SHACK-HARTMANN TEST EQUIPMENT

Technical Manual and Operating Instructions

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Cabling details provided by E.J.Mills

1. Introduction

The Shack-Hartmann test equipment is provided for the assessment of the low order aberrations of the telescopes on La Palma. It can be configured for operation at any of the foci of the WHT, INT and JKT. It uses a standard science CCD as its detector and requires an image area with minimum dimensions of 24.5 x 24.5 mm. The data frames are reduced using a suite of programs, resident on the Suns, which provide measurements of spherical aberration, coma and astigmatism and Zernike fitting.

The schematic layout of the equipment is shown in Figure 1. The light from the telescope comes to focus in front of a cube beamsplitter which diverts 50% of the light from the star to a TV camera, through relay optics which reduce the image by a factor of two. A calibration source is located to the side of the beam-splitter so that it can be seen directly by the TV while 50% of its light is directed into the measurement optics. The light from either the star or the lamp is collimated at the collimating lens, passes through a filter and, in the case of the star, forms an image of the telescope primary mirror at the Shack-Hartmann lenslet array. These lenslets produce a set of star images, or spots, at the CCD each image coming from a small section of the primary mirror. The lamp calibration source is used to map the lenslet spot pattern for an unaberrated image and the difference in spot positions between the lamp and the star can be used to determine the aberrations in the telescope optical system.

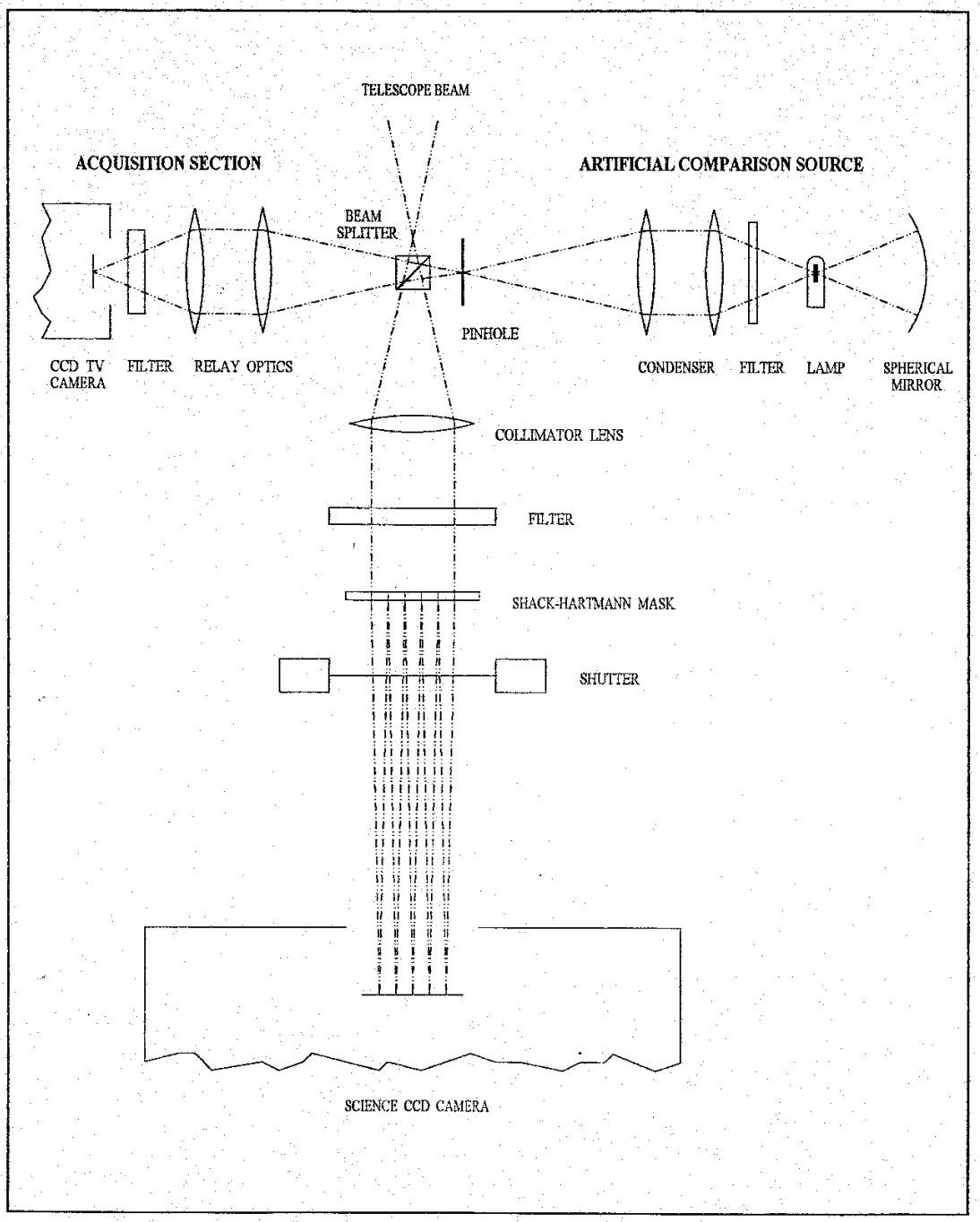


Figure 1. Shack-Hartmann optical path schematic (not to scale).

2. Basic system parameters

The assembly consists of four main sections. Working from the telescope focal station interface these are :-

A) The telescope interface plate and spacer ring.

B) The acquisition and calibration section.

C) The collimating lens section.

D) The mask, filter and shutter section.

Items **B** and **D** are common to all the configurations required for the different telescopes, **C** is changed to accommodate the different f-numbers. An interface ring and/or spacer (**A**) is required at all focal stations except the WHT prime focus.

A) The telescope interface and spacer ring.

The spacer rings are required to position the test optics at the correct distance from the telescope interface. They are sometimes combined with an interface plate which attaches to the standard mounting holes at the telescope focal station. The spacer rings have a male register which locates into the top of the acquisition and calibration section and are attached with M6 bolts and nuts.

B) The acquisition and calibration section.

The general layout of this section is shown in drawing W/BM/071 . The telescope focal plane lies 26 mm from the front plate of this assembly. A 5 mm cube beamsplitter is placed 5 mm beyond this focus and is used to divert 50% of the light from the star and the calibration lamp to a CCD television camera. This facility provides means of checking that the telescope and calibration source are parfocal and co-incident so that the same light path through the measurement optics is used by both sources. The TV camera is provided with three, 25 mm diameter, filters of similar specification to those used in the collimated beam. The calibration source is provided with a pinhole with a diameter of 20 microns. The unvignetted fields passed by the beam-splitter at each focus are listed below.

Telescope	Focal station	Field size in arcseconds
JKT	Wide field f/8	76
	Cassegrain f/15	47
INT	Bare prime f/3	34
	Corrected prime f/3.3	37
	Cassegrain f/15	19
WHT	Bare prime f/2.5	14
	Corrected prime f/2.8	18
	Cassegrain/Nasmyth f/11	15

C) Collimating lens section.

