Isaac Newton Group of Telescopes

William Herschel Telescope

ISIS USERS' MANUAL

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1 The Cassegrain A&G Box

1.1 Design of the A&G unit

The layout of the A&G Unit is shown in Figure 1. It is described in some detail by P.A. Ellis in *ING La Palma Technical Note no. 56.* Briefly, the unit has a full field of 15 arcmin diameter at the nominal telescope focus, 150 mm below the A&G to instrument interface. Facilities are provided to view the on-axis field, either directly or reflected from the ISIS slit jaws, autoguide using the off-axis field, take calibration exposures, use colour or neutral density filters and image by deflecting the on axis field to the auxiliary port.

1.2 Object acquisition

Object acquisition is carried out via an extendable probe carrying a mirror feeding a Westinghouse ISEC TV camera. When used direct (*not* the usual mode of acquisition when ISIS is in use), this provides a 1.5 arcmin field at the telescope scale of 4.51 arcsec mm^{-1}. It is possible to insert a focal reducing system, which provides a larger field of 4 arcmin at a scale of 12 arcsec mm^{-1}. The TV camera is provided with a filter wheel with six filter positions. The available filters are CLEAR (UBK7), B (BG 28), V (BG 38), R (RG 630) and EMPTY (no filter). Note that the empty position will give a different focus position for the TV. These filters do not give a standard photometric system and the Johnson letters are given for guidance only.

The TV can be focussed independently to compensate for different filter thicknesses.

1.3 Slit viewing

The normal method of acquisition when ISIS is being used is to view the slit, which is tilted by 7.5 degrees, and can be imaged via a one to one transfer lens and flat into the same TV camera used for direct viewing acquisition, with field sizes identical to those provided by the acquisition system.

1.4 Autoguider

The CCD Autoguider is described in detail in *The WHT Autoguider System User Guide*, by P.J. Rudd. The autoguider consists of a CCD detector head fed by a right-angled prism and focal reducing optical system, with a field diameter of 1.8 arcmin. The autoguider utilises the off-axis field. The centre of the autoguider field rotates about the centre of the main field at a radius of 110 to 150 mm (8.2 to 11.2 arcmin) and the entire probe assembly has a radial displacement of 40 mm. The extreme edge of the autoguider field is partially vignetted, but only by about 5%. The autoguider has an azimuthal scan of 180 degrees, so the total area scanned at a field scale of 4.51 arcsec mm^{-1} equals 152 square arcmin or 0.04 square degrees. This gives a good chance of finding a star brighter than 11th magnitude at the galactic equator or 13th magnitude at the galactic pole (C.W.Allen,*Astrophysical Quantities, publ. Athlone Press, 1976*).

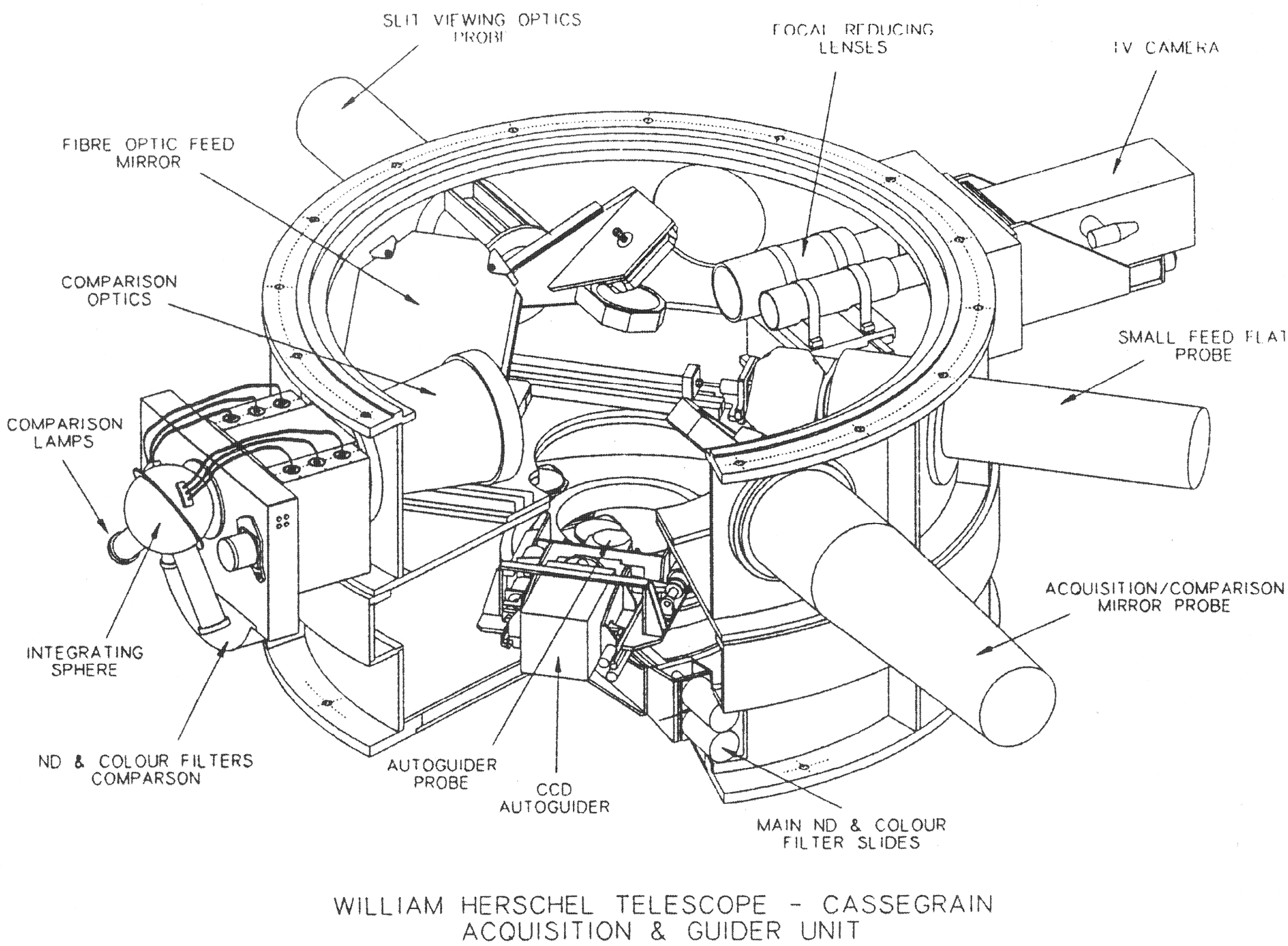

Figure 1: Cutaway view of the WHT Cassegrain A&G Unit, showing the positions of the folding mirrors, Autoguider Probe, and Calibration Sources.

The autoguider head is mounted inside the Cassegrain A&G box, and contains a frame-transfer CCD having 385 by 288 active pixels, with 22 μm pixels, with a peak quantum efficiency of 50% at 7500Å. This is mounted on a copper block connected to a two stage Peltier thermo-electric cooler. This cools the CCD to around -35°C to reduce the dark current. The CCD must be flushed with Nitrogen when the cooler is in operation to prevent the formation of condensation and ice crystals on the CCD surface. If this is not done the CCD could be badly damaged. There is a flowmeter on the nitrogen outlet line from the CCD Autoguider, the user should check that nitrogen is flowing through this as soon as the CCD begins cooling.

The limiting magnitude of the autoguider, for guiding at 1 Hz, is about V=17.5 in good conditions (i.e. 1-arcsec seeing and a dark sky). Autoguider errors are sent to the telescope control system. When the telescope is servoing on these errors, the telescope tracking errors are reduced to the 0.1 arcsec level. The autoguider is provided with a filter wheel with six filter positions. The available filters are CLEAR (UBK7), EMPTY (no filter; different focus), OPAQUE (blanking disk), B (BG 28), V (BG 38), and I (RG 630). These filters do not give a standard photometric system and the Johnson letters are given for guidance only.

The autoguider can be focussed independently to compensate for different filter thicknesses.

1.4.1 Autoguider Geometry

The relative geometry of the slit and the autoguider field is illustrated in figure 2. The autoguider has an azimuthal travel of 180 °, but use of the first 35° of this will result in the autoguider probe vignetting the slit viewing optics. The azimuthal co-ordinate of the autoguider is specified in millidegrees, and the radial co-ordinate in microns, and they are related to the distance from the guide star from the slit centre, and the position angle of the guide star relative to the slit centre, by:–

$$r = 221.7 \times (R_{gs} - 505) \qquad \text{(microns)}$$

$$\theta = 1000 \times (PA_{gs} - PA_{slit} - 90) \qquad \text{(millidegrees)}$$

Where r and θ are the co-ordinates of the autoguider probe in the frame of the A&G box; R_{gs} and PA_{gs} are the distance and sky position angle of the guide star relative to the slit; and PA_{slit} is the sky position angle of the slit.

1.5 Comparison lamps

A calibration system is provided consisting of an integrating sphere into which light is fed directly from two hollow cathode lamps (Cu-Ar and Cu-Ne) and a Tungsten lamp for a red continuum source. Light from a further 6 lamps (Fe-Ar, Fe-Ne, Th-Ar, Al/Ca/Mg-Ne, Na/K-Ne and Deuterium) is imaged via fused silica lenses onto 3 mm diameter fused silica light guides. The Al/Ca/Mg-Ne and Na/K-Ne multi-alkali lamps are primarily for use with TAURUS-2, whilst the Deuterium lamp provides a blue continuum source. Any combination of lamps may be used simultaneously. The exit pupil of the integrating sphere is fitted with an obscuring disk to simulate the telescope entrance aperture obscuration, i.e. the secondary mirror structure. The reverse side of the acquisition mirror is used to feed the calibration light to the instrument. Line maps of the Cu-Ar, Cu-Ne and Th-Ar lamps are published in *ING Technical Note 84*, by J.E. Sinclair.

Two eight-position filter wheels are provided for the comparison system. The filters available in filter wheel A are a clear position, ND filters of 0.2, 0.6, 0.8, 1.8, 3.0 and colour filters GG375

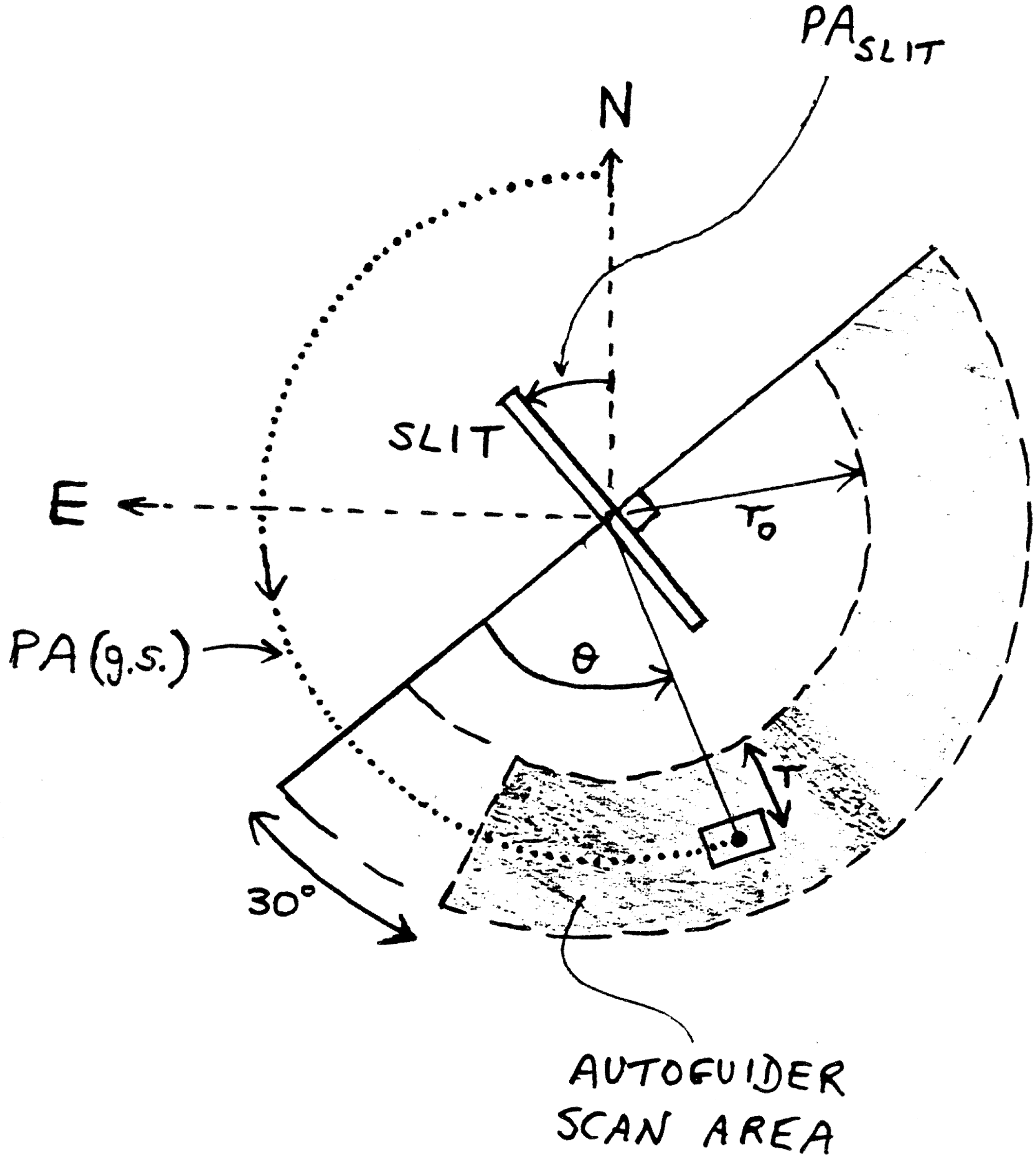

Figure 2: The relative geometry of the Cassegrain Autoguider field. Short bar: the 4 arcmin slit. Long straight line: normal to the slit. Solid short arc: position angle (degrees E of N) of the slit. Black dot in box: guide star in CCD autoguider field. Dotted line: position angle of guide star. The autoguider probe moves in an annulus between the dashed lines, between 8.4 arcmin (r_0) and 11.4 arcmin from the slit centre, but to avoid vignetting the slit viewing optics should be restricted to the shaded area, at $\theta > 30°$. The co-ordinates of the guide probe are r and θ, and the equations relating these co-ordinates and the slit orientation are given in the text.

