PHARO has three internal sensors that indicate the temperature at three points:

T1: Radiation Shield (cooled by outer can)
T2: Workplate (cooled by inner can)
T3: Detector (cooled by inner can)

Power is applied to the sensors through the momentary-on toggle switch on the Stepper Motor Drive Box, and the sensor readings are visible on the nearby digital display. The display shows degrees Kelvin divided by 100 (e.g. 77 K reads as 0.77). Monitor the sensors periodically during a cooldown.

1. If necessary, raise the dewar about 1 foot off the floor using the orange hydraulic lift.
2. If necessary, install the insert tubes in the 2 necks using the T-handle tool. (The inserts are usually left in the necks.) If they are already installed, check them with the T-handle to make sure they are tight. (A light amount of torque on the T-handle is sufficient!)
3. Use the special PHARO fill tube with the 90 degree elbow for the fill.
4. Fill the outer can first, which is accessed through the neck at the middle of the dewar. Point the outlet of the fill tube toward the other neck, and use a bungee cord to pull the bottom of the tube in the other direction. This will push the top end of the fill tube against the edge of the insert tube, minimizing spillage. If there's a lot of spillage, the tube is almost certainly not inserted properly. The outer can should fill in 20 to 30 minutes, depending on the storage dewar pressure.
5. Fill the inner can through the neck at the window end of the dewar, again pointing the outlet of the fill tube toward the other neck. This should also take ~20 to 30 minutes.
6. Refill the inner can after 1 hour. The first fill does not last long because 3 liters of LN2 is cooling a large mass.
7. Refill both the inner and outer cans after another 6–12 hours. After this the hold time of the outer can is 30–36 hours; the exact hold time appears to depend on the ambient room temperature. The hold time of the inner can is about 60 hours.
8. The detector cools fairly rapidly and can be turned on and checked a few hours after the first fill (through step 5) is complete. The detector temperature should be below ~ 85 K before the detector power is turned on. The filter wheels in the dewar require ~ 20 hours to cool fully, and they should not be moved extensively until about 12 hours after the first fill is complete.

2.2 Cabling

A diagram of the complete AO System + PHARO cabling is shown in Figure 2.1.

PHARO has only three cables and a fiber-optic bundle. The connector for each cable is different, so it is (virtually!) impossible to connect them incorrectly.

1. Install the purple cable between the red and aluminum boxes. (This is usually left in place.)
2. Connect the first 30-foot power cable from the Detector Electronics power supply to the red detector electronics box.
3. Connect the second 30-foot power cable from the Stepper Motor power supply to the aluminum electronics box.
4. Plug the two cords from the Detector Electronics and Stepper Motor power supplies into UPS outlets.
5. Connect the optical fiber pair between the workstation and the red box (directly or through the observatory patch panel depending on the installation). At the workstation, plug the red side into the left connector as you look at the back of the workstation. At the dewar, the red side also goes into the left connector as you face the rear end of the red box.