The collimating lens focal lengths are chosen to give a collimated beam diameter between 17 and 23 mm at the Shack-Hartmann mask. The greatest range of beam size occurs with the prime focus collimators which have a focal length of 59 mm and are fed

with f-ratios varying from f/2.5 at bare WHT prime to f/3.3 at corrected INT prime. There are two of these assemblies consisting of a standard 100 mm focal length coupled with an achromatised aplanatic meniscus lens, one is optimised for the blue (380-490 nm) and the other for the green/red (470-700 nm). There is a set of doublets used for the slower focal ratios.

Focal length mm	f-number	Telescope focus
180	f/8	JKT wide field
260	f/11	WHT/INT[a] Cassegrain
350	f/15	JKT Cassegrain

[a] The f/11 collimator must be used on the INT because of the reduced floor clearance.

D) Filter, mask and shutter section.

Filters

A filter holder is provided in the collimated beam in front of the Shack-Hartmann mask. Filters up to 50.4 mm square and 10 mm thick can be accommodated. The filter must be selected and installed manually prior to observations. The filters provided are listed below.

Collimated beam filters

Central Wavelength mm	Half power bandwidth nm	10% bandwidth nm	Peak Transmission %	Size mm
433	78	115	53	50x50
504	63	106	60	50x50
577	64	112	67	50x50

A similar set of filters is provided for the TV camera in the acquisition and calibration section.

Shack-Hartmann mask

The Shack-Hartmann mask consists of two arrays of cylindrical lenses mounted orthogonally to produce an array of 1 mm square lenslets. The focal length of these lenses is 170 mm and the diffraction spread from each lenslet is approximately 100 microns at a wavelength of 500 nm. The image scales obtained at the array focal plane on the CCD are listed below, together with the arcseconds per 24 micron CCD pixel.

Scales for Shack-Hartmann mask on ING telescopes

Telescope	f-number	microns/ arcsecond	arcseconds/ mm	arcseconds/ 24 micron CCD pixel

WHT	2.5	144	6.9	0.166
WHT	2.8	164	6.1	0.146
WHT	11.0	146	6.9	0.166
INT	3.0	104	9.6	0.230
INT	3.3	115	8.7	0.208
INT (f/11 260 mm collimator)	15	118	8.5	0.204
JKT	8.0	37	27.0	0.648
JKT	15.0	35	28.6	0.686

The following table gives the collimated beam diameter and the size of the telescope central obstruction at the Shack-Hartmann mask, the size of the patch on the primary mirror sampled by each lenslet and the number of lenslets spread across the primary for each of the telescope focal stations. Some of the lenslets will be vignetted by the inner and outer edges of the primary and by the telescope vanes.

Beam diameters and lenslet parameters for ING telescopes

Telescope	f-number	Diameter of collimated beam mm	Diameter of central obstruction mm	Patch on primary covered by lenslet cm	Number of spots within telescope aperture
WHT	2.5	23.6	6.9	17.8	370
WHT	2.8	21.1	6.1	20.0	310
WHT	11.0	23.6	6.9	17.8	370
INT	3.0	19.6	7.0	13.0	240
INT	3.3	17.9	6.4	14.2	210
INT (260 mm collimator)	15.0	17.3	6.2	14.7	205
JKT	8.0	22.5	13.9	4.4	220
JKT	15.0	23.3	9.5	4.3	330

One lenslet on the mask is blanked off to provide a fiducial mark for matching the star and lamp frames. A second mark, further from the centre of the mask, will be required if the JKT wide field system is to be tested.

Shutter

An electronic shutter is mounted 140 mm forward of the mask focal plane. At the moment this is a Compur shutter with a 29 mm opening which vignets the chip at the corners but passes the test field. This shutter also requires modification to the CCD controller to drive it. It is hoped to fit a Prontor shutter, which is now the standard

adopted by the ING. This new shutter has a full opening of 40 mm and will not require modification of the CCD controller.

CCD mounting ring
A standard CCD mounting ring is attached to the bottom of the mask section and provides the interface to the detector. The CCD should be mounted such that the cone seat should lie in the middle of one of the sides of the chip, this ensures that the lenslet array is aligned with the rows and columns of the CCD. The azimuth rotation on the CCD ring provides the fine adjustment to align the rows and columns of the CCD with the rows and columns of the Shack-Hartmann mask.

3. Building the configurations for the ING telescopes

The modular construction of the Shack-Hartmann test optics means that the equipment can be re-configured for each of the telescope focal stations. The two modules that are common to all configurations are the acquisition and calibration section and the mask section. Pictures of these two sections are given in Figures A and B and there are drawings W/BM/071 and V/BM/071 for the acquisition module and V/BM/072 for the mask section. The acquisition module has an aperture plate mounted in the face that lies closest to the telescope to restrict the field of view of the test optics so that the measurements are not compromised by nearby stars. The mask section has a standard CCD ring which provides the detector interface, the orientation of the CCD within this ring should be such that the cone seat lies in the middle of one of the sides of the chip ensuring that the mask and the CCD rows and columns are co-aligned. The various parts of the assemblies are centred with registers on the different sections, those on the acquisition and mask sections are female those on the spacers and collimator sections are male. The equipment is heterosexual if you find two males or two females together something is wrong! The photographs referred to in this section will be found at the end of the section, the drawings are in an appendix at the end of the manual.

Figure B: Shack-Hartmann mask section.

3.1 WHT prime focus (see photograph Figure C)

Items required:- Acquisition and calibration section (drawings W/BM/071,V/BM/071)
Prime focus collimator (usually blue optimised, drawing W/BM/074)
Mask section with blue filter(drawing V/BM/072)

The three sections are bolted together with M6 nuts and bolts, the collimator plate has the protruding lens cell toward the acquisition section and the mask section is oriented so that the filter holder is at 90^{o} to the lamp/TV axis. The assembly is mounted in to the prime focus instrument platform using the dummy photographic plate holder plate that has been drilled for 6 M6 bolts on a 252 mm pcd. the CCD controller also mounts on this plate and the equipment should be mounted so that the filter faces away from the controller.