Table 1: CCD pixel and field sizes at the Auxiliary port

CCD	Pixel size (arcsec)	Field size (arcmin)
GEC P8603	0.10	0.95×0.63
EEV P88300	0.10	2.1×1.9
Tek 1024	0.11	1.8×1.8

and GG495. The filters available in filter wheel B are a clear position, ND filters of 0.3, 0.5, 0.9, 1.2, 2.0, a BG24 colour filter and a clear position.

1.6 Filters

Two filter slides, situated below the autoguider assembly, in the on axis light path, provide colour and ND filtering. Each slide carries five filters in cells, and the cells all carry discrete bar coding for filter identification. The filter cell carrier may be removed and alternative cells fitted. The filters have a maximum diameter of 85 mm. The name of the filter mounted in each position may be determined using a barcode reader. The neutral density filters mounted are ND0.3, ND0.9, ND1.2, ND1.8, ND3.0 and the colour filters mounted are UG1, BG38, GG495, RG630, WG320.

1.7 Polarisation calibration

For polarisation module calibration, a special double cell containing two dichroic polymer filters (i.e. Polaroid) with their polarising axes orthogonal to each other may be fitted to the carrier. Further cells containing either a calcite or quartz crystal may be used for broader wavelength coverage. There may be some spatial problems if the required crystal thickness is too great. This also applies to the use of two parallel silica plates for partial polarisation.

1.8 Auxiliary focus

It is possible to change rapidly from long slit spectroscopy to imaging at the Cassegrain focus by inserting a diagonal flat into the light path in the A&G unit, sending the light to a CCD camera mounted at the auxiliary port. At this f/11 Cassegrain focus, the telescope scale is 4.51 arcsec mm^{-1} at the detector, which gives a scale of 0.10 arcsecs per 22 μm CCD pixel. At present GEC P8603, EEV P88300 and Tek 1024 square CCDs are offered at the Auxiliary focus; these detectors are described in more detail in Chapter 2. Table 1 summarises the pixel and field sizes given by these CCDs.

The unvignetted field at the Auxiliary port is currently limited by the shutter to 2.0 arcmin diameter, thus the final unvignetted field is the intersection of this circle with the rectangle given in the table.

2 ISIS and FOS-II Spectrographs

2.1 Overall layout

ISIS and FOS-II comprise three spectrographs sharing a common slit unit, dekker slide, optics for spectropolarimetry, and some filter slides. FOS-II lies directly below the optical path, and is designed to provide the highest throughput at a dispersion of 400 Å/mm in first order, and 200 Å/mm in second order. Each of the two arms of ISIS is a conventional spectrograph, with interchangeable reflection gratings, and a horizontal optical layout. The optical components of the two arms, and the anti-reflection coatings on those components, are optimised for specific wavelength ranges. The upper arm is optimised for the range 3000 - 6000 Å, and is called the BLUE arm, whilst the lower arm is optimised for the range 5000 - 10000 Å, and is called the RED arm. Light is fed into the two arms of ISIS by 45° folding mirrors or prisms on the optical axis of the telescope and at the levels of the respective collimators. The folding mirror for the blue arm can be replaced by one of a range of dichroic filters, which reflects blue light and transmits red light, allowing simultaneous use of the blue arm of ISIS with either the red arm or FOS-II.

2.2 Polarisation optics

There are four optical components immediately above the dekker slide and immediately below the slit assembly which are used exclusively for polarimetric observations. The principles behind spectropolarimetric observing, and the ISIS/FOS-II system, are described in detail in *The ISIS Spectropolarimetry Users' manual*, by J. Tinbergen and R.G.M. Rutten. Briefly the polarisation optics consist of:-

- A quarterwave plate, at present borrowed from the People's Photometer, effective over the wavelength range 3000-11000 Å, which can be inserted into the beam, set to any position angle, or rotated continuously at a speed of several Hz. The quarterwave plate converts circular into linear polarisation, so that the Savart plate (linear beamsplitting polariser) can detect its presence. Rotating the quarterwave plate rotates the linear polarisation striking the Savart plate.

- A halfwave plate, 40mm diameter, which can similarly be set to any angle or rotated continuously. Rotating the halfwave plate through n degrees results is a rotation of $2n$ degrees of the polarisation vector of the light. The halfwave plate is usually mounted below the quarterwave plate, which gives the largest field of view and best slit viewing for linear polarisation studies. It is possible to interchange these plates, although this requires that ISIS be taken off the telescope.

- A calcite block or Savart plate, located in the FCP (Field lens, Calcite, Polaroid) tray immediately below the slit. This is effective over the wavelength range 3300-11000 Å, and gives two beams separated by an amount which depends upon wavelength, but is in the range 2.1 - 2.6 mm over the effective wavelength range. The two beams are 100% polarised, orthogonally, and their relative intensity depends upon the polarisation vector of the incoming beam. Use of the Savart plate requires the spectrograph to be refocussed by 9600μm in the Blue arm, and 9300μm in the red in the sense that both collimator positions

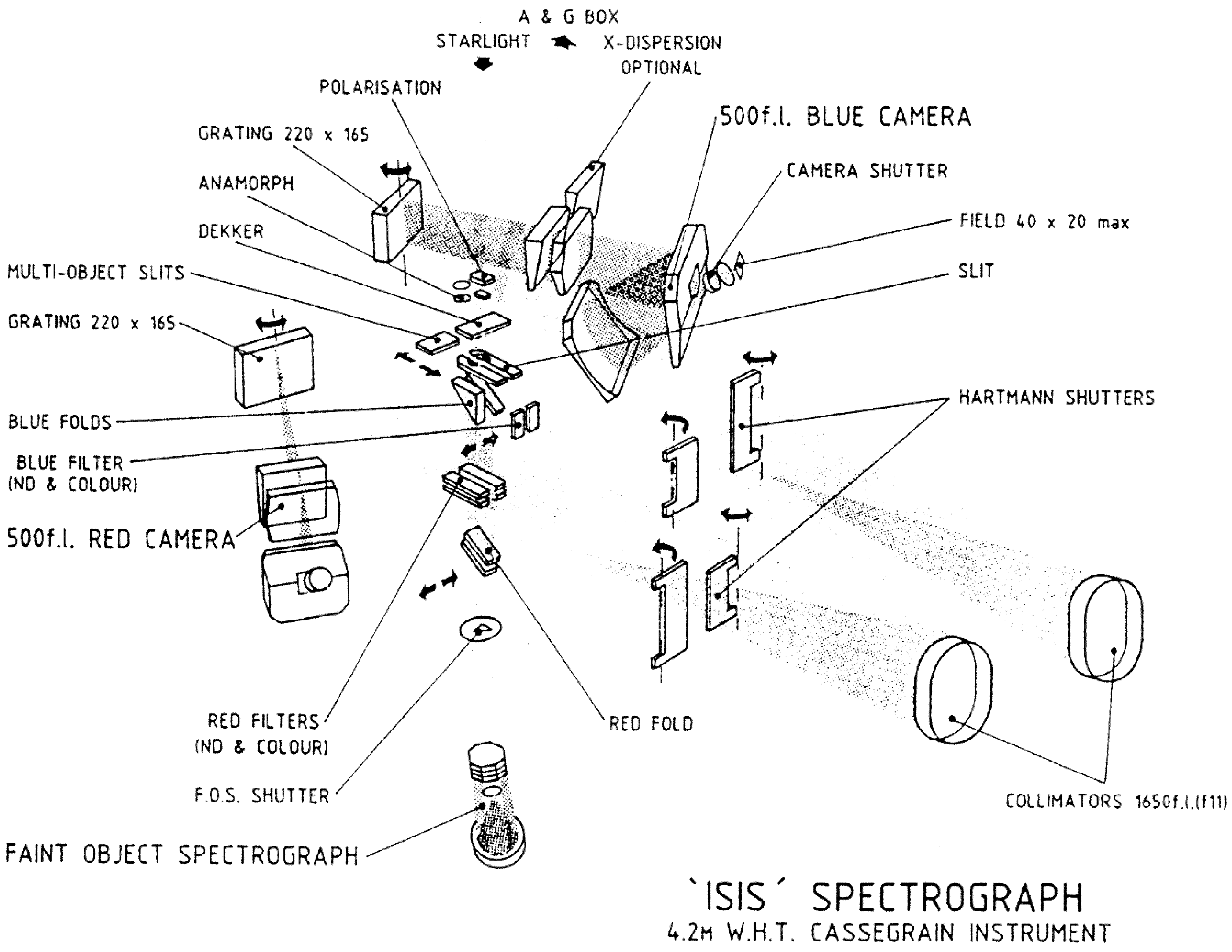

Figure 3: Exploded view of the optical components of ISIS and FOS-II, showing the light paths through the components.

Table 2: The General and Polarimetry Dekker Slides

Slide position	General dekker	Polarimetry dekker
1	1.2 arcsec hole	Right half of slit clear
2	20 arcsec slot	Left half of slit clear
3	Two 20 arcsec slots 100 arcsec apart	Comb: 9 arcsec holes, 13.5 arcsec gaps
4	1.2 arcsec occulting bar in 20 arcsec slot	Comb: 4.5 arcsec holes, 13.5 arcsec gaps
5	Clear	Comb: as position 4 but offset by 9 arcsec
6	Clear	3 hole comb
7	Clear	5 hole wide comb on right half of slit
8	Clear	Clear

must be increased. Full details of the Savart plate are given in *The ISIS spectropolarimetry users' manual.*

- A polaroid filter, located in the FCP tray. This is used when full spatial coverage is required, and it is therefore impossible to use the dekkers which are used with the Savart plate.

2.3 The slit area

The slit is common to the two arms of ISIS, as well as FOS. The slit length is 53mm (4 arcmin), and the width is continuously variable between 30 μm (0.14 arcsec) and 5 mm (22.6 arcsec). The slit is polished and aluminised and inclined to the optical axis of the telescope at an angle of 7.5 degrees to allow viewing of the reflected image in the A&G box TV camera. The width is driven by a linear motor controlled by the ISIS 4ms microprocessor, and encoded via the ASL transducer bridge which also encodes the collimators. The slit unit is a two position carriage, one position contains the conventional long slit, and the other position is a two position cross slide, containing a wide aperture which is used for mounting multi-slit masks, and the slit end of the ISIS fibre system. This cross slide is itself remotely driven from the ISIS 4ms microprocessor.

Dekkers are mounted in 8 position slides, which are inserted in a driven mechanism immediately above the slit. The slides are interchangeable and the procedure for changing them is described is section 8.2.3. At present there are two dekker masks, one for general use and one for spectropolarimetry, and they contain:-

The long slit unit has gaps at each end, and it is important to use a long slit dekker (position 6 or 7) when observing, and not to observe with the dekker out (position 0). Ghosting is reduced considerably by use of the long slit dekkers.

2.4 Folds and Dichroics

There is a remotely driven three position slide which mechanism contains options for the blue fold. One of these positions is usually clear; the others contain any of: a folding prism; a 45 degree mirror; or any of a number of dichroic filters, which are listed in Table 3 ; and described in more detail in Appendix C . There are three interchangeable slides for this slide mechanism; the procedure for changing these is described in Section 8.2.3. If the folding prism is used then

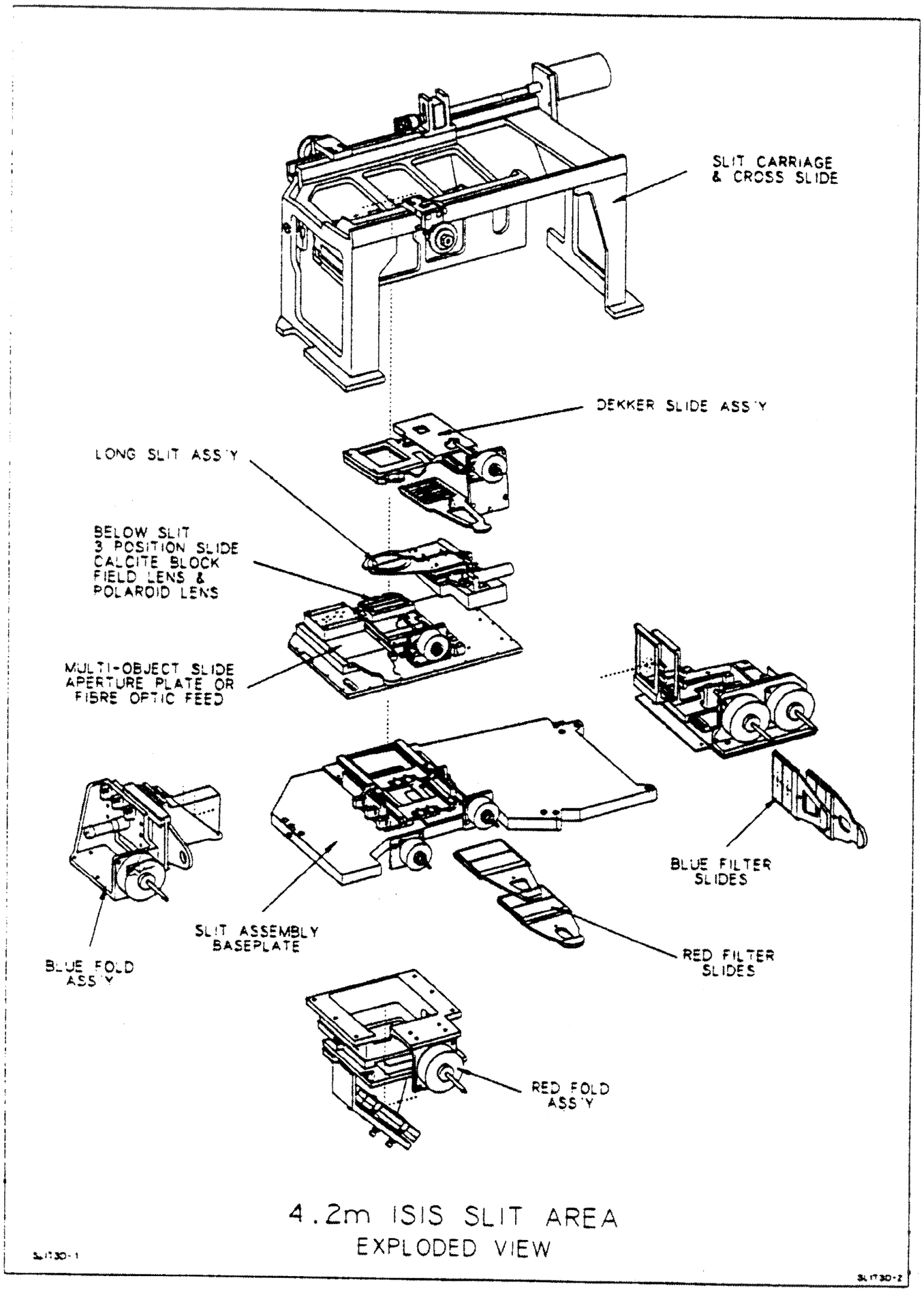

Figure 4: The Polarimetry optics, slit area components, folds, and below slit filters of ISIS and FOS-II.