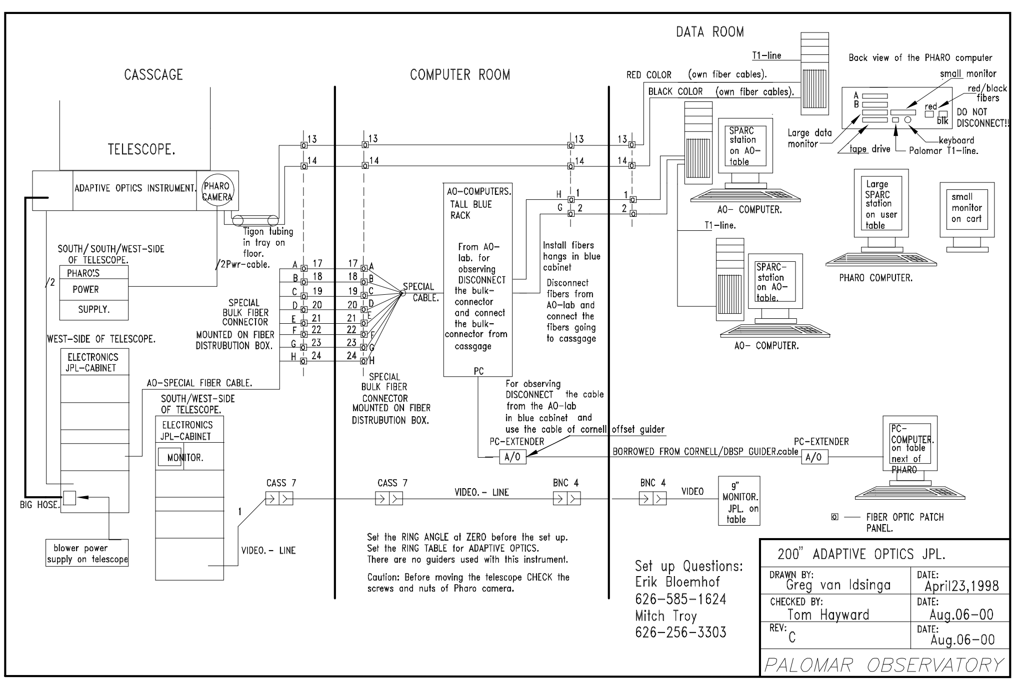

Figure 2-1 AO System & PHARO cabling diagram. Provided by Greg van Idsinga.

2.3 The PHARO Workstation

PHARO's workstation is a Sun UltraSparc 2, and its name is **ezra2**. The system includes two video cards to drive two monitors, and an S-Bus fiber optic board.

2.3.1 Connections

The following connections are needed. Many cables are usually left in place between runs.

1. CPU box SCSI connector to Exabyte tape drive.
2. CPU main monitor connector to large monitor, using the long (10') cable.
3. CPU secondary monitor connector to small monitor.
4. CPU ethernet connector to T1 socket.
5. CPU keyboard connector to keyboard.
6. Fiber optic bundle from workstation to instrument, as described in preceeding section.

2.3.2 Power up and booting

1. Plug the workstation cart's power strip into a UPS wall socket.
2. Plug the two monitors into **non-UPS** sockets.
3. Turn on the power to the system components in the following order.
   i. Exabyte tape drive
   ii. CPU box
   iii. The two monitors

   After the CPU is turned on, it should boot automatically.

2.3.3 Logins

The ezra2 user account for operating PHARO is **pharo**. You must select the CDE window manager when logging in (it's usually the default) for the xpharo program to run properly. Get the current password from one of the Palomar staff or AO team members.

2.3.4 Power down

The ezra2 workstation, like any Unix system, should be powered down only with a specific procedure, to protect the file systems.

1. If necessary, log in as user **pharo**. If already logged in as any user, don't log out.
2. Press the power key in the very upper right corner of the keyboard.
3. A popup menu should appear on the screen; select **Shutdown**.
4. The system should immediately begin syncing the file systems. After about a minute, the CPU box power will go off automatically.

5. Occasionally the shutdown process will not execute properly, and you may have to close extra warning menus and select additonal buttons to complete the procedure.
6. Switch off power to the monitors and tape drive manually.

2.4 Powering up and testing PHARO

1. Check PHARO's temperature sensors to make sure the internal componets are near 77 K. Avoid powering up the detector when the cryogens are close to running out.
2. Turn on the instrument power supplies in the following order: Detector Main, Stepper Controller Main, Stepper Controller Motor.
3. Power up the workstation if necessary.
4. Log into the workstation as user **pharo**. You must use the CDE window manager to run xpharo properly with the two monitors.
5. In the console window, run the xpharo program by typing the following command according to the situation:

   To attempt a network connection to the AO and TCS when xpharo starts:
   ```
   > xpharo
   ```

   If the network is not connected properly, or if the TAO program on the AO computer is not running and communicating with the TCS, pop-up warning windows will appear. You can ignore the warnings if you're just testing PHARO itself, but beware that TCS and AO header data will not be available and remote control of the AO system from PHARO will not be possible.

   If you explicitly don't want a network connection to the AO and TCS:
   ```
   > xpharo –nonet
   ```

   No network connection will be attempted, and no warning windows will appear. Use this option cautiously; remember to manually initialize the network connection before you actually start observing.

6. If necessary, test the fiber connection by selecting the **FOI** pulldown menu, then selecting **Send Null Command**. If the fiber system is functioning properly, a pop-up menu will appear with the message **Null command echo OK**. If the null command is not echoed properly, the message **Null command echo not received: try resetting FOI** will appear.