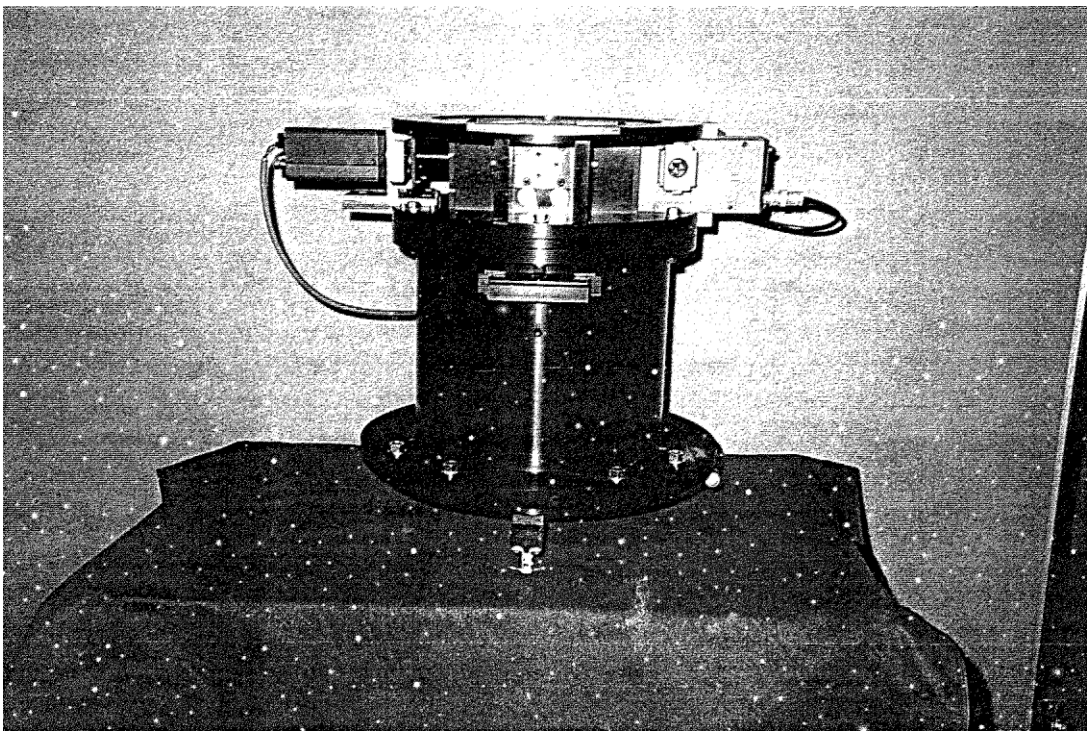


Figure C: Shack-Hartmann WHT Prime Focus configuration.

3.2 WHT auxiliary port (see photograph Figure D)

Items required:- Auxport spacer (drawing W/BM/077)
Acquisition and calibration section (drawings V/BM/071,W/BM/071)
f/11 260 mm collimator (drawing V/BM/075)
Mask section with blue filter (drawing V/BM/072)

The acquisition and calibration section bolts to the auxport spacer such that the flattened edges of the spacer are aligned with the lamp/TV axis. The collimator has the end with the scribed f/11 mark attached to the mask section and the mask section is aligned with the filter in line with the lamp/TV axis of the acquisition section. The whole assembly

should be oriented at auxport so that the CCD filler tube is uppermost in the cryostat to avoid excessive loss of liquid nitrogen.

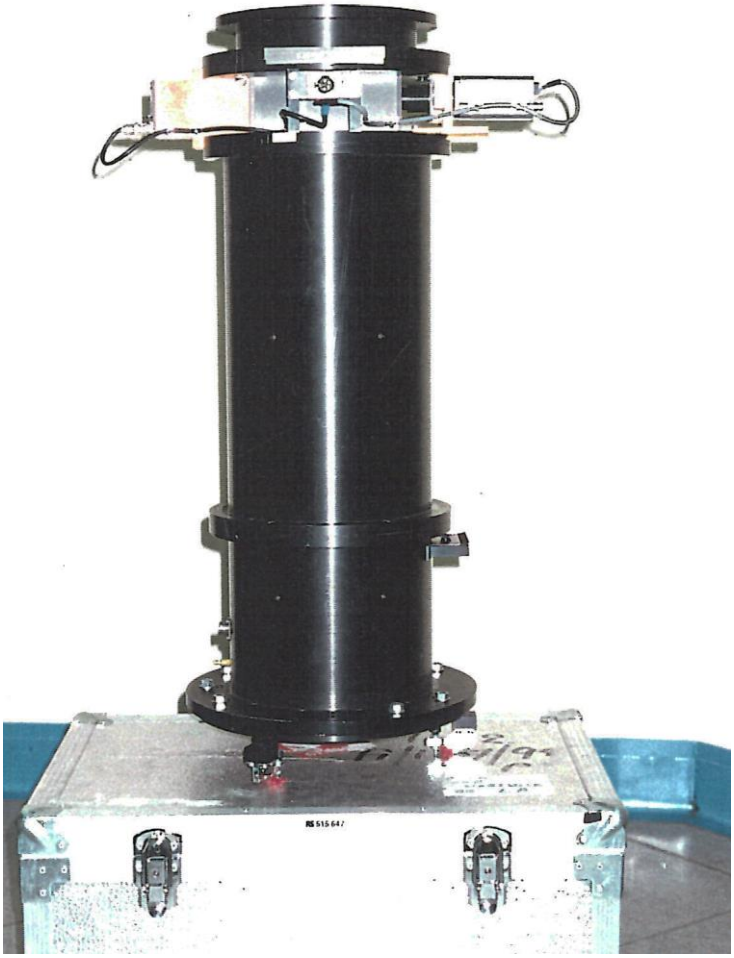


Figure D: Shack-Hartmann WHT Auxiliary Port configuration.

3.3 WHT direct Cassegrain (see photograph Figure E)

Items required:- 150 mm back focal distance spacer plus standard A&G box interface plate (drawing W/BM/076)
Acquisition and calibration section(drawings V/BM/071, W/BM/071)
f/11 260 mm collimator (drawing V/BM/075)
Mask section with blue filter (drawing V/BM/072)

The standard A&G box interface plate attaches to the 150 mm back focal distance spacer with 6 M6 countersunk bolts. This assembly, in turn, is attached to the acquisition section collimator and mask sections such that the filter in the mask section is in line with the lamp/TV axis of the acquisition section. The scribed f/11 mark on the collimator is toward the mask section. The whole assembly attaches to the WHT A&G box.