Table 3: Dichroic Filters for the blue fold slides

Dichroic Name	Half Power point of crossover ($\mathring{A}$)	Width of crossover ($\mathring{A}$)	Half power point of blue rolloff ($\mathring{A}$)	Focus Offset for Red Arm (microns)
4550	4400	900	<3100	250
5300	5300	900	3300	250
5400	5370	800	3350	250
5400	5400	350	3350	750
5700	5720	350	3450	750
6100	6100	500	3800	750
7500	7200	800		250

the blue arm of ISIS will require a substantial refocus, in the sense that the blue collimator position must be increased by about 26000 microns compared with the value for a mirror or dichroic.

If a dichroic filter is in the beam the optical thickness of the material introduces a focus offset for the red arm or FOS. The focus offset for the red arm, in microns, is tabulated above. The value of the red collimator position is always higher if a dichroic is in the beam than if the red fold position is clear.

The 7500 $\mathring{A}$ dichroic gives only a 2 arcminute unvignetted field along the slit, and is generally used for stellar observations.

The red fold consists of a remotely driven two position slide; one position is clear while the other contains a silver mirror with a reflective stack overcoat to send light into the red arm.

2.5 Below Slit filters

There are four 2-position remotely driven filter slides: two in the blue arm beam just after the blue fold; and two below the blue fold but above the red fold; the latter two are for use with both the red arm of ISIS and FOS-II. There is a range of neutral density and colour filters for use in these slides. The blue arm filter slides are normally used to hold neutral density filters for when the IPCS is in use; the red arm filter slides are used to hold long pass filters to cut out second order blue light. The red arm filters slides cal also hold a coloured field lens for use with FOS-II in multi-slit mode.

Procedures for changing the below-slit filters are described in Section 8.2.3.

2.6 Collimators

Both collimators are off-axis parabaloids with a focal length of 1650mm, and provide a collimated beam of 150mm diameter. The coating material on the collimators is optimised for the wavelength range of the particular camera, and is silver with a reflective stack overcoat for the red collimator and aluminium for the blue camera.

As with most astronomical grating spectrographs, an image of the pupil is formed on the grating in order to minimise the grating size required.

The collimators are remotely driven by stepper motors and their position is encoded by the ASL bridge which is also used to encode the slit width. The spectrograph arms are normally focussed by driving the collimators; and the collimator position is repeatable to better than 10

Table 4: Properties of the ISIS gratings used blaze to collimator with the common detectors

Grating name	Blaze (Å)	Dispersion (Å/mm)	Wavelength Pixel (Å) EEV	Tek	IPCS	Spectral range (Å) EEV	Tek	IPCS	Slit Width (arcsec) for 50μm (detector)
R158B	3600	120	2.70	2.88	1.26	3350	2949	3225	0.77
R300B	4000	64	1.44	1.54	0.67	1788	1576	1720	0.78
R600B	3900	33	0.74	0.79	0.35	919	809	887	0.82
R1200B	4000	17	0.38	0.41	0.18	472	420	457	1.00
R2400B	Holo	8	0.18	0.19	0.08	224	195	215	1.15
R158R	6500	121	2.72	2.90		3378	2970		0.78
R316R	6500	62	1.40	1.49		1733	1525		0.82
R600R	7000	33	0.74	0.79		919	809		0.90
R1200R	7200	17	0.38	0.41		472	420		1.15

μm. With no extra refractive components (dichroics, prisms, Savart plate, filters) between the slit and the collimators the *nominal* focus positions for the ISIS collimators are 6000μm for the blue arm, and 9000μm for the red arm. The spectrograph should be focussed with the collimators within 3000μm of these nominal values, otherwise the spectrograph will be astigmatic, and the best focus on a spectral line will result in a degradation of the spatial resolution along the slit. If the best focus falls outside this tolerance, then the detector must be moved until the best focus is within this range. The procedure for doing this is described in Chapter 5.

2.7 The ISIS gratings

Nine gratings are provided for ISIS, four for the red arm and five for the blue arm. The first letter of the grating name denotes the method of manufacture, eight of the nine gratings are copies of ruled masters manufactured by Milton Roy, whilst H2400B is a holographic grating manufactured by Jobin Yvon. The number denotes the number of lines per millimeter. The last letter of the name indicates which arm of ISIS it is intended for; those ending in B are intended for the blue arm, and those ending in R for the red arm. However the grating cells are identical, and all gratings will mount in either arm. All gratings have a ruled area of 154 x 206 mm. Grating R1200B was ruled in two halves; this can be seen quite easily if the grating is held up to the light.

Gratings can be used either blaze to collimator or blaze to camera. Use blaze to camera gives somewhat higher dispersion, but as the anamorphic reduction factor is reversed this is at the expense of a greatly reduced slit to plate reduction factor, *especially* at high dispersions. The ISIS gratings are almost invariably used blaze to collimator, and the slit width in the table below, and the grating angles given by the procedure `CENWAVE` rely upon the assumption that the grating is mounted blaze to collimator.

The table below gives the parameters of the gratings, and the pixel size and spectral range obtained with EEV and Tektronix CCDs (22.5 and 24 micron pixels respectively) and for the blue gratings with the CCD-IPCS (10.5 micron pixels). The final column in the table below gives the slit width in arcseconds which will project to 50 μm on the detector.

There is also a single silver coated plane mirror in a grating cell, originally intended for alignment purposes, but which can be used in place of the gratings for direct imaging at a plate scale of 14.9 arcsec/mm. To use the mirrors for imaging they should me mounted in the grating

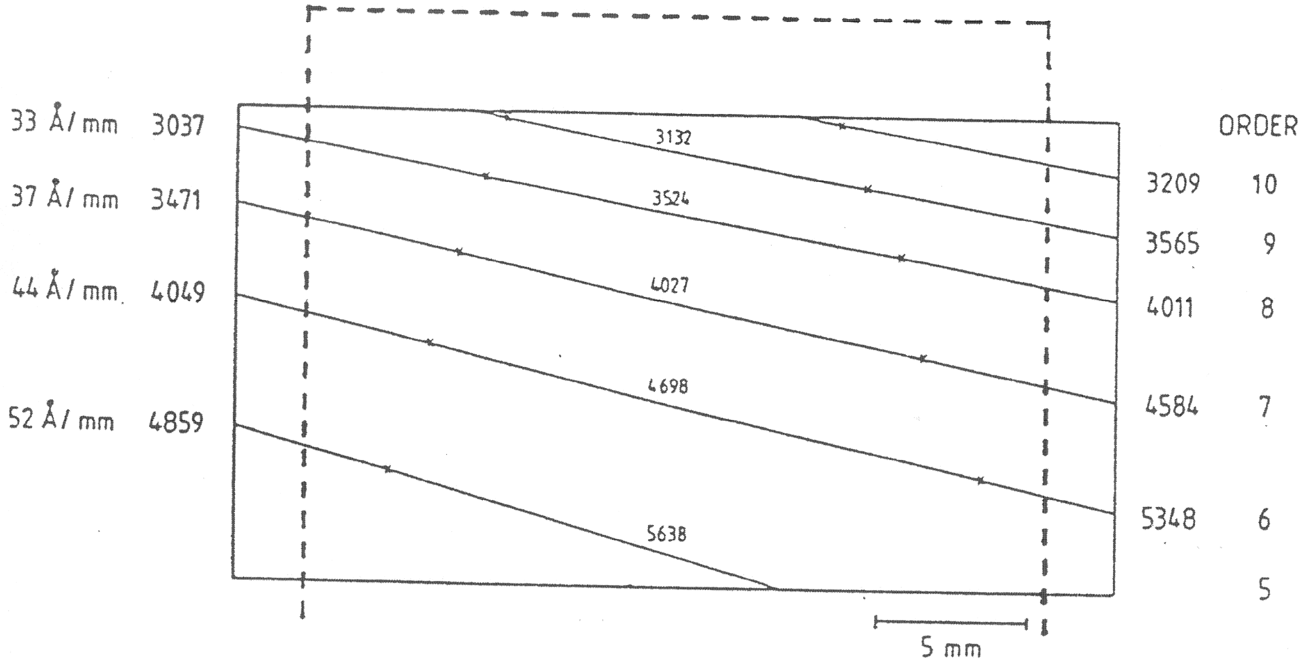

Figure 7: Format of the output of the blue cross-disperser, with IPCS (solid lines) and EEV P88300 CCD (dashed lines) outlines superimposed. The solid lines represent the outline of the IPCS field in a typical format, and the dashed lines a TEK 1024 chip. The crosses mark the points at which the grating efficiency drops to half of its peak value in that order. The central wavelength of each order is marked.

cells, which should then be set to the autocollimation angles with the commands `REDGRAT` or `BLUEGRAT`. The autocollimation angles are 35500 for the red arm and 30800 for the blue arm.

The grating cell angles are driven by a stepper motor from the ISIS 4ms microprocessor, and their positions are encoded by Ferranti 35HA optical absolute encoders. The units for these mechanisms are millidegrees, and the encoders are accurate to 3 millidegrees, and repeatable to 2 millidegrees. The grating angle offsets are grating independent. The demanded central wavelength can be specified with the ICL procedure `CENWAVE` (see chapter 7), and the grating angle offsets are taken into account by this procedure.

2.8 Cameras

The ISIS blue and red cameras are of a folded Schmidt design, with a focal length of 500 mm giving a scale of 14.9 arcsec/mm along the slit. The reduction factor along the spectrum is dependent upon the grating angle, and is presented graphically for the ISIS grating set in Appendix D. The air-glass surfaces of the refracting elements of the two cameras are coated with anti-reflection coatings optimised for the respective wavelength ranges, and the reflecting elements are coated with silver plus a reflective stack for the red arm, and aluminium for the blue arm.

2.9 Cross-Dispersers

Each arm has a slide for an optional cross-dispersing grism, although at present only the blue cross-disperser has been purchased. The cross-disperser is a special ruling 100 lines/mm fused silica grism blazed at 4400 $\AA$. This will be used in conjunction prime disperser which is a Bausch and Lomb 75 lines/mm grating blazed at 3μm, to provide complete spectral coverage from 3000 - 5600 $\AA$ on an EEV P88300 or Tek 1024 CCD or the IPCS on the blue camera. The cross-dispersed mode will use orders 5 to 10, and the maximum slit length to avoid order overlap will be 30 arcsec. The spectral resolving power of the cross-dispersed mode is about 2200. Figure 7 shows the format of the cross-dispersed spectrum superimposed on the outlines of the IPCS and a TEK 1024 CCD.

2.10 The Faint Object Spectrograph (FOS-II)

The original 'FOS' concept for a high-throughput, cross-dispersed spectrograph (FOS-I on the INT) was described by Breare *et al.* (*MNRAS*, **227**, 909, 1987). FOS-II for the WHT follows the same basic design, but with a higher dispersion, and is described by Allington–Smith *et al.* (*MNRAS*, **238**, 603, 1989). In brief, it covers a wavelength range from 4600–9700Å in 1st order and 3500–4900Å in 2nd order, with dispersions of 8.7 and 4.3Å per CCD pixel, respectively. The optical design of FOS-II is due to S.P. Worswick, and is based upon the design by C.G. Wynne for FOS-I.