   If the Null Command does not work properly:
   i. Check all the fiber connections carefully. Make sure the red/black polarity of the fibers is correct all the way through the system. Verify that the PHARO power cables are connected correctly and that the power to the red instrument electronics box is turned on.
   ii. Select **FOI:FOI Reset**.
   iii. Select **FOI:Send Null Command** again.
   iv. If a Null Command still fails, close xpharo by selecting **File:Exit**, then restart the program and try the Null Command again.
   v. If the fiber still fails, you need to consult someone for further assistance.

7. Start an integration by clicking **Quick Src**. An image should appear after about 5 seconds. If an image does not appear and the integration time counter keeps counting below zero, press **STOP**, select **FOI:FOI Reset**, then try again. If it still doesn't work, check the fiber system with the Null Command as explained in step 6 above.

8. Remove the window cover as necessary.

2.5 Maintaining PHARO

1. Keep the Lyot wheel in the Block position, or the Shutter in the Closed position, when PHARO is not in active use to keep the detector dark. This is necessary to avoid latent images from bright light sources.
2. Make sure that personel entering the Cass. cage check that the detector light path is blocked (see step 1) before turning on lights, flashlights, etc.
3. Refill the outer can once every 24 hours and the inner can at least once every 48 hours.

2.6 Powering Down PHARO (e.g. at end of night)

Execute the following power down procedure if PHARO is to be left unattended for a significant period of time.

1. Set the Lyot wheel to Block.
2. Turn off the instrument power, preferably in the following order: Stepper Controller Motor, Stepper Controller Main, Detector Main.
3. If the instrument is to be inactive for a long period of time, reinstall the window cover.

2.7 Shutting Down PHARO at the end of a Run

1. Power down PHARO as described in Section 2.6.
2. Remove the Cass Cage fibers, cables, and PHARO power supplies and store them in the PHARO cabinet in the AO lab.
3. Leave PHARO on the AO bench unless special circumstances require that it be removed.
4. Power down the ezra2 workstation as described in Section 2.3.4.
5. Store the workstation cart, the large monitor, and the data room fibers in the AO lab.

2.8 Mounting PHARO on the AO Bench

2.8.1 Introduction

PHARO can be mounted on (and dismounted from) the AO bench when the bench is on the "Handling Cart" (cart w/ telescoping posts used for transfer to telescope), the "Spit" (used for rotating AO bench in AO lab), or on the telescope itself. The procedures are somewhat different, so the three cases will be described individually here.

Usually PHARO is left on the AO bench between observing runs, so mounting it is not normally required when preparing for a run.

The following items will be needed:
- PHARO on its wheeled cart
- The orange hydraulic lift (from SC-10)
- Socket wrench with 24" extension and 7/16 socket
- Open end wrenches
- If the AO bench is on the handling cart, you'll need two small pieces of 3/8-inch plywood to prop the PHARO cart up to the proper angle.
- If the AO bench is on the spit, you'll need the special piece of ¼-inch plywood to put under the cart so the lift tines will support the cart properly.

2.8.2 AO Bench on Handling Cart

The PHARO cart was specifically designed to fit on the lift and under the AO cart for this procedure, so it is preferred over the others. Two people can safely perform it.

1. Remove all fittings from the PHARO LN2 necks, valves, etc., that are protruding from the bottom of the dewar past the lowest level of the handling cart. Also, remove the 30-foot power cables and fibers. The red and aluminum electronics boxes can stay attached to the dewar.
2. On the PHARO mounting cradle, loosen the front-to-back and side-to-side motion locking bolts. Set the top plate all the way inward (away from the red electronics box), and about in the middle of its travel front-to-back. This makes the bolts on the back edge easier to reach when the dewar is raised to the AO bench, and gives the stepper motor box on the back of the dewar sufficient clearance. You may wish to mark the location of the cradle in both axes before moving the plate so that the dewar can be returned to its original position.
3. Check that the ~8 captive screws in the mounting plate are installed properly.
4. Move the orange lift tines so that they're centered on the cart and are separated by the same amount as the side-to-side ribs on the PHARO cart.
5. Roll the orange lift under the PHARO cart, with the red electronics box facing the lift.