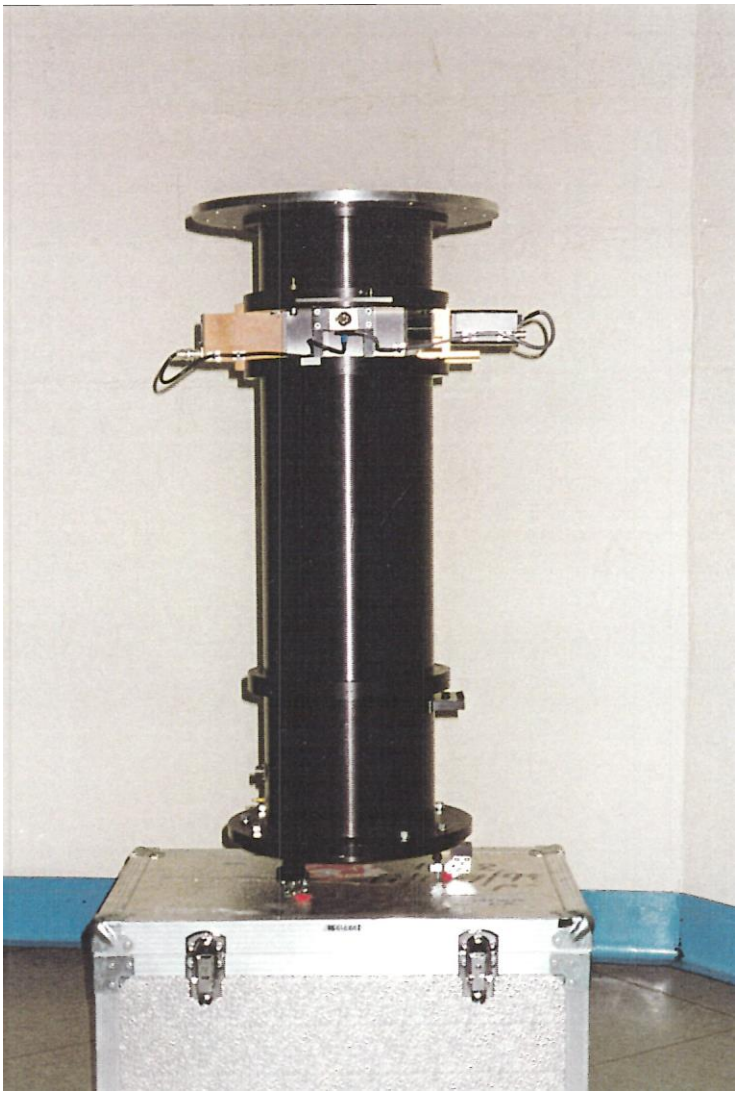


Figure E: Shack-Hartmann WHT direct Cassegrain configuration.

3.4 INT prime focus (see photograph Figure F)

Items required:- INT prime focus interface plate (drawing AK/1502)
Acquisition and calibration section(drawings V/BM/071,W/BM/071)
Prime focus collimator (usually blue optimised ,drawing W/BM/074)
Mask section with blue filter (drawing V/BM/072)

The interface plate attaches to the acquisition section as indicated on the plate. The acquisition section, collimator and mask section bolt together with one set of M6 bolts and nuts. The collimator has the protruding lens cell towards the acquisition section and the mask section is aligned so that its filter holder is at 90^{o} to the lamp/TV axis of the acquisition section. The whole assembly attaches to the telescope with a special D-plate (see drawings AK/1501 and AK/1500) which has been drilled to take the INT prime focus interface plate.

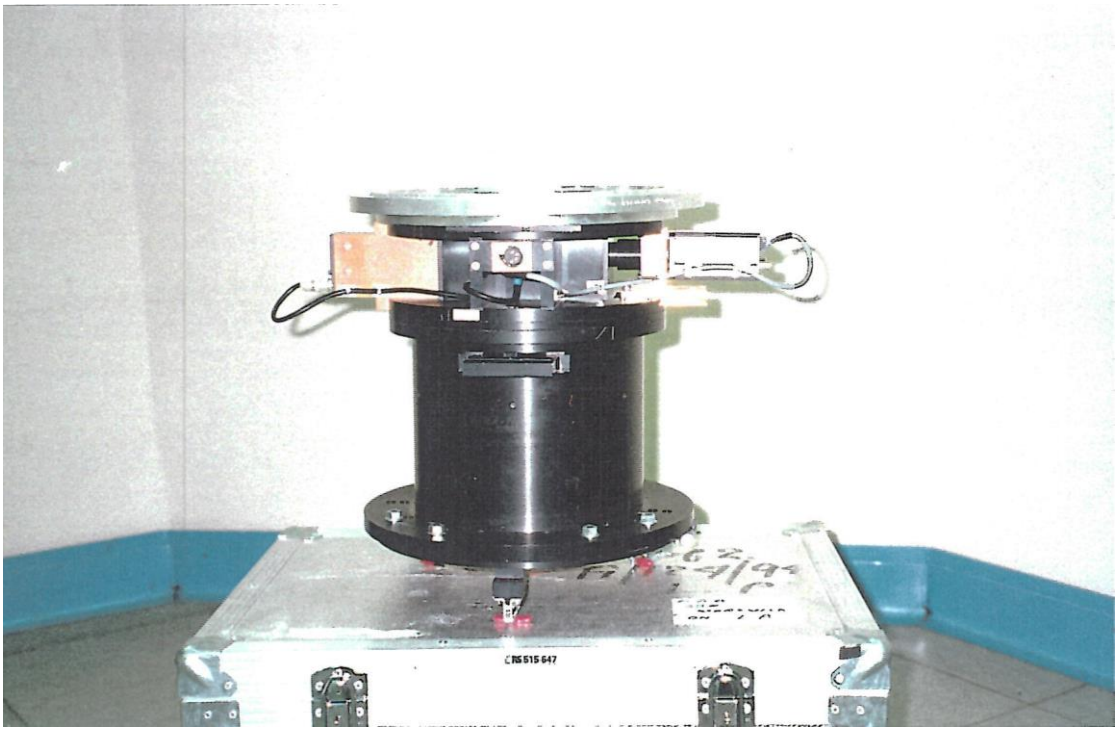


Figure F: Shack-Hartmann INT Prime Focus configuration.

3.5 INT Cassegrain focus (see photograph Figure G)

Items required:- 150 mm back focal distance spacer plus standard A&G box interface plate (drawing W/BM/076)
Acquisition and calibration section(drawings V/BM/071,W/BM/071)
f/11 260 mm collimator (drawing W/BM/076)
Mask section with blue filter (drawing V/BM/072)

The standard A&G box interface plate attaches to the 150 mm back focal distance spacer with 6 M6 countersunk bolts. This assembly, in turn, is attached to the acquisition section collimator and mask sections such that the filter in the mask section is in line with the lamp/TV axis of the acquisition section. The whole assembly attaches to the INT Cassegrain A&G box. Because of the restricted space below the telescope an EEV chip in the old 'standard' short cryostat must be fitted.