The optical design is based upon an F/1.4 Schmidt camera, working without a collimator in the diverging f/11 Cassegrain beam. The dispersion is provided by a 150 l/mm transmission grating, blazed at 7300 $\AA$, together with a cross-dispersing prism. The camera has an aspheric corrector plate cemented to the underside of the grism/prism assembly and a silver-coated spherical mirror. This optical arrangement gives a dispersion of 400Å/mm in 1st order and 200Å/mm in 2nd order. A field flattening lens produces a flat focal plane at the detector surface. The detector package is small enough to fit within the shadow of the telescope's secondary mirror

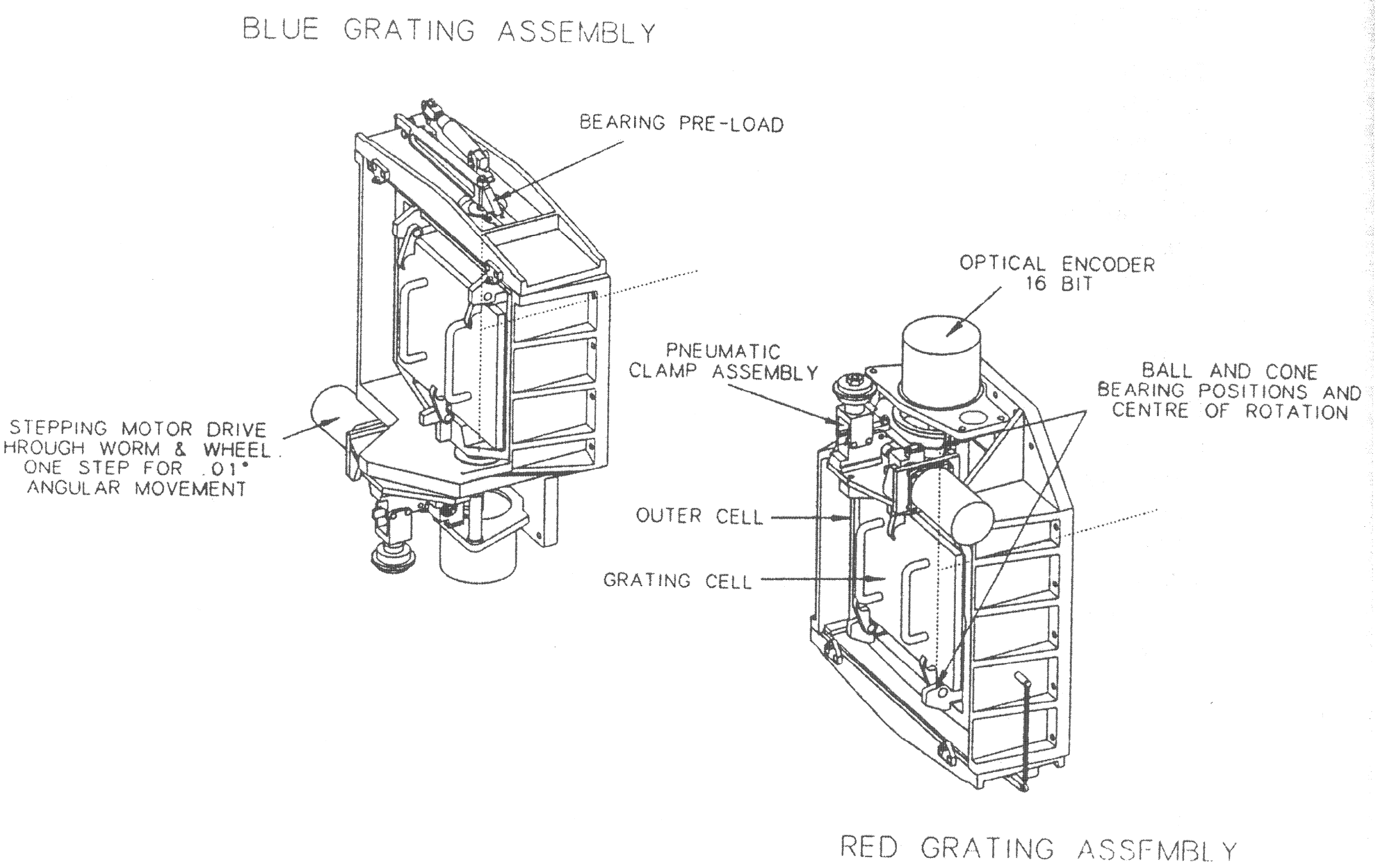

Figure 6: The ISIS Grating Cells

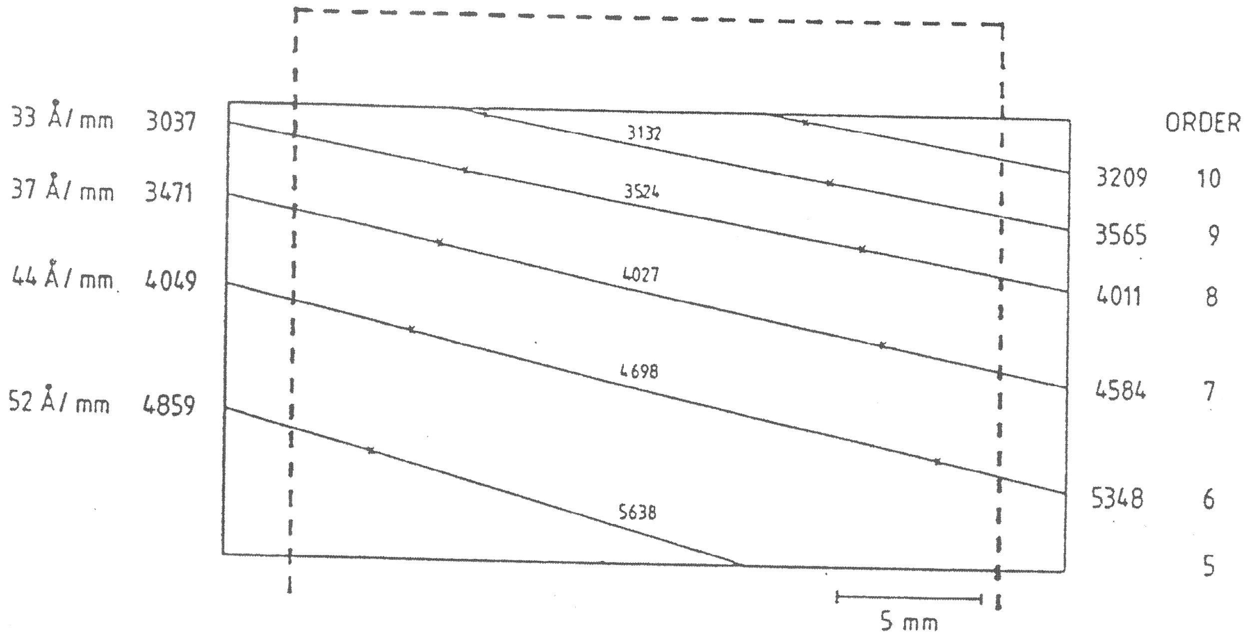

Figure 7: Format of the output of the blue cross-disperser, with IPCS (solid lines) and EEV P88300 CCD (dashed lines) outlines superimposed. The solid lines represent the outline of the IPCS field in a typical format, and the dashed lines a TEK 1024 chip. The crosses mark the points at which the grating efficiency drops to half of its peak value in that order. The central wavelength of each order is marked.

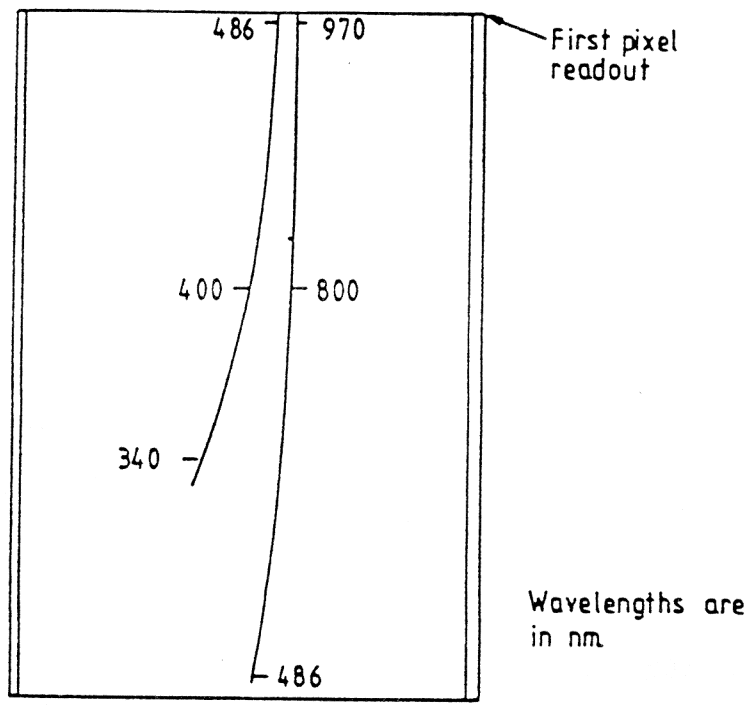

Figure 8: The format of the first and second order spectra on the FOS-II Chip

and so minimize obscuration losses. The optical system has a resolution of 33μm FWHM (zero slit width) at the camera focus, corresponding to 13Å in first order in the spectral direction, and 1.2 arcsec along the slit.

The electronic iris shutter is located just below the interface between FOS-II and ISIS, and a pair of Hartmann shutters, which can be inserted into and removed from the beam either by operation of a manual lever, or by motors controlled by the FOS 4ms controller The focus position and tilt of the detector can be remotely set by the 4ms controller. The focus and CCD tilt are defined by the position of three push rods on which the ring bearing the CCD is supported. The push rods are moved along axis by three motor-micrometers. The 4ms microprocessor is located in one of the Cassegrain cubicles, and is interfaced to the WHT Utility Network, and can accept commands over the Utility Network or from a local terminal.

The current detector for FOS-II is a GEC P8603 CCD, with a dye coating to enhance the blue response, and the format provided by the spectrograph is shown superimposed upon an outline of this CCD in Figure 8. Because the inter-order separation at the blue end of the CCD is small FOS-II is used either with a 20 arcsec dekker to limit the spatial coverage, or with a GG495 filter in the below slit filter slide to eliminate second order for longslit work. The readout noise of the current FOS-II CCD chip is 8e$^-$ r.m.s.

2.11 Multi-Slit Unit

The wide aperture in the slit unit can accommodate multi-slit masks containing slits for observation of up to 10 separate objects. The total field of view is 4 by 2 arcminutes for FOS-II and 4 by 0.9 arcminutes for the red and blue arms of ISIS. The multi-slit masks are made from 0.55mm brass plate on La Palma with a CAMM3 engraving machine, which is controlled by a PC. Use of multi-slits has now been superseded by the Low Dispersion Survey Spectrograph (LDSS), which is built specifically for multi-object work, and the multi-slit unit is not currently offered to users.

2.12 Then ISIS Fibre System

The ISIS fibre system enables the ISIS spectrograph on the WHT to be fed with fibre optic bundles. The bundles link the auxiliary focus, located on the acquisition and guiding box, with the ISIS slit area (see figure 9). Below this position, ISIS can be configured in the same way as for the long-slit unit. Then, both arms and FOS can be used in the usual form. However, several ISIS facilities, including autoguider and comparison lamps, cannot be used.

The ISIS fibres system is composed of the following elements:

- **Auxiliary focus**. As the Cassegrain focus is inaccessible when ISIS is mounted on the telescope, the fibres will be placed at the Auxiliary Port of the A&G box. This focus, with a 15 arcmin field, is fed through the large mirror of the A&G box. *FOCAP* aperture plates are used at this auxiliary port to plug the fibres.

- **Fibre optic bundle**. One bundle with 61 fibres allows up to 61 objects to be observed simultaneously. The diameter of the fibre core is 400 microns or 1.8 arcsec.

- **Guiding system**. One coherent fibre bundle and two semicoherent fibre bundles allow autoguiding or manual guiding. These bundles also enable the focussing and set up of the telescope.

- **Calibration system**. Wavelength calibration is provided by a box which can be mounted on the opposite side of the A&G box from the Auxiliary port, in which any of Argon, Neon or Mercury lamps can be located. The calibration lamps provide a diffuse illumination over the entire Auxiliary port of the A&G box; no attempt is made to mimic the pupil of the telescope.

2.12.1 Auxiliary focus mounting

The Cassegrain focal plane is inaccessible when the ISIS spectrograph is mounted on the telescope. An auxiliary focus is needed when fibre systems are used. This auxiliary focus is available at a side of the Cassegrain acquisition and guiding box. It is accessed via a large flat mirror which is inserted at a 45^o angle to the main telescope beam. The large flat mirror provides a full 15 arcmin field.

The optical characteristics of the Cassegrain focus are well established theoretically and they would be expected to be the same on the auxiliary focus. In order to corroborate this, an experimental scale has be obtained for the auxiliary focal plane within this work. For multi-object spectroscopy with fibre optics, an accurate focal plane scale determination is necessary because the fibre positions (X and Y) on the focal plane are calculated from the object R.A. and DEC coordinates through the scale. An error of 0.2% in the scale results in a loss of 50% of the star's light on a fibre at the edge of the field.

To obtain the focal plane scale several photographic plates of good astrometric fields have been taken. With the star positions on the plates and their astrometry, apparent celestial coordinates have been found. Finally, effects of annual aberration, diurnal aberration, light deflection, atmospheric refraction have been taken into account to find the angular separation between each star pair. The average of the ratios between the separation of each star pair in plate and celestial coordinates yields the focal plane scale. The value of the auxiliary focal plane scale found in this way is 221.863 $\pm$ 0.134 microns/arcsec (ie. 4.507 $\pm$ 0.003 arcsec/mm).

The mounting for the fibre system at the auxiliary focus consists of two main structures; an interface for the auxiliary port and a plate holder. The fibres are placed at the auxiliary port using aperture plates, *FOCAP* system (see section 2.12.4). These aperture plates are held in position by four flanges on the plate holder. Three pilot pins determine the aperture plate position. Finally, the plate holder is mounted on the A&G box by means of the interface, using kinematic seats in order to be relocated accurately.

2.12.2 Fibre Bundle

The ISIS Multi-object fibre optic bundle consists of 61 Polymicro Technologies FHP400/475/510 fibres of 2.6m length each. Figure 10 shows their attenuation curves. On the auxiliary focus, the 400 μm diameter fibre core covers an area of 1.8 arcsec in diameter on the sky.

The focal plane end of the fibre is inserted into a connector which serves to protect and accurately align the fibre on the aperture plate. Figure 11 shows this connector, where **A** is the focal plane terminal ' **B** is a stainless steel microtube with diameters 685/1100 (inner/outer) and **C** is a silica microtube, TPS530/660 of Polymicro Technologies. **B** holds the fibre to the terminal, while **C** ensures that the fibre is concentric. Epoxy resin Epotek354 was used only between the fibre and **C**, and between **C** and **B**. In this way, stresses caused to the fibre end are reduced.