6. Place two ~3/8 thick blocks under the inner (red box side) rail of the PHARO cart. This will tilt the cart to counteract the tilt of the AO bench on its handling cart (and may not be necessary if the AO tilt has been corrected).
7. Lift PHARO slightly off the floor. Roll the lift & dewar up to the side of the bench. Align the dewar with the bench to minimize the motion required when the lift is raised (and very top-heavy). The sections extending out from the cradle's upper plate fit into the recesses cut in the AO cover lip.
8. Raise lift to bring the cradle about ½ inch below the AO bench. Roll the lift & dewar carefully into place, then raise the dewar further until the mounting frame just touches the AO bench.
9. Tighten as many of the captive mounting bolts as you can reach. **All bolts should turn freely if the alignment is correct – do not force or cross-thread the bolts.** Use the socket wrench with the long extension to reach the two bolts along the inner edge of the dewar. You can tighten every bolt except the one at the front of the dewar (which is blocked by the PHARO cart).
10. Unbolt the dewar from its cart (a couple 10-32 screws from cart up into dewar flange).
11. Lower the lift & cart slightly. Have two people hold the cart while the lift is backed away. The cart can then be maneuvered out from under the dewar.
12. Tighten the captive bolt at the front of the dewar (the one that couldn't be reached in step 9), and check the tightness of all the bolts.

2.8.3 AO Bench on Spit (Provisional – not checked as of 6/8/99)

The PHARO cart is not well designed for this procedure – the balance of the raised dewar on the orange lift is more precarious than with the Handling Cart method, and the dewar must be physically lifted several inches onto the lift. Three or four people are required to maintain a good safety margin. Please exercise great care!

1. Remove all fittings from the PHARO LN2 necks, valves, etc., that are protruding from the bottom of the dewar past the lowest level of the handling cart. Also, remove the 30-foot power cables, the purple cable connect the red and aluminum electronics boxes, and fibers.
2. Remove the aluminum stepper motor box from the back of the dewar. Unbolt the box, pull it back about 1 inch, then uncouple the two cables from the dewar.
3. On the PHARO mounting cradle, loosen the front-to-back and side-to-side motion locking bolts. Set the top plate all the way inward (away from the red electronics box), and about in the middle of its travel front-to-back. This makes the bolts on the back edge easier to reach when the dewar is raised to the AO bench, and gives the stepper motor box on the back of the dewar sufficient clearance. You may wish to mark the location of the cradle in both axes before moving the plate so that the dewar can be returned to its original position.
4. Check that the ~8 captive screws in the mounting plate are installed properly.

5. On the orange lift, move the right tine so that its outer edge is aligned with the outer edge of the vertical rail. Then move the left tine until both tines fit under the skinny axis of the PHARO cart.
6. Place the ¼ -inch plywood sheet on the lift tines.
7. Raise the lift tines about 1 foot off the floor.
8. Using 3 or 4 people, pick up PHARO and its cart, and set it on the plywood. Be careful to push the cart all the way back on the tines before setting it down so that the lift does not tip forward.
9. Make sure the dewar is stable before raising the lift further.
10. Roll the lift & dewar up to the side of the bench. Align them fairly accurately to minimize the motion required when the lift is raised (and very top-heavy).
11. Raise lift to bring the cradle about ½ inch below the AO bench. Roll the lift & dewar carefully into place. The sections extending out from the cradle's upper plate fit into the recesses cut in the AO cover lip. Once aligned, raise the dewar the rest of the way.
12. Tighten as many of the captive mounting bolts as you can reach. Use the socket wrench with the long extension to reach the two bolts along the inner edge of the dewar. You can tighten every bolt except the one at the front of the dewar (which is blocked by the PHARO cart).
13. Unbolt the dewar from its cart (a couple 10-32 screws from cart up into dewar flange).
14. Lower the lift & cart down and away from the dewar.
15. Tighten the captive bolt at the front of the dewar (the one that couldn't be reached in step 9), and check the tightness of all the bolts.
16. Remount the aluminum stepper motor electronics box on the back of the dewar. Plug in the two cables, then bolt the box to the dewar flange.

2.8.4 AO Bench on Telescope

As of this writing, we have not mounted or dismounted PHARO with the AO bench on the telescope, so step-by-step procedures for this have not been developed.

Chapter 3. PHARO Maintenance

3.1 Detector Electronics

The PHARO detector electronics are housed in the red box mounted on the side of the dewar. There are a few displays, test pins, and controls on the electronics boards that may occasionally require monitoring or adjustment.

There are four boards in the electronics box.

FPGA board (upper right quadrant) – communicates with the EDT Fiber-optic interface board in the workstation via two optical fibers. There are several LEDs that indicate the status of the board.