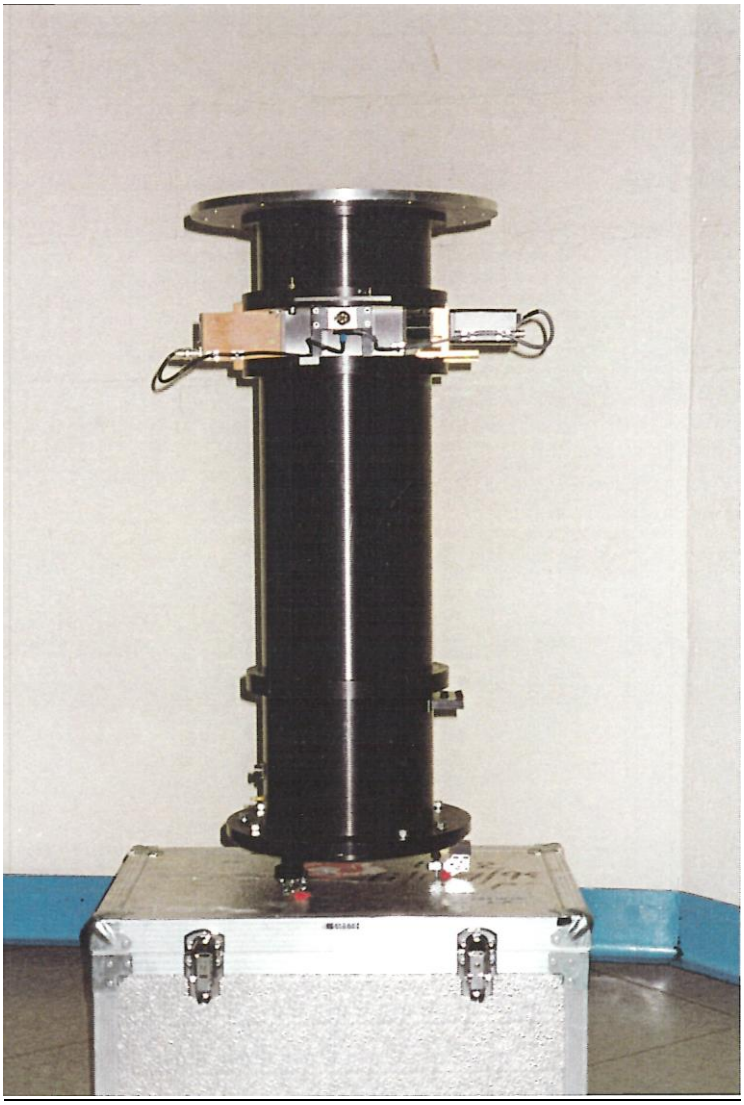


Figure G: Shack-Hartmann INT Cassegrain configuration (same as WHT direct Cassegrain).

3.6 JKT f/8 wide field (see photograph Figure H)

Items required:- JKT f/8 spacer (not yet available)
Acquisition and calibration section(drawings V/BM/071,W/BM/071)
f/8 180 mm collimator
Mask section with blue filter (drawing V/BM/072)

The acquisition section is bolted to the collimator as directed on the collimator. The mask section is bolted to the collimator such that the mask section filter is at 90^{o} to the lamp/TV axis of the acquisition section.

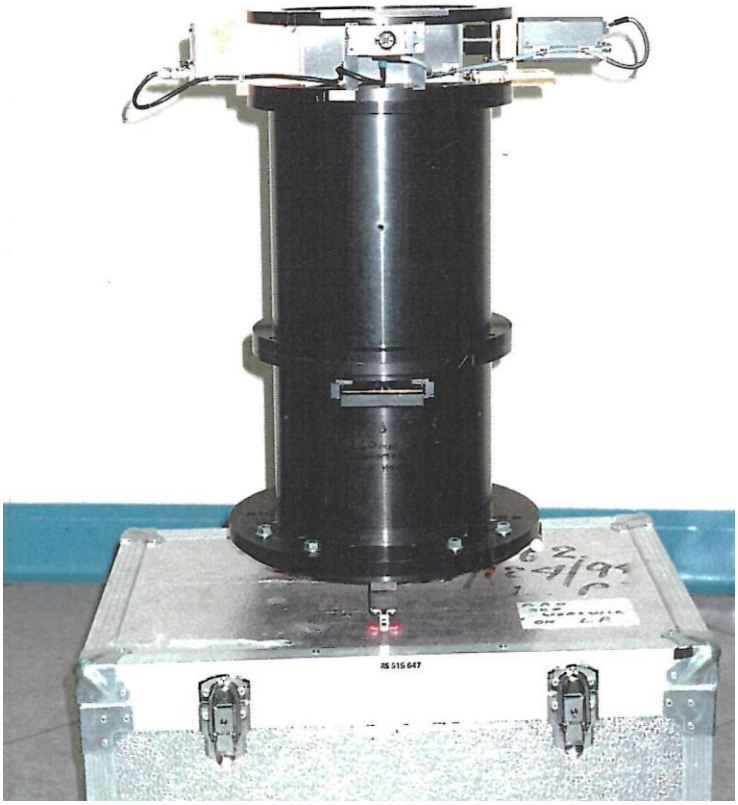


Figure H: Shack-Hartmann JKT f/8 wide field configuration.

3.7 JKT f/15 Cassegrain (see photograph Figure I)

Items required:- 150 mm back focal distance spacer plus standard A&G box interface plate (drawing W/BM/076)
Acquisition and calibration section (drawings V/BM/071,W/BM/072)
f/15 350 mm collimator (drawing V/BM/079)
Mask section with blue filter (drawing V/BM/072)

The standard A&G box interface plate attaches to the 150 mm back focal distance spacer with 6 M6 countersunk bolts. This assembly, in turn, is attached to the acquisition section collimator and mask sections such that the filter in the mask section is in line with the lamp/TV axis of the acquisition section. The scribed f/15 mark on the collimator is toward the acquisition section. The whole assembly attaches to the Ellis Acquisition Unit.

Figure I: Shack-Hartmann JKT f/15 Cassegrain configuration.

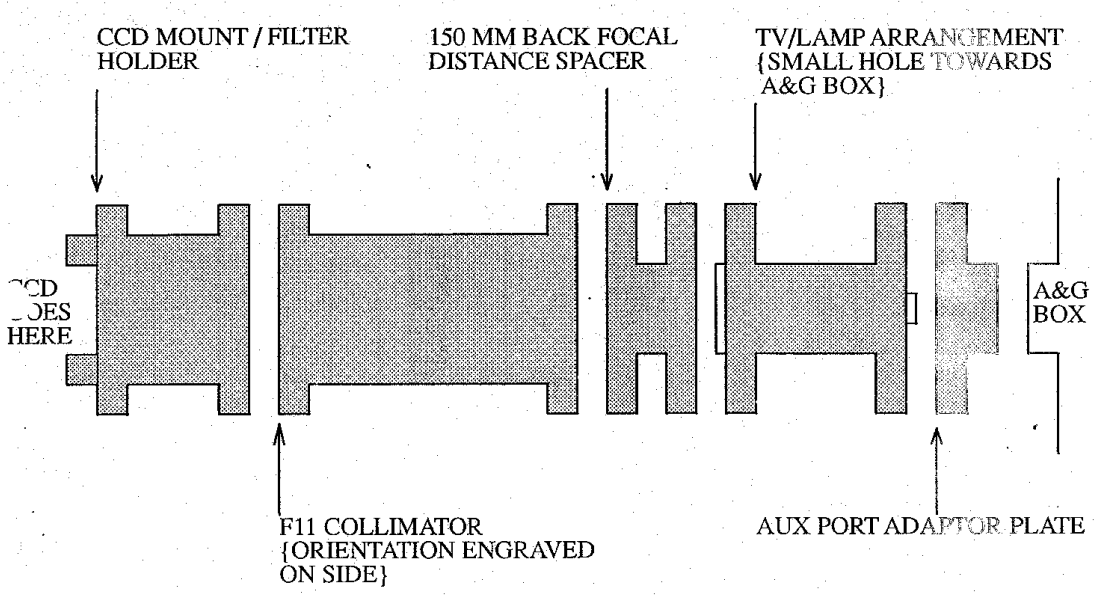
3.8 Alignment of configurations to telescope structure

The Shack-Hartmann screen should be aligned with the telescope so that the vanes run along the directions of the rows and columns of the mask. This can be judged by using the telescope rotator to position the TV/lamp axis of the acquisition section in line with one of the sets of the vanes. In the case of the WHT the rotator should then be turned off so that there is a constant mapping between the test equipment and the telescope optics.