For the mounting corresponding to the slit 61 holes have been made in an aluminium alloy piece. The hole diameter is 680 μm and the separation between hole centres is 860 μm. Then, the separation between the centres of two adjacent fibres is 2.15 times the fibre nucleus diameter. This is enough to avoid optical cross talk, except for extreme conditions. A TSP530/660 silica microtube has been used to ensure the concentricity between the fibres and the holes . Keeping in mind the 3.3 ISIS reduction factor, the fibre nucleus diameter is 5.5 pixels on the detector and the separation between the centres of two adjacent fibres is 11.8 pixels.

All the fibres were numbered at the focal plane fibre end. Each fibre number is fixed by its position at the slit.

Both bundle ends were polished using diamond abrasives from 25 to 0.1 microns of particle size. The bundle was tested in the laboratory in order to determine the focal ratio degradation of each fibre.

Figure 12 shows the results of this test. The efficiencies correspond to output beams with the same focal ratio of the input beam (f/11). Neither the fibre absorption or reflection losses at the fibre end are considered.

2.12.3 Guiding system.

The autoguider system in the Cassegrain A&G box cannot be employed when the fibre system is used with ISIS, due to the size of the LARGEFEED mirror.

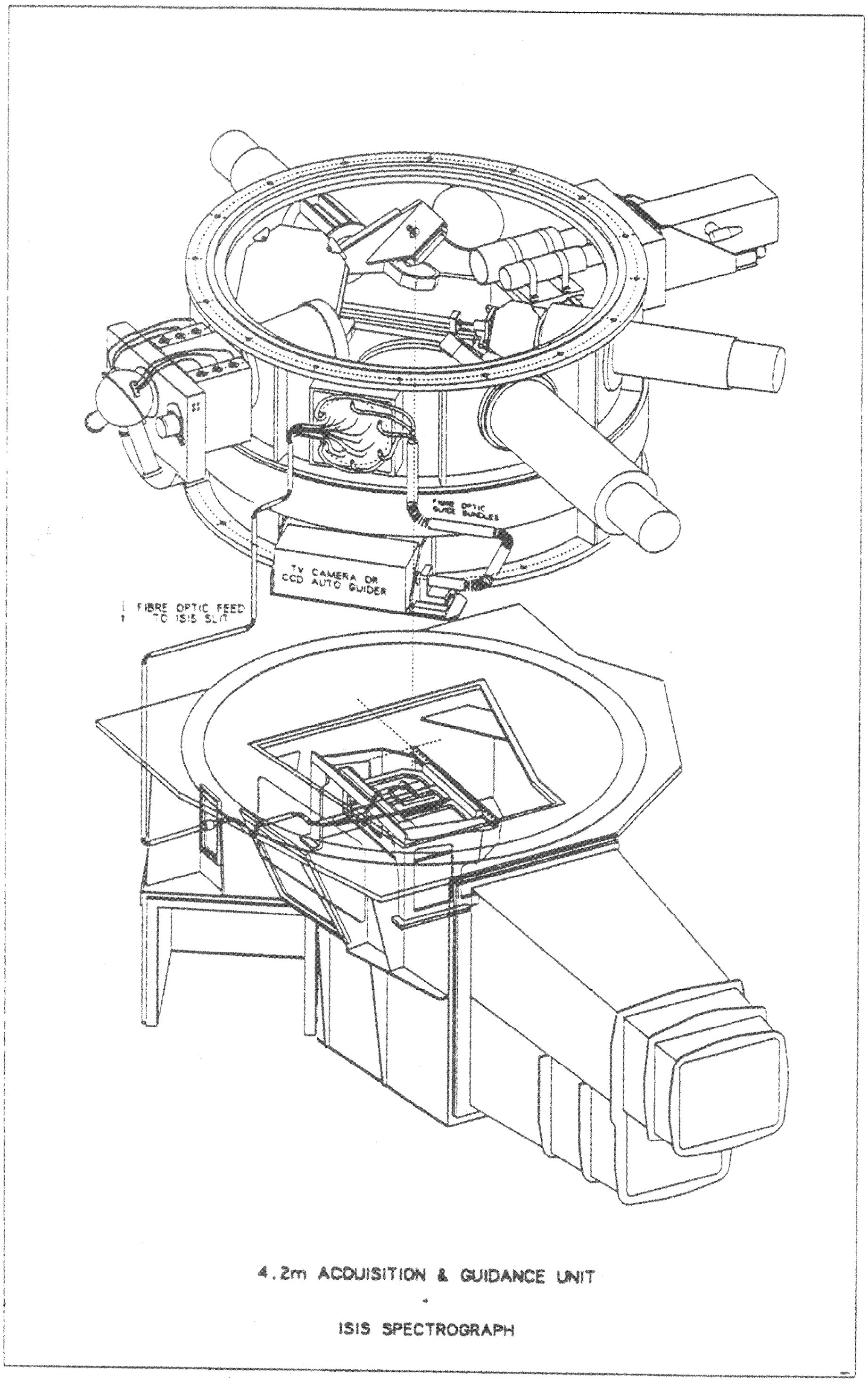

Figure 9: The ISIS Spectrograph and the A&G box with the fibre system

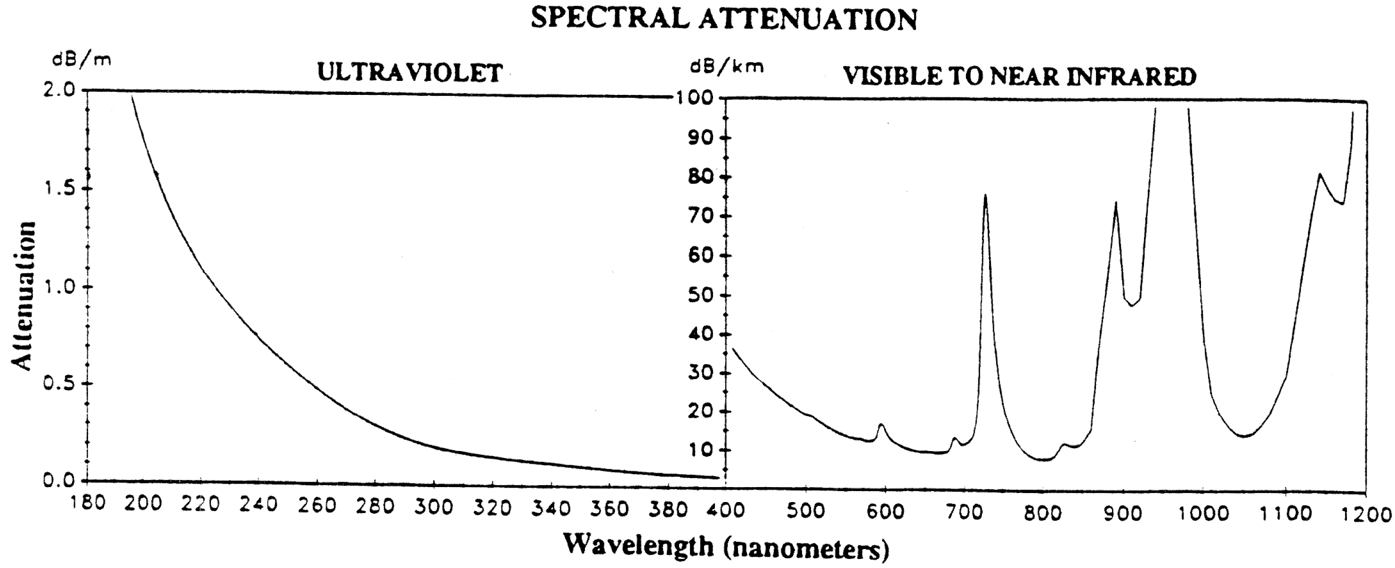

Figure 10: Attenuation curves for Polymicro high OF (FH series) optical fibre

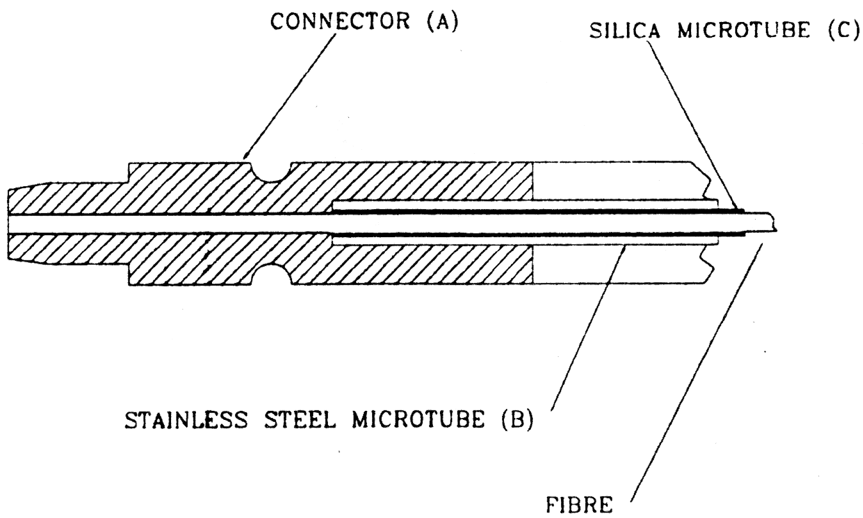

Figure 11: Focal Plane connector for the fibre multi-object bundle

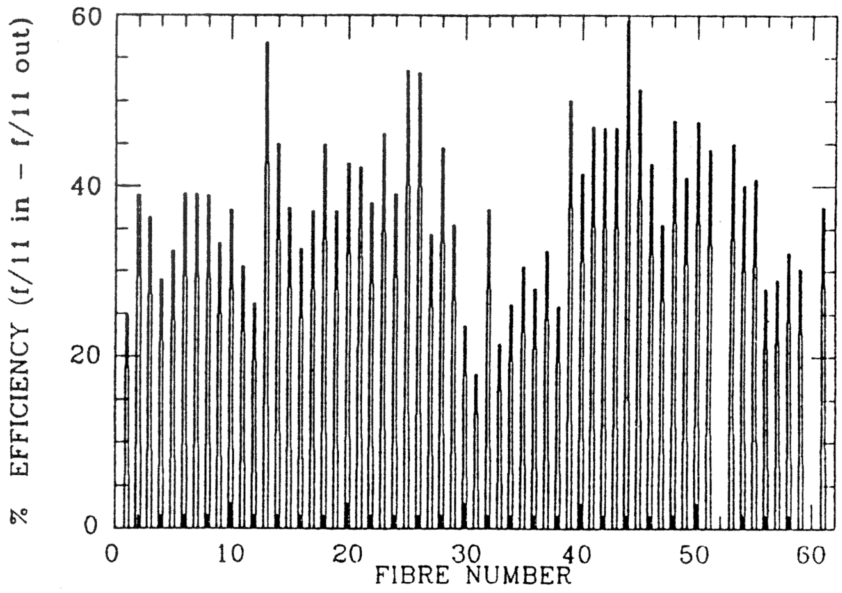

Figure 12: Focal Ratio Degradation Fibre Efficiency

The guiding system consists of three fibre bundles - two semicoherent and one coherent - to carry the image of three stars to a CCD camera. The image of the guide star, obtained with the coherent bundle, can be use by the TV software to generate error signals for the telescope control computer, in order to improve the tracking of the telescope. This image and the two semi-coherent ones can also be used for the set up of the telescope rotator (see section 9.6.2) and for the acquisition of the field (see section 9.6.3).

The guiding system includes:

- A coherent bundle manufactured by ORIEL; it covers a rectangular area of 1.89 X 2.38 mm (8.5 X 10.7 arcsec on the sky). One half has a better packing quality than the other half and, therefore, it is used to monitor the object. The focal plane bundle end is connected to the aperture plate via a connector. This connector has a pin to fix the orientation (North) of the bundle. In order to group together the three guiding bundles, the other end of the coherent bundle was shaped to accommodate the semi-coherent bundles. (Figure 13).

- Two semi-coherent bundles 2.35 m long, each containing 15 fibres; the central fibre and 6 ones in the first ring are of type FHP100/110/125 while the 8 fibres in the second ring are of type FHP200/240/270. The 7 central fibres were introduced in a polymide microtube of type PPC406/444. This group covers an area of $\sim$ 1.6 arcsec on the sky. The second ring of fibres was glued surrounding this microtube. In order to protect it, the whole structure was inserted in a stainless steel tube of type 1100/1470. Each of the semi-coherent bundles built this way covers an area of $\sim$ 4 arcsec on the sky (Figure 14). The orientation (North) of each bundle is marked by a pin.

- A piece to group the 3 guiding bundle ends when connected at the CCD camera. This can be rotated and must be mounted at a certain orientation which is clearly marked.

- A Westinghouse ISEC TV camera.

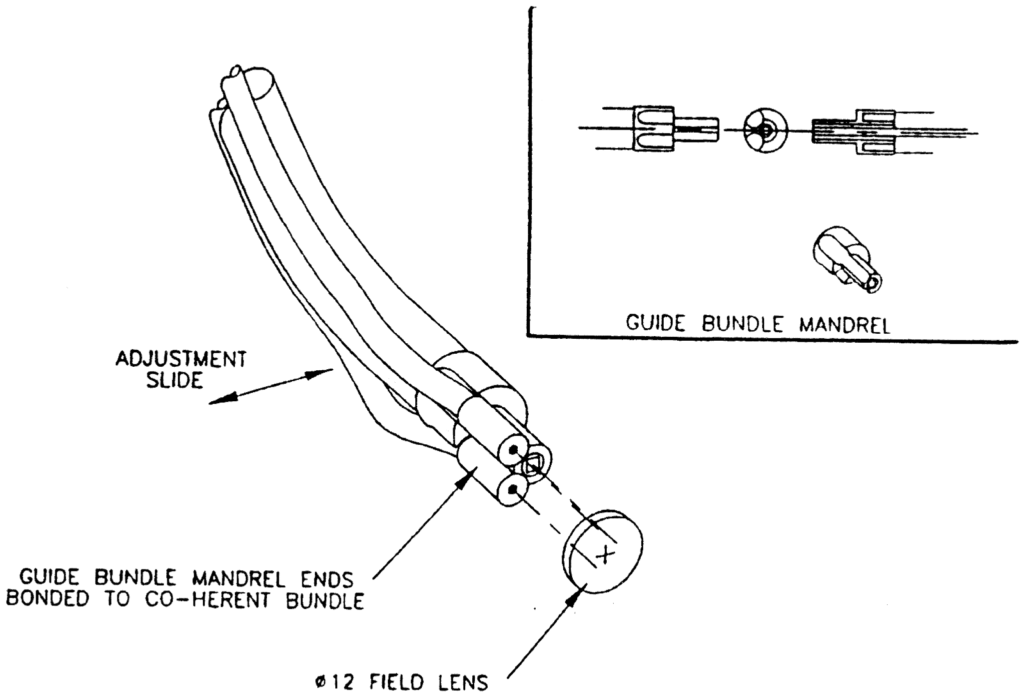

Figure 13: The TV camera end of the coherent and semi-coherent bundles.