Upper Left Corner:
Green : Illuminated when board is receiving power
Yellow:

Lower middle:
Red: Illuminated when FPGA board is correctly programmed. On power-up, the board loads a default program from the on-board EPROM, illuminating this LED. When a new program is transmitted from the workstation, the LED goes dark for a few seconds then comes back on. If the new program is not transmitted successfully, the LED will not illuminate.

Driver Board (upper left quadrant): Conditions DC voltages and and Clock signals for use by the detector. There are no user-adjustable elements on this board.

Pre-Amp Board (lower left quadrant): Ampifies signals from detector.

There are seven 10-turn potentiometers at the top of the pre-amp board that must be adjusted properly for optimal performance of the detector and electronics. For each pot there is a test pin on the board which can be monitored with a voltmeter to check the precise setting of the pot. There is also a ground test pin in the lower-left quadrant of the board.

The seven pots, left-to-right, are:

VRESET: The pot controls the VRESET (Reset Voltage) of the detector with the array wired with off-chip FETs as it is in PHARO. Originally this pot controlled another voltage, so it and its test pin were named DETBIAS on the board. Therefore, you'll need to find the DETBIAS test pin to monitor the voltage controlled by this pot.

VRSET should be between 0.5 and 1.0 V. In PHARO it is nominally set to 0.5 V.

FETSOURCV: Set so that the FETSOURCEV test pin reads +5V

OUTPUTBIAS: Set so that the OUTPUT BIAS GATE test pin reads +5V. In practice the test pin voltage reads only about 4.9 V when the pot reaches its upper limit.

OFFSET1, OFFSET2, OFFSET3, OFFSET4: These pots control the offset biases of the detector's 4 quadrants. They should be set so that the mean Signal from each quadrant is a few thousand DN when the array is dark and the majority of pixels are above zero. If the offset is set too low, the lowest bias (darkest) pixels will be below zero, so they will be "clipped" at zero by the A/D converters. If set too high, then pixels with high signal (on bright stars) may be clipped at 65535 before the detector wells actually fill. Therefore, the pots must be set properly to ensure the maximum possible dynamic range.

It is desirable to set the same offset bias for each of the four quadrants, to ensure consistent performance no matter where a source may be on the array. To do this:

1. Set Lyot to Block.

2. Set the display mode to "Signal." This is very important so that you are looking at the raw signal level coming from the array, not the Signal – Reference, or "Diff."

3. Take Quick frames with 1.8 sec integration time.

4. Set the Channel 2 Offset pot until the mean signal is a few thousand DN, and essentially all pixels are at least slightly above zero as viewed on the display. Start with channel 2 (which corresponds to the lower left quadrant) because the pixels at the left edge of the array tend to have the lowest dark signal and therefore require the highest offset bias. The test pin voltage doesn't mean much, just monitor the DN numbers on the display. Don't worry about the few outlier pixels that are well below zero – it's not worth decreasing the dynamic range to these pixels which are probably bad or noisy.

5. Carefully set the channel 1, 3, and 4 offsets until the mean signal is similar to channel 2. Ideally, you should barely be able to see the seams between the quadrants when the voltages are properly matched. In practice, however, this is very difficult to achieve because a 1-step change in the pot setting produces an obviously visible change in the signal level. Precise matching is not important for the array to function properly.

6. Check all four quadrants one last time to make sure that most of the lowest signal pixels are above zero.

A/D Board (lower right quadrant): Analog-to-Digital converter board that converts analog signals from Pre-Amp board to the digital signals that are fed to the FPGA board. No user-adjustable elements.

3.2 Stepper Motor Electronics

The aluminum box on the back of the dewar contains driver boards for the six cryogenic stepper motors inside the PHARO dewar. There are three adjustments on each board, each facing the back of the box so they are easily accessible when the back panel is removed.

1. Mode switch – an ~ 10 position miniature rotary switch that controls the stepper motor mode. Normally set to 1 which enables half-step mode; this setting should not be changed.

2. Drive current – A one-turn potentiometer near the middle of the board, between the Mode switch and the second (hold current) pot. Controls the drive current for the motor. Full CCW sets the drive current to zero; turn CW to increase the drive current. The normal position is about 9 or 10 o'clock.

3. Hold current – A second one-turn pot that controls the hold current for the motor. In PHARO the hold current is set to zero, corresponding to the full CCW position of this pot.