4. Connections.

4.1 General.

A schematic showing the connections to the Shack-Hartmann assembly is shown in figure 2. The CCD TV camera and the fan in the lamp housing share a 12V DC supply which is connected to a small panel on the side of the Acquisition and Comparison Section. The supply is divided at this point with one cable connecting to the terminals on the rear of the TV camera and the other connecting to a BNC socket on the rear of the lamp housing. A separate, variable supply of up to 6V (at the lamp) is required to control the current and hence the intensity of the lamp source. This supply connects directly into the lamp housing. The shutter control cable connects to the side of the Mask Section. The connector type was chosen to match the Phase 2 CCD controller standard for the Compur shutter. ING have provided a conversion cable for use with the Phase 1 systems on the INT and JKT. At the time of writing this manual a Prontor shutter has been supplied for ING to fit and so connection details may change. The lower part of the Mask Section has a pneumatic connection for flushing the science CCD window with dry air.



N.B. 1. The TV and the lamp cooling fan require 12Volts and the lamp requires 6Volts. These are supplied from PSUs in the control room via any ALPHA cable using the adapter cables provided.
2. The TV also requires a coax connection to either a monitor in the control rooms or into the normal TV system

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Figure 2. Shack-Hartmann box at AUX port on the WHT.

4.2 Power Supplies.

Two bench-type power supplies are required but are not supplied. The 12V DC supply for the TV camera and the fan only needs to supply 0.3 Amps. The variable supply needs to be capable of supplying up to 4 Amps at around 6V to 8V, depending on the cable volt-drop.

4.3 Telescope cabling.

Cable runs have been identified and used at each focal station on each telescope. The cable runs terminate in the control room reasonably close to the control desk where the power supplies can be set up. Connection harnesses are provided for each end of the telescope cable run. The the cabling details have been prepared by ING and are included in Appendix I.

4.4 TV Camera.

The video output from the TV camera can be connected into a standard monitor. The spot illuminated by the lamp source should be marked on the screen so that the star can be brought to the same point and guided, if necessary, when the lamp is switched off. This reference point will change slightly with elevation and therefore it is more convenient to connect the TV camera video into the telescope's TV system so that a cursor can be used. It is also an advantage to be able to use contrast enhancement for faint stars. Since most exposures are likely to be between 100 and 200 seconds guiding is not essential and can be done by hand. However it is possible to guide with the WHT TV system provided the correct rotation offset and co-ordinate system has been determined and set up in an "Own Instrument" configuration file (contact the WHT TCS expert for help/information). Note: If the TV camera video is connected into the WHT TV System then the 'Ext. Sync.' signal must also be connected. Hence two coax cables are required to run in this mode on the WHT. A data sheet on the TV camera is provided in the appendix. Note that the shutter speed should be set to OFF. If AUTO is selected then the background level becomes very noisy.

5. Test and set up of equipment

Once the equipment has been installed and connected the following checks can be made during the day.

5.1 TV focus

The lamp current should be set to about 2 amps and the output from the TV camera should be viewed using a monitor close to the equipment. The pinhole in the calibration source should appear as a small bright spot but beware that the size is dependent on the lamp current. The camera is located on a dovetail slide and has a set of filters mounted in a slide in front of it. The system has been focused for the blue filter, which is located to one end of the filter slide(drawing W/BM/079). The equipment is often stored with the slide parked on centre so check that the blue filter is deployed before touching the focus. If either of the other two filters are used the camera must be refused. The clamping screws on the dovetail slide runners are released as well as the central locking screw which is located at the optical relay end of the TV slide. The TV is positioned manually until the lamp source appears in focus and the screws are locked down. Once the camera has been focused it can be used as the reference for setting the telescope focus so that it is parfocal with the lamp.

5.2 Lamp Frames

The exposure time for lamp frames should be about 10 to 20 seconds with a peak count in the spots of 20,000 to 40,000 adu. The lamp current should be set to achieve this with a lower current required for the faster collimating lens systems. As a guideline a lamp current of 2.8 amps was used for the f/15 system yielding 20,000 to 40,000 counts in spot peaks with an exposure of 15 seconds. When a good lamp frame has been obtained check the alignment of the spots with the rows and columns of the CCD and adjust the CCD rotation so that the tilt across the whole frame is better than four pixels. There is

no focus adjustment to be done on the CCD, with a f-number of f/170 for the lenslets the focus is very insensitive. The distance between spots should be measured and should come out at about 1 mm . If there is a gross change from this value, i.e. more than 5%, then the distance from the telescope focus to the collimator is not correct. This could happen if either the collimator section has been put in the wrong way round or an additional component has been put into the stack.

6. Taking Data

6.1 Lamp frames

A lamp frame should be taken at the beginning of an observing sequence, and after large changes (15 degrees) in zenith distance.

6.2 Positioning stars

The position of the lamp source should be marked on the TV monitor, fed by the on board TV camera, the stars used for the telescope testing should be positioned on this mark. The position of the lamp spot should be checked for movement after large changes (15 degrees) in zenith distance.

6.3 Brightness of stars

The measurement of aberrations requires a fairly high signal to noise ratio for the spots. Since the telescope mirror is being divided into 200 to 300 sub-apertures a bright star is needed. The magnitude should be picked such the required signal level in each spot (~ 20,000 adu) is obtained with an exposure of 60 to 300 seconds. Exposure times should not be reduced below 60 seconds because the seeing variations need to be averaged out. The measuring equipment is usually used in the blue in order to reduce the diffraction spread from the lenslet, this means that fainter A and B stars can be used as compared with G and K. Some guidelines for magnitude ranges for the telescopes are given below.

Telescope	Magnitude	Spectral type	Exposure time seconds
WHT	6.7	K0	150
	6.5	G0	100
INT	3.8	K0	150
	3.0	B4	80
JKT	4.6	G7	120
	5.0	A0	80

These estimates are also seeing dependent and this shows in the results from the INT.

6.4 Star Observations

For each star observed, two to three exposures should be taken to check the consistency of the results. On the WHT the output from the TV camera can be fed into the TV system and can be used to guide the telescope. On both the INT and JKT guiding is manual.

6.5 Pattern of observations

This will depend on the information required. When a check is being carried out after aluminising a measurement at zenith and a couple of zenith distances should be sufficient. If telescope optical and mechanical performance is to be characterised then long sequences with systematic changes in the attitude of the telescope with respect to the gravity vector are necessary.