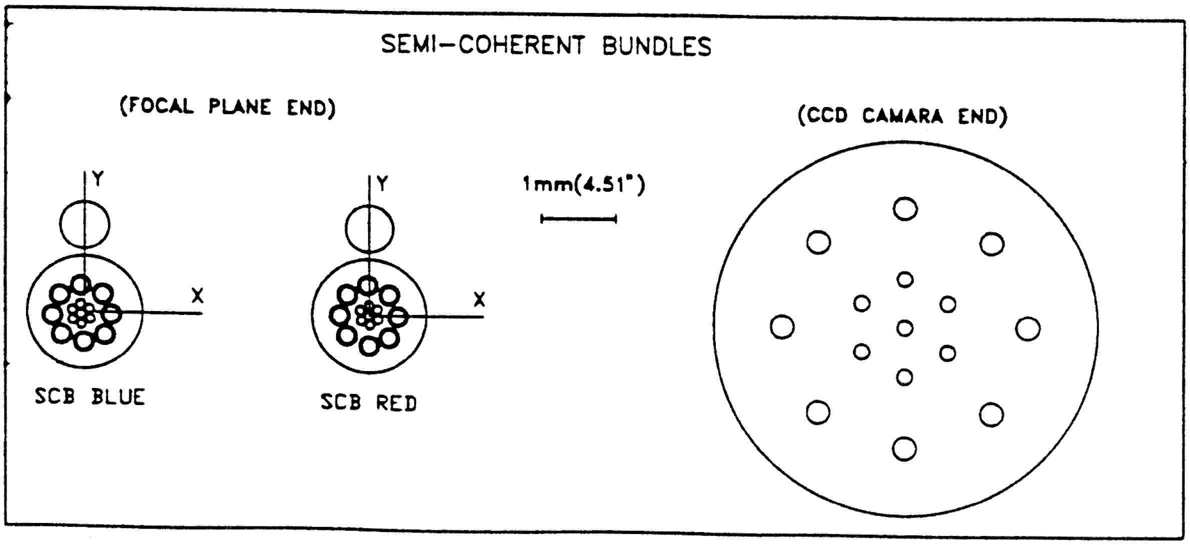

Figure 14: Schematic of the focal plane and TV camera ends of the two semi-coherent bundles.

Table 5: Specification of the holes to be drilled in the Aperture Plates

	Object Position	Drilling Position	Drill diameter (mm)
Single Fibre	(x1,y1)	(x1,y1)	1.983
Semi-coherent bundle	(x2,y2)	(x2,y2)	1.500
Semi-coherent bundle (pin)		(x2,y2+1.175)	0.650
Coherent bundle	(x3,y3)	(x3,y3-0.590)	6.300
Coherent bundle (pin)		(x3,y3+3.010)	0.650

- A lens relay system to produce the image of the guiding bundles on the detector.
- A Melles Griot mechanical system for the manual focussing of the guiding bundles

2.12.4 Aperture plates

For multi-object spectroscopy, the acquisition of the field is performed by means of an aperture plate of type FOCAP. This aperture plate is a 3mm thick brass plate. The plate is drilled at precise locations with holes to accept fibre connectors. The holes must be made for each of the three types of connectors: for the individual fibres, for the two semi-coherent bundles and for the coherent bundle. The characteristics of the holes are specified in the Table 5 (it is assumed that the OY+ direction corresponds to the North direction during the observing epoch).

The vertical displacement that the coherent bundle has with respect to the object coordinates allows it to be observed by the northern part of the bundle, where the packing quality is best (see section 2.12.3).

A high precision (on the order of 20μm) both for the coordinates and the hole diameters is fundamental for accurate field acquisition.

The number of holes to be performed for each type of connector is as follows:

- for individual fibres: – one hole for each target – one for each sky area to be sampled
- for the semi-coherent bundle: – one hole 400" North of the field centre (relative to observing epoch) – one 400" South of the field centre (relative to observing epoch) – one for each guide star for manual guiding (two at least)
- for the coherent bundle: – one hole for the field centre – one for the guide stars chosen for telescope tracking (one at least).

The aperture plates can be made by the CAMM3 engraving machine, in the same way as the multi-slit masks. Observers wishing to use the fibre system should provide accurate co-ordinates for aperture plate manufacture to La Palma staff at least one month in advance of the observing run.

2.12.5 Observing coordinate determination.

The (X,Y) coordinates of the targets to be observed with multi-object spectroscopy, can be obtained in two ways:

- From the astrometry of the field. Transformation of the equatorial coordinates of the targets onto the corresponding aperture plate coordinates (X,Y), is performed with the LAPLATE programme, which is described in Appendix F and which is a modification of the APLATE programme of the STARLINK package, for the geographical coordinates of the ORM. LAPLATE takes into account the following parameters: telescope focal plane scale, thermal dilation coefficient of the aperture plate material, astronomical coordinates for the centre of the field, and possible proper motions of the targets. These are all considered by the programme in order to obtain the appropriate corrections of the X,Y coordinates.
- By taking photographic plates of the field in advance. The positions can be measured with a microdensitometer or other coordinate measuring machine.

Several error sources can contribute to the field acquisition, for example poor astrometry (the drilled holes for the stars do not coincide with the apparent positions) or bad centering of the field and rotator adjustment. Taking direct plates eliminates some sources of astrometric error, at the expense of requiring extra observing time.

Besides the coordinates of the targets, at least three other field stars must be chosen for telescope guiding. These stars must fulfil the following requirements:

- They must have magnitude 12 to 13 in V. Brighter stars are close to the Earth and can have large proper motions, so that it is in general difficult to obtain good astrometry of them. Less bright stars are difficult to observe.
- They must have similar brightness. If not, simultaneous observation on the monitor could be prevented as the brightest ones can saturate the camera while the weakest remain unseen.
- They must be as separated from each other as possible in the field, and, preferably along the East-West direction which is free of atmospheric refraction. This helps in obtaining a more precise field acquisition.

Finally, some positions free of stars must also be chosen, in order to perform sky corrections.

2.12.6 Overall Performance

Geometrical losses, mainly caused by focal ratio degradation, give a mean efficiency of around 25% of the value when observing directly through the slit. Transmission losses in the 2.5 metre fibre length are small, except shortward of 4200 Å; between 7200 and 7500 Å; and longward of 8700 Å. However acquisition is critical, and much larger losses can be produced if the astrometry is not better than 0.5 arcsec for any reason. Some on-sky measurements, taken in 1.3 arcsec seeing, show that the total sensitivity of the system, is 1 photon/s/Å at 4500 Å for a star of B=15 with the TEK1 CCD on the blue arm; and 1.7 photon/s/Å at 7000 Å for a star of R=15 with the EEV3 CCD on the red arm. There is a fibre-to-fibre scatter of 30% in each of these values.

The efficiency is very sensitive to the acquisition procedure, a shift of 1 arcsec from the best position loses about 55% of the light, and a shift of 11 arcmin in the Cassegrain rotator position angle loses about 50% of the light, although this latter figure depends upon the radial distribution of objects.

3 Performance

3.1 Throughput

Nearly all of the light losses within ISIS are due to reflective and air-glass surfaces. There is a small loss of light (<10%) in each camera due to optical vignetting; and for the highest dispersions there is some loss due to overfilling of the grating (see Appendix D). The throughput of ISIS has been measured by C.R. Jenkins and P. Terry, and their results are discussed in detail in *ING La Palma Technical Note no. 88.* Briefly the throughput of the red channel without the grating is measured to be 51%, and that of the blue channel without the grating to be 42%. These measurements were made with a HeNe laser at 6300 Å, and thus for the blue arm are slightly beyond the wavelength range over which it is optimised. The values for the red arm are also slightly low as the red fold mirror in use at the time was below its specification.

The efficiencies of the ISIS gratings have been measured in the laboratory and are presented in Figure 15. The holographic grating has a lower efficiency than the ruled gratings, and is also used at a grating angle such that the beam overfills the grating, resulting in some light loss.

The calculated peak efficiency for FOS-II is 70% in first order at 7300 Å, and 50% in second order at 4100 Å. The diagrams below show the calculated efficiency as a function of wavelength, and the measured efficiency of the entire system (including telescope, atmosphere and detector) as a function of wavelength

The efficiency of the overall system is dependent upon the throughput of atmosphere, telescope and instrument, and the efficiency of the detector. Measured values of the number of photons/AA/s detected for objects of accurately known magnitude are presented in Section 6.

3.2 Stability and radial velocities

The original specification for ISIS was to have flexure no more that 5μm/hour along and perpendicular to the slit during telescope tracking. However measurements of the flexure caused by movements in elevation, and movements of the instrument rotator, suggest that flexure during tracking could be up to 15μm/hour. The cause of the extra flexure is not yet known, and until it is corrected it is recommended that observers requiring accurate radial velocities should take a calibration lamp exposure every 15 minutes.

Measurements of radial velocity standard stars taken during commissioning show that if care is taken with the calibration exposures it is possible to measure radial velocities to an r.m.s. accuracy in the range 1-2 km/s with the highest dispersion gratings (H2400B and R1200R) with either arm of ISIS. The *systematic* offset between ISIS radial velocities and the IAU velocity system is measured to be:-

$$(V_{IAU} - V_{ISIS}) = 8.9 \pm 4.9 km/s.$$

from blue arm observations of radial velocity standard stars and nebulae.

The stability of FOS-II has been measured to be better than 1μm/hour when tracking an object through the zenith.

3.3 Scattered Light

Scattered light in ISIS is minimised by the use of optimised anti-reflection coatings, and if scattered light would be a serious problem for a particular observation it is important to exclude

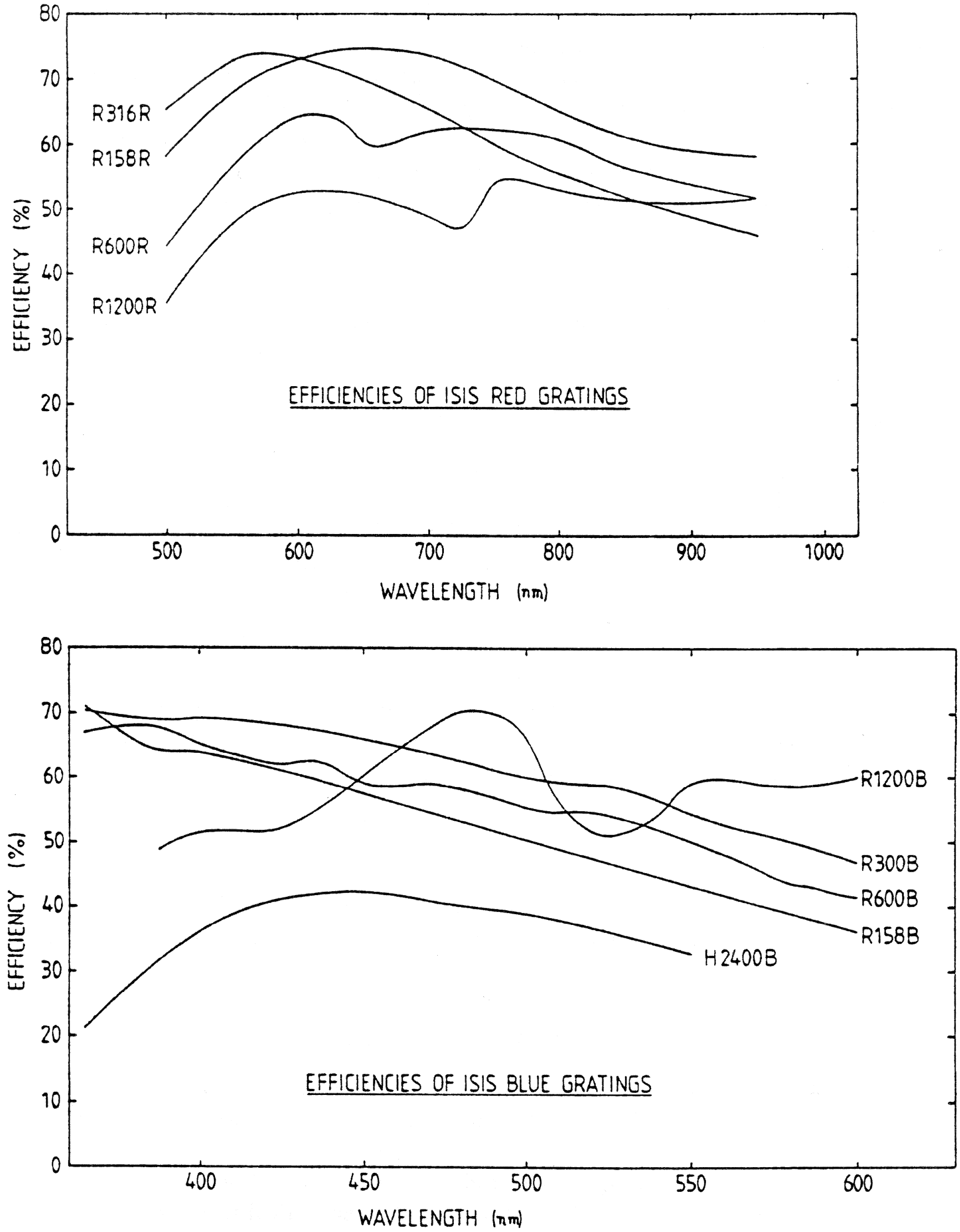

Figure 15: The upper panel shows the efficiencies of the ISIS red gratings, and the lower panel those of the blue gratings, as measure in the laboratory.