7. Data Analysis

At present the data reduction packages are resident on the Suns. There are two options in the analysis of a set of Shack-Hartmann spot displacements. The first (NEWHART) calculates spherical aberration, coma, astigmatism and defocus and produces spot diagrams , the second (PFITSH) fits a set of Zernike polynomials and maps the results as wavefront error and encircled energy. Both of these options require a list of spot displacements to be generated from two CCD frames, one taken of the system under test and the other of a calibration source, the list is produced using the program REDHART.

7.1 Access to the programs

1) Login on a Sun using your own username. (See 3 below)
2) When you get to the stage of having a cmdtool and file manager window open an xterm window. Do this by moving the cursor to a blank area o the screen, press the right mouse button, select programs and then xterm.
3) Remote login to the optics account (note - it is not possible to log into the optics account directly, only via an account with privileges so to do, make sure that you have those privileges set up by the system manager)

rlogin -1 optics host (e.g. lpss1)

At this stage if you do a directory listing, i.e.

ls -aF

you will see a large number of files beginning with . and a subdirectory **hartmann** (shown as **hartmann**/) containing four further subdirectories, **bin,jkt,int** and **wht**. Subdirectory **bin** contains the fortran files (e.g redhart.f) and the executable images (e.g. redhart) for the programs redhart and newhart. Subdirectories **jkt,int** and **wht** contain the parameter files peculiar to those telescopes.

4) It is unlikely that there is sufficient space to store any data frames on the home disks, so create a subdirectory on a scratch disk e.g.

mkdir /scratch/host/optics

Move to this directory using the command

cd /scratch/host/optics

Copy into this directory, from the optics home disk, the files you need to process the Shack-Hartmann images.

cp /home/optics/hartmann/***/filename .

These are .dat files, there is no need to copy the executable images of redhart and newhart as these are set up as aliases. For each telescope there are three files needed defaults.dat , ***c_parms.dat and ***ab_parms.dat, where *** can be jkt,int or wht.

List the directory and you should see the parameter files, e.g. jktc_parms.dat present in the directory.

7.2 REDHART

7.3 NEWHART

7.4 PFITSH

Appendix I

CABLE CONFIGURATIONS FOR THE SHACK-HARTMANN BOX

Shack-Hartmann box mounted at WHT Cass focus or Cass A&G Aux port

Function	Telescope connector	Number	WHT Control room
S-H Power	55w socket	123	123 Engineering terminal switch box
TV Video	BNC	132	132 Focal station rack (Cass) End blue cabinet
TV Sync	BNC	136	136 Focal station rack (Cass) End blue cabinet

WHT Cass focus cabling up notes:

With the telescope at the zenith park position and the Shack-Hartmann box fitted :

- Connect the large cable from the ccd cryostat to the ccd controller. Fit the cable **S-H SHUTTER** between the socket **SHUTTER 1** on the ccd controller and the **SHUTTER** connector on the Shack-Hartmann box.

nb. *As the Shack-Hartmann box uses a COMPUR shutter, it will be necessary to change/check the link JP4 on the SPRAT card within the ccd controller. The ram disk (block 18) will also need to be edited to reflect this change.*

- Remove the engineering RS232 break-out box cable from the 55w socket **123** on the Cass turntable connection box.

nb. *When the Shack-hartmann box is used at Cass, we loose both the instrument and CCDC engineering terminals for the duration of the run.*

- Fit the cable **S-H TELESCOPE** to the 55w socket **123** on the Cass turntable connection box and the free ends with the 3 and 4 pin power connectors to the Shack-Hartmann box.
- Connect the **S-H VIDEO** and **S-H SYNC** co-axial cables from the RS TV camera to BNC sockets **132** and **136** respectively on the Cass turntable connection box.

In the Control Room:

- Remove the cable **123** from the engineering terminal switch box and plug the cable **S-H CONTROL ROOM** directly into the connector on cable **123.** Connect the free ends of this cable to the respective 6v and 12v power supplies. Remember to connect the PSU sense lines also.
- Locate the cables **RS TV VIDEO** and **RS TV SYNC**. These are normally left connected to BNC sockets **132** and **136** respectively on the Cass focus connector panel. This is located in the focal station rack at the back of the control room. The other ends of these cables come into the Integrating TV rack and are fitted with BNC in-line plugs.
- Locate the ribbon cable with the group of BNC connectors in the TV rack. These carry the TV video and sync signals from the Westinghouse TV controllers to the VME crate. One of these cables has a black marker band and carries the sync signal and the video cables are marked as 0 and 1. Cable 0 is used for the Cass TV and cable 1 for the UES TV.
- Remove the cable with the **BLACK** marker from the socket SYNC IN on the TV controller and connect the cable **RS TV SYNC** via the in-line BNC connector directly to this cable.
- Remove the cable with marker **0** from the socket VIDEO OUT on the TV controller and connect the cable **RS TV VIDEO** via the in-line BNC connector directly to this cable.

The output from the Shack-Hartmann's TV camera will now be available on the WHT Integrating TV system and can be used for guiding.

Shack-Hartmann box mounted at WHT Prime Focus

Function	Telescope connector	Number	WHT Control room
S-H Power	55w socket	8	8 Focal station rack (Prime) End blue cabinet
TV Video	BNC	19	19 Focal station rack (Prime) End blue cabinet
TV Sync	BNC	18	18 Focal station rack (Prime) End blue cabinet

WHT Prime focus cabling up notes:

With the telescope at the AP3 position and the Shack-Hartmann box fitted :

- Connect the large cable from the ccd cryostat to the ccd controller. Fit the cable **S-H SHUTTER** between the socket **SHUTTER 1** on the ccd controller and the **SHUTTER** connector on the Shack-Hartmann box.

nb. *As the Shack-Hartmann box uses a COMPUR shutter, it will be necessary to change/check the link JP4 on the SPRAT card within the ccd controller. The ram disk (block 18) will also need to be edited to reflect this change.*

- Fit the cable **S-H TELESCOPE** to the 55w socket **8** on the prime focus connector panel and the free ends with the 3 and 4 pin power connectors to the Shack-Hartmann box.
- Connect the **S-H VIDEO** and **S-H SYNC** co-axial cables from the RS TV camera to BNC sockets **19** and **18** respectively on the prime focus connection panel

nb. *These cables will need to be passed over the swan neck cable twister down to the telescope connector panel and may require extending .*

In the Control Room:

- Connect the alpha cable **S-H LINK WHT/JKT CONTROL ROOM** to the 55w socket **8** (also labelled as Shack-Hartmann LV Power) mounted on the prime focus connector panel. This is located near the bottom of the focal station rack at the back of the control room.
- Plug the cable **S-H CONTROL ROOM** into the link cable and connect the free ends of this cable to the respective 6v and 12v power supplies. Remember to connect the PSU sense lines also**.**
- Locate the cables **RS TV VIDEO** and **RS TV SYNC**. These are normally left connected to BNC sockets **132** and **136** respectively on the Cass focus connector panel. Remove these cables and connect them to the BNC sockets on the prime focus connector panel. **RS TV VIDEO** to socket **19** and **RS TV SYNC** to socket **18**. The other ends of these cables come into the Integrating TV rack and are fitted with BNC in-line plugs.
- Locate the ribbon cable with the group of BNC connectors in the TV rack. These carry the TV video and sync signals from the Westinghouse TV controllers to the VME crate. One of these cables has a black marker band and carries the sync signal and the video cables are marked as 0 and 1. Cable 0 is used for the Cass TV and cable 1 for the UES TV.

- Remove the cable with the **BLACK** marker from the socket SYNC IN on the TV controller and connect the cable **RS TV SYNC** via the in-line BNC connector directly to this cable.

- Remove the cable with marker **0** from the socket VIDEO OUT on the TV controller and connect the cable **RS TV VIDEO** via the in-line BNC connector directly to this cable.

The output from the Shack-Hartmann's TV camera will now be available on the WHT Integrating TV system and can be used for guiding.

Shack-Hartmann box mounted at INT Cassegrain focus

Function	Telescope connector	Number	INT Control room	(stored under floor)
S-H Power	55w socket	TCZ3	55w plug	Alpha cable 6TKA17
TV Video	BNC	TCT31	BNC socket	Co-ax cable S-H VIDEO
TV Sync	BNC	TCT32	BNC socket	Co-ax cable S-H SYNC *not used

INT Cass focus cabling up notes.

With the telescope at the zenith park position and the Shack-Hartmann box fitted:

- Connect the large cable from the ccd cryostat to the ccd controller. Fit the cable **S-H SHUTTER** between the socket **SHUTTER 1** on the ccd controller to the **SHUTTER** connector on the Shack-Hartmann box.

nb. *As the Shack-Hartmann box uses a COMPUR shutter, it will be necessary to change/check the link JP4 on the SPRAT card within the ccd controller. The ram disk (block 18) will also need to be edited to reflect this change.*

- Remove the cable **TAC3** from the 55w socket on cable **TCZ3** on the mirror cell connector panel.

- Fit the cable **INT CASS LINK** into the connector on cable **TCZ3.**

- Fit the cable **S-H TELESCOPE** directly into the **INT CASS LINK** cable and the free ends with the 3 and 4 pin power connectors to the S-H box.

nb. *As there is no spare alpha cable in the Cass rotator, it is neccesary to use this drop cable from the mirror cell*
connector panel. The cable should be routed and strapped to allow for movement of the Cass rotator.

- Fit the co-axial cable **S-H VIDEO** from the BNC connector **TCT31** on the Cass rotator connector panel to the RS TV camera's video input socket.

In the Clip Centre:

- Plug the cable **S-H CASS TV VIDEO** (TCT31) into the BNC connector on the cable labelled **S-H TV MONITOR VIDEO**. This cables is found in a group in Bay 7.

In the Control Room:

- Remove the floor tile with cutout below the observers desk and pull out the co-axial cable **S-H TV VIDEO** and locate the alpha cable **6TKA17**. This cable is also labelled as **Shack-Hartmann**.

- Plug the cable **S-H CONTROL ROOM** directly into the alpha cable **6TKA17** and connect the free ends of this cable to the respective 6v and 12v power supplies. Remember to connect the PSU sense lines also.

- Find a suitable TV video monitor and plug the cable **S-H TV VIDEO** into the monitor's video input connector.

Shack-Hartmann box mounted at INT prime focus

Function	Telescope connector	Number	INT Control room	(stored under floor)
S-H Power	55w socket	TAC3	55w plug	Alpha cable 6TKA17
TV Video	BNC socket	TAW4	BNC socket	Co-ax cable S-H VIDEO
TV Sync	BNC socket	TAT12	BNC socket	Co-ax cable S-H SYNC *not used

INT prime focus cabling up notes.

With the telescope at the access park position and the Shack-Hartmann box fitted:

- Connect the large cable from the ccd cryostat to the ccd controller. Fit the cable **S-H SHUTTER** between the socket **SHUTTER 1** on the ccd controller and the **SHUTTER** connector on the Shack-Hartmann box.

nb. *As the Shack-Hartmann box uses a COMPUR shutter, it will be necessary to change/check the link JP4 on the SPRAT card within the ccd controller. The ram disk (block 18) will also need to be edited to reflect this change.*

- Fit the cable **S-H TELESCOPE** to connector **TAC3** on the prime focus instrument connector panel and the free ends with the 3 and 4 pin power connectors to the S-H box.

- Fit the co-axial cable **S-H VIDEO** from the BNC connector **TAW4** to the RS TV camera's video input socket.

In the Clip Centre:

- Plug the cable **S-H PRIME TV VIDEO** (TAW4) into the BNC connector on the cable labelled **S-H TV MONITOR VIDEO**. This cable is found in a group in Bay 7.

In the Control Room:

- Remove the floor tile with cutout below the observers desk and pull out the co-axial cable **S-H TV VIDEO** and the alpha cable **6TKA17**. This cable is also labelled as **Shack-Hartmann**.

- Plug the cable **S-H CONTROL ROOM** directly into the alpha cable **6TKA17** and connect the free ends of this cable to the respective 6v and 12v power supplies. Remember to connect the PSU sense lines also.

- Find a suitable TV video monitor and plug the cable **S-H TV VIDEO** into the monitor's video input connector.

Shack-Hartmann box mounted at JKT Cassegrain focus

Function	Telescope connector	Number	JKT	Control room	
S-H Power	55w socket	Y	Y	55w socket	End of control desk
TV Video	BNC socket	M	M	BNC socket	End of control desk

JKT Cass focus cabling up notes.

With the telescope at the zenith park position and the Shack-Hartmann box fitted:

- Connect the large cable from the ccd cryostat to the ccd controller. Fit the cable **S-H SHUTTER** between the connector **SHUTTER 1** on the ccd controller and the **SHUTTER** connector on the Shack-Hartmann box.

nb. *As the Shack-Hartmann box uses a COMPUR shutter, it will be necessary to change/check the link JP4 on the SPRAT card within the ccd controller. The ram disk (block 18) will also need to be edited to reflect this change.*

- Fit the cable **S-H TELESCOPE** to the 55w socket **Y** on the telescope instrument connector panel and the free ends with the 3 and 4 pin power connectors to the Shack-Hartmann box.

- Fit the co-axial cable **S-H VIDEO** from the BNC socket **M** on the telescope instrument connector panel to the RS TV camera's video input socket.

In the Control Room:

- Connect the alpha cable **S-H LINK WHT/JKT CONTROL ROOM** to the 55w socket **Y** at the end of the telescope control desk.

- Plug the cable **S-H CONTROL ROOM** into the link cable and connect the free ends of this cable to the respective 6v and 12v power supplies. Remember to connect the PSU sense lines also.

- Find a suitable TV video monitor and plug the cable **S-H VIDEO** from the monitor's VIDEO INPUT connector to the BNC socket **M** at the end of the telecope control desk.