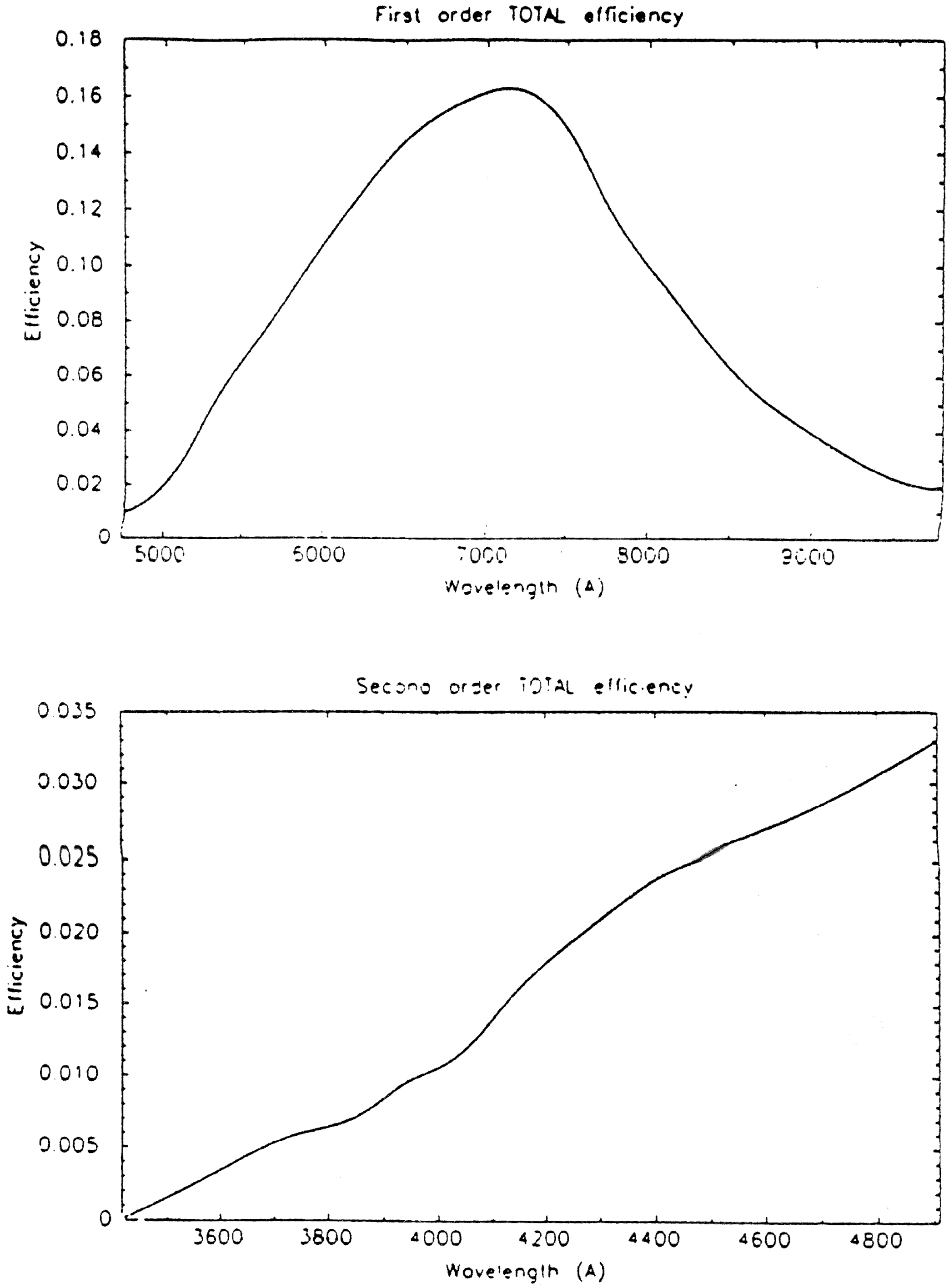

Figure 16: Total efficiency of the FOS-II system including atmosphere, telescope, spectrograph and detector in first order (upper panel), and second order (lower panel), as derived from observations of standard stars taken in October 1987

light of wavelengths other than those required, particularly wavelengths outside the range for which the coatings are optimised, from the optics by use of appropriate colour filters.

Diffuse scattered light has be shown to be below 2% by observations during commissioning of Quasar absorption lines known to be completely black.

Ghost images are caused by stray reflections within the spectrograph, and can either be in-focus images or images of the pupil. Pupil images take the form of the telescope pupil with the central obstruction, even if the illumination is from the comparison lamp system, because the illumination from the integrating sphere is designed to mimic exactly that of the telescope. This is not true of the comparison lamps for the fibre optic system.

There are a number of known ghosts in the ISIS system, these are listed below:–

- A ghost spectrum parallel to the primary spectrum which is seen in blue arm observations when a dichroic filter is used. It is caused by light reflected off the back surface instead of the front surface of the dichroic. It is strongest at wavelengths in the crossover region. The offset on the detector from the primary spectrum is 0.2 mm for the older (thin) dichroics; and 0.6 mm for the new (thick) dichroics.
- A Narcissus ghost pupil image which is caused by reflection between the surface of the CCD or its surrounds and the cryostat window. This appears strongest when caused by strong spectral features just off of the CCD, for example when looking at a Copper-Argon source at blue wavelengths at low dispersion, when the ghost is caused by reflection of the strong red lines from the surrounds of the CCD. If it is due to a continuum source the pupil image will be smeared in wavelength, and may be difficult to recognise as such. The intensity of this ghost is at the level of 10^{-4} of the primary source.
- A grating ghost caused by reflection between the grating and the aspheric plate of the camera when using grating R158R in the red camera. The ghosts images of all wavelengths add, so this ghost can appear quite strong.
- An in-focus ghost caused by a reflection from the folding prism, in either the red arm of ISIS or in FOS.
- Rowland ghosts, which are caused by periodic errors in the ruling of the gratings. These appear around strong emission or comparison lines, as satellite lines at the level of $>10^{-5}$ of the primary.

3.4 Wood's Anomalies in the ISIS gratings

Wood's anomalies are discussed in detail by P.G. Murdin in *ING La Palma Technical Note No. 76* in the context of INT IDS gratings, and a summary of the physical explanation for Wood's anomaly is repeated here.

Consider a reflection grating which produces a range of diffracted light in successive orders diffracted away from the normal. In some order, at some critical wavelength, the diffracted light lies in the plane of the grating. It is not possible for light beyond this point to be diffracted behind the glass of the grating. The power which would be sent into the forbidden region is redistributed back into the allowed orders. The power appears as an addition to the spectral response, with a sharp cut on at the critical wavelength and a steep decline to the red. This additional efficiency is almost entirely polarised perpendicular to the grating rulings.

Wood's anomalies occur at wavelengths:-

$$\lambda = d(\sin(\alpha) \pm 1)/n$$

where d is the grating groove separation; α is the grating angle (the angle between the grating normal and the collimator axis); and n is a positive or negative integer.

There are known to be Wood's anomalies in ISIS at 7200 $\AA$ (1200 grating, $n = 2$), 6400 $\AA$ (600 grating, $n = 4$) and 4400 $\AA$ (600 grating, $n = -2$).

Part II
Detectors

4 CCD Detectors

CCDs are widely used in astronomy, and are the major detectors for almost all of the instruments of the Isaac Newton Group. Descriptions of CCDs and their operation at a non-technical level are given in a number of astronomical publications; two recent reviews have been given by C.D. Mackay in *Annual Reviews of Astronomy and Astrophysics*, volume 24, page 255; and by P.R. Jorden in *Modern Technology and its Influence on Astronomy*, edited by J.V. Wall and A. Boksenberg, published by Cambridge University Press, page 271.

4.1 Schematic view of the CCD systems

The CCD systems in use at the WHT are described by P.R. Jorden *et al.* in *Proc. SPIE.* In brief the CCD systems consist of the following components, ordered approximately by the data path from detector to user.

- CCD chips contained in Oxford Instruments cryostats (the cryostats are painted bright red). New chips and types of chips are frequently brought into use, but at the time of writing the main chips in use at the WHT are GEC P8603, EEV P88300 and Tek 1024. The properties of these, and the next generation of CCD chips (the EEV P88500) are tabulated below. New types of chips will be announced in *Gemini* as they become available. The Oxford Instruments cryostats contain liquid nitrogen, and the CCDs are mounted on a heated copper block. By controlling the current into the heating elements, and by sensing the chip temperature with a platinum resistor, it is possible to maintain the CCD temperature at a preset value to an accuracy of about 0.1°C. The value of this preset temperature depends upon the CCD, and typical values for the CCD types are listed in the table below. The FOS-II CCD is mounted differently, in that the liquid nitrogen reservoir is much further from the CCD, and is connected to by a copper cold finger.
- A preamplifier box, usually painted blue, which is mounted on the side of the cryostat.
- The compact CCD controller, designed by NFRA Dwingeloo, and described in detail by J.D. Bregman and A. Doorduin in *Proc. S.P.I.E., volume 627, page 616 (1986)*, and by J.D. Bregman and N.R. Waltham in *Proceedings of the ESO-OHP workshop on The Optimisation of the use of CCD Detectors in Astronomy, p127 (1986)*, and which is mounted in one of the electronics racks on the Cassegrain cable wrap. The compact controller contains the following components:-
  - A low heat dissipation power supply.
  - A CPU card containing an MC68008 microprocessor running a PROM based FORTH system.
  - A Temperature, shutter, and preflash control card for each CCD head controlled by the controller.
  - Cards which provide and sequence the clock and bias voltages for each CCD.

  - An analogue to digital converter card containing a 16 bit analogue to digital converter.
  - A Correlated Double Sampler (CDS) board.
  - A fibre optic transmitter and multiplex control card.
  - A floppy disc controller for FORTH software development.
  - A real time board with opto-isolated RS232 ports for communication with the Utility Network and with terminals.

- A fibre optic cable run, with a number of connectors, passing through the cassegrain cable wrap. The fibre optic cables usually have a bright yellow sheath.

- The Fibre Optic Multiplexer (FOX) unit, containing the CCD Interface sequencer and one CCD interface card for each controller, in the upper rack of the Detector Memory System cabinet in the control room. The CCD interface card includes a fibre optic receiver, which decodes the serial data from the optical fibre, and a 512 by 24 bit FIFO buffer into which the data is placed in parallel form. The Interface Sequencer card is responsible for reading data from the CCD interface cards into the DICI card (see below). There can be up to 16 individual CCD interface cards in the rack, although there are not usually more than three. Each pixel, when read from the CCD interface card FIFO, has 24 bits, of which 16 are data bits, and 7 are address bits, which ensure that the data arrive in the correct buffer in the Detector Memory System. The CCD interface card has three lights on the front. These are:-

  - *Data Available*, a green light which indicates that data are available in the FIFO, and the CCD controller is sending data.
  - *FIFO Full*, a yellow light which indicates that at some point the FIFO has been filled, and CCD data have probably been lost.
  - *G.O.A.T*, a red light which indicates that CCD Interface card cannot detect the carrier for the optical signal.

  If either the yellow or red lights are showing on the relevant CCD interface card then there is a problem.

- The Dual IPCS CCD Interface (DICI) card in the DMS rack.

- The Detector Memory System. This is described in brief in the next chapter.

4.2 CCD chips in current use at the WHT

The table below summarises the characteristics of the types of CCD chips in current use for all instruments at the WHT. Availability of CCDs changes frequently, and updates to this information will be published regularly in Gemini. At the time of writing the CCDs available on the two arms of ISIS are: EEV3 and EEV6 which are EEV P88300s; TEK1 which is a Tektronix 1024 square; and GEC5 which is a GEC P8603. In the very near future EEV8, an EEV P88500 will become available. The CCD in FOS-II is currently a GEC P8603.

There is a choice of two readout speeds for the CCDs, known as *"normal"* and *"quick"*. It is possible to switch between these modes from the ICL interface with the commands `SPEEDY`

Table 6: CCD types available at the WHT (as of May 1993)

CCD Type	Pixel (μm)	CCD Format (pixels)	Image Format (pixels)	Read noise (e^-) normal	(quick)	Dark Current e^-/hour	Operating Temp °K
EEV P88300	22.5	1242×1152	1280×1180	3–4	5	3–10	140-150
EEV P88500	22.5	2172×1152	2200×1180				140-150
GEC P8603	22.0	576×380	590×400	6–10			150
Tek 1024	24.0	1024×1024	1124×1124	5	6	<10	183

Table 7: Recommended bias regions for WHT CCDs

CCD Type	Recommended bias region in X pixels	Recommended bias region in Y pixels
EEV P88300	6–15	101–1000
EEV P88500	6–15	101–1000
GEC P8603	5–9	101-500
Tek 1024	11–40	101-1000

`<channelname>` and `SLOUCH <channelname>`, which select quick and normal speed respectively. The advantages of quick speed are a faster readout (less overhead), and a higher dynamic range. The disadvantage is a higher readout noise (column 6 of the table above). For each CCD there is a distinct value of the "gain"; the conversion factor between the output of the analogue to digital converter and the number of detected photoelectrons per pixel, for each readout speed. The values of "gain", usually expressed in e^-/adu, will be known to local staff.

All CCDs produce an image which is larger in both dimensions than the active area of the CCD, this area is given in column 4 above. The additional image area consists of *underscan* and *overscan* and *dark reference regions*. The difference between these types of reference regions, and the location of the regions for CCD types in use on the WHT, are discussed by P.R. Jorden in *ING La Palma Technical Note no. 79.* The bias level in each data frame, which is an electronic offset with a low frequency time dependence, is estimated most reliably from the serial underscan region, in regions of the image frame which are given in the table below.

On-chip binning and windowing are available for any CCD, and the parameters can be controlled using the ICL commands `BIN` and `WINDOW`. On-chip binning is useful not only in reducing the amount of data read out from the CCD, and thus the dead time between exposures, but also in reducing the effective readout noise in the data. Because the readout noise occurs only once for each summed pixel, the effective readout noise is reduced by the a factor of the square root of the number of pixels summed. On the other hand, because the output of the analogue-to-digital converter limits the amount of charge that can be read from the CCD in any one pixel, on-chip binning reduces the maximum dynamic range that the CCD can provide by this same factor.

The Tektronix CCD, being thinned, has a higher Quantum Efficiency (QE) than the EEV and GEC CCDs, particularly at blue wavelengths. At far red wavelengths (>8000Å) it does suffer from a degree of "fringing", which causes a modulation of sensitivity with amplitude <5%, which is very dependent on grating position. When using a thinned CCD at red wavelengths it is vital

Figure 17: Quantum Efficiency of the CCD types available on the ISIS and FOS-II spectrographs.

to obtain and use flatfields taken at precisely the same grating angle at the target observations.

5 The CCD–IPCS Detector

5.1 Scientific Description

The photon–counting detector available on the blue arm of the ISIS spectrograph is the CCD–IPCS. It is fully described in *The IPCS-II Users' Manual* by J.S.B. Dick.

The CCD–IPCS provides true photon counting with no readout noise, but has an important limit on the maximum photon count rate for a linear response. The present version was rebuilt in June 1990. It has an S20 photocathode, a 4–stage EMI intensifier image tube with phosphors at the last stage, and as back end detector the rebuilt version has a thinned GEC CCD. This latter is slightly smaller than the original (an RCA CCD) so that slightly less spectrum is accommodated. The back end CCD has 22μm square pixels which can be subdivided into 2, 4 or 8 sub–pixels in spectral or spatial directions. However, there is an internal demagnification, so that 'effective' sizes at the photocathode are 3.8$\times$ larger. The maximum available area is 256 $\times$ 320 pixels. In the spectral direction, with '$\times$8' subdivision there are 2560 pixels each with an effective size of 10.5μm; with no subdivision, there are 320 pixels of 84μm each. In the spatial direction, no subdivision ('$\times$1') yields 1.2 arcsec/pixel, and '$\times$8' gives 0.16 arcsec/pixel.

The CCD-IPCS resolution obtained depends very slightly on wavelength (worse to the blue); a resolution (FWHM) of 32μm (i.e., 3.0 pixels at '$\times$8') is obtained at 4300Å.

Observers familiar with IPCS-I detectors, used at the AAT and on the INT, will find many things in common between the systems. The principal difference is that the CCD–IPCS has a GEC CCD as back end detector, whereas IPCS-I has a Plumbicon TV tube. Also, IPCS-II has a linear response up to somewhat higher photon count rates than does IPCS-I (see below).

The maximum count rate per CCD pixel for a deviation from linearity less than 10% is dependent upon the frame size (higher maximum rate for a smaller frame), and upon the distribution in intensity of the source (higher maximum rate for emission line than continuum sources). In tests with a prototype CCD–IPCS in 1987 with full format (250×320 CCD pixels) and frame time of 17 ms, about 5% loss was found at a measured rate of 1 ct/s/CCD pixel. In a 'spectroscopic' format (64×320 at '$\times$ 8' spectral resolution), with a frame time of 5 ms, line ratios showed no sign of nonlinearity at count rates up to 6 ct/s/CCD pixel. This corresponds to a rate of 0.75 ct/s/channel at a spectral resolution '$\times$8' and spatial resolution '$\times$1'.

There are two real–time display screens showing the detection of photon events. On the telescope the display is located next to the high–tension (EHT) controls so that the detector can be monitored as the EHT is brought up. The second display is in the control room, and here the screen must be monitored carefully each time the IPCS shutter is opened.

The IPCS is easily damaged by bright light, and great care must always be taken using it. For any new setup, new on–sky source or new calibration lamp, it is safest to include a large amount of neutral density (*eg*, ND4.2) in the beam and reduce it gradually. For comparison lamps, this can be achieved by putting ND3.0 in COMPFILTA and ND1.2 in COMPFILTB. For sky objects, you can do it by putting ND in the main beam filter with the command `MAINFILTND ND3.0`.

There is a red 'Panic Button' and you should keep your finger over this as you open the IPCS shutter each time on a new source of light. Operation of this button will close the IPCS shutter immediately, but will not affect the EHT voltage. Two typical symptoms of a dangerously-high rate are: (a) the dots of light on the real–time CRT display merge to form a solid 'splodge' of light (which is not flickering), or (b) if the IPCS shutter is closed, the glow on the real–time display takes more than 2.5 secs to fade.

5.2 CCD–IPCS granularity and Dithering

The CCD-IPCS has sensitivity variations over its field of view which are due to physical irregularities in the photocathodes inside the intensifier.. The spatial variation in sensitivity is referred to as 'granularity' because of the grainy appearance it gives to images.

In order to reduce the effect of granularity due to last three stages of intensification, a scheme of 'dithering' was introduced for the IPCS-I (Jorden & Fordham *Q.J.R.A.S.*, **27**, 166, 1986). By moving the image around on the last three photocathodes in the intensifier, the signal in a given pixel, averaged over time, is proportional to the mean sensitivity within the scanned area. Hence, the pixel-to-pixel granularity is (typically) reduced by a factor of two. A similar technique is used with the IPCS-II but this also counteracts the fixed pattern noise due to the centroiding algorithm used in that detector; the granularity of the first photocathode is not diminished by these techniques since the image on this photocathode cannot be scanned.

The effects of granularity may be reduced by dividing an acquired image by a flat–field, so compensating for the pixel–to–pixel variations in sensitivity. The exposure required for a 'correct' flat-field depends on the spatial scale of both the granularity and the information content within an image. Jenkins (*MNRAS*, **226**, 341, 1987) analysed granularity using Fourier techniques and showed that most of the power is on scales of many pixels (>5); little power was seen on small scales (<5 pixels).

Flat-fielding is, therefore, highly desirable when the noise in the data due to photon noise is less than the power density of the granularity at the spatial frequencies of interest. To adequately

Table 8: Measured magnitude for one photon/second/$\AA$ for the red and blue arms of ISIS

Wavelength($\AA$)	3500	4000	4500	4700	5000	5500	6000	7000	8000	9000	10000
Red arm + EEV CCD[1]				15.8	16.5	17.2	17.4	17.5	17.1	16.0	14.2
Blue arm + EEV CCD	15.9	16.1	16.3	16.5	16.9						
Blue arm + Tek CCD	17.1	18.0	17.8	17.7	17.5	17.3	16.9				
Blue arm + IPCS	16.0	16.3	16.0	15.8	15.6						
FOS-II(1^{st} order)[2]						17.4	17.8	18.0	17.4	16.3	

1) The red arm data are for an *uncoated* EEV CCD.
2) Some of the FOS-II data are interpolated from measurements at intermediate wavelengths.

describe the granularity on a scale of P pixels, typically a flat field of at least N counts per pixel should be taken, where $\log_{10}(N) = 3.2 + 2\pi/P$.

Because there is little power at small scales, using a flat field with a small differential shift (<2 pixels) between the image and the flat-field will still improve rather than degrade signal–to–noise of the resulting image.

However, in practice obtaining IPCS-II flat-fields is very difficult, because the required exposure time would be many hours because of the low count rate limit of the CCD–IPCS.

6 Overall performance of the system

Table 8 gives sensitivity values for ISIS and FOS-II measured from wide slit observations of spectrophotometric standards, in the case of ISIS with the low dispersion (158 line/mm) gratings. These measurements give the overall performance for the entire system, including atmosphere, telescope, spectrograph and detectors. The performance is expressed as a magnitude (AB magnitude in Oke's system; see for instance Oke, Astrophys. J. suppl. **27**, 21, 1974) which gives a measured count rate of 1 photon/second/$\AA$ at the detector. When comparing these values with observed count rates measured from CCD data it is important to convert to detected photons using the correct "gain" (electrons/ADU) factor, and to subtract the correct bias value. When comparing with data measured of the DMS display using the X-CUT and Y-CUT functions in the STATISTICS menu it is also important to remember that the DMS averages CCD data, it does not sum it. On the other hand for IPCS data the DMS does sum.

Part III
Computers and Operations

7 Control System

7.1 Control system overview

The main elements of the control system are shown in Fig. 18. ISIS mechanisms are controlled by the observer typing commands at the ICL instrument control interface. The ICL interface runs on the system computer (currently a Vax 4000 called LPVF), and the display is via the Observer's Vaxstation 3100 (LPVS2). ICL commands are typically procedures containing lower-level commands to d-tasks (device tasks) which are high-level (PASCAL) programs running on the system computer (LPVF) as sub–processes of the main observer's process. There are d-tasks for each of the major mechanisms e.g. ISIS, A&G, UES, telescope, DMS, each CCD. The d-tasks in turn exchange messages over the utility network Ethernet with the Motorola microprocessors controlling individual stepper-drive motors, barcode readers and shutter modules. The messages are typically commands to move, status requests and status returns.

Most of the mechanisms are controlled via Motorola 6809 (locally known as '4MS') microprocessors; there is one for each of ISIS, A&G, FOS, LDSS, TAURUS, UES and IPCS. The TV, autoguider and Detector Memory System (DMS) each use a 68020 processor in a VME chassis (housed in the blue control cabinets). The CCD controllers (including that for the autoguider CCD) are based on 68008 microprocessors. The microprocessors are programmed in FORTH. Each of the microprocessors, and the system computer, is connected to the utility network via a Network Interface Unit (NIU). Each NIU can connect up to four microprocessors. There are currently two NIUs on the telescope and two in the control room. Data from the CCDs is transmitted via fibre-optic links to the autoguider and DMS VME systems. Data arriving at the DMS are automatically sent to the data disk on the system computer and may also be transferred to the SPARCstation (currently LPSS3). The integrating TV system is currently stand–alone and cannot be controlled across the Utility Network. If the ICL/d-task control route fails for some reason, mechanisms can often be controlled more directly from the engineering terminals in the control room, by keying in messages to be sent over the utility network. At a still-lower level, duty tecnicians can plug a terminal directly into a microprocessor on the telescope and send commands from there.

LPVF is linked via DECNET, running over a separate Ethernet, to the telescope-control computer (a microVAX-II, currently LPVB), to the VAXstation running the user interface, to other VAX 4000 computers on a DEC cluster, to the DECservers serving terminals and printers, and to SPARCstations on a SPARC cluster. Separate Ethernets at the INT and JKT are connected to the WHT ethernet via fibre-optic links.

The DMS and several of the VAXes and SPARCstations can be used for data reduction. The DMS provides a few simple analysis functions e.g. cuts, statistics. FIGARO and other reduction packages are available on the VAX clusters on both the mountaintop and at sea level. IRAF and SAOIMAGE can be run on the SPARCstation on the control desk (Section 7.3).

Telescope control is effected via commands issued to the control system running on the telescope-control computer, which is interfaced to the telescope mechanisms via CAMAC. Most telescope-control commands can be issued from the ICL interface and it is intended that in the future the distinction between operator control of the telescope and observer control of the instrument will blur.

Most of the information needed by the observer about the status of the system is included in the telescope-control information display, the instrument-control MIMIC and the white-board. The MIMIC is discussed in Section 7.6 below; it displays information contained in the 'notice-boards' which are continually updated by the d-tasks as a result of the commands and status returns they receive. Ephemeral information which is not (yet) held on-line e.g. contents of filter slides, gratings loaded, CCD locations, is usually recorded on the whiteboard in the control room. There is some overlap between the information held on-line and that written on the whiteboard. Some useful instrumental information (e.g. focus offsets) is recorded in the telescope logbook.

7.2 The Detector Memory System

The Detector Memory System allows detector data to be collected, displayed and transferred to the system computer. A detailed description of the system is given by *Johnson 1986 (Electronics report 413, the Detector Memory System)*.

The DMS is a purpose-built computer, based upon a Motorola 68020 microprocessor, with a large area of memory (128 Mbytes) for storage of detector data. The system design is based on the industry–standard VME architecture. There is a high speed data interface (DICI; Dual IPCS CCD Interface) between the detectors and the VME memory. The system also has an image display facility, based on an Opal Graphics Controller.

Immediately after each exposure the data from all detectors appears in memory in the Detector Memory System (DMS). Images obtained with CCD detectors are read out into the DMS at the end of an exposure. Photon counts from the IPCS–2 are continually transferred to the DMS during an exposure, where they are built up into an image.

The DMS is capable of handling multiple detectors simultaneously, reading the data from different detectors into different areas of memory (normally referred to as buffers). This feature is particularly important for the operation of ISIS.

7.3 The SPARCstation

Data collected by the Detector Memory System (DMS) may be saved to the SPARCstation 2 (currently LPSS3) for examination using SAOIMAGE or IRAF applications.The Sparcstation is intended to meet the need for very rapid on-line evaluation of data, using standard reduction software. The system consists of a Sparcstation 2, with 64 Mbyte of memory and 3 Gbyte of local disk storage, connected to the DMS via a commercial S-bus to VME adapter. This allows very rapid transfer of data from the DMS to the SPARCstation.

The run number of the saved data is the same as that used on the VAX. At present, the data are transferred without headers. Data may be written from the SPARC to an exabyte in TAR format, or FITS format, from IRAF. Instructions on starting up the SPARC and on using the various applications are kept in the control room. Image-examination routines run much faster on the SPARC than on the VAXes.

IPCS data can be saved to the SPARC while the exposure is building up.

The windows typically open on the SPARC are:

- DMS-SPARC interface, used to save data from any of 7 DMS buffers to the SPARC, and also to obtain statistics on any of the images in the buffers (size, min, max and SD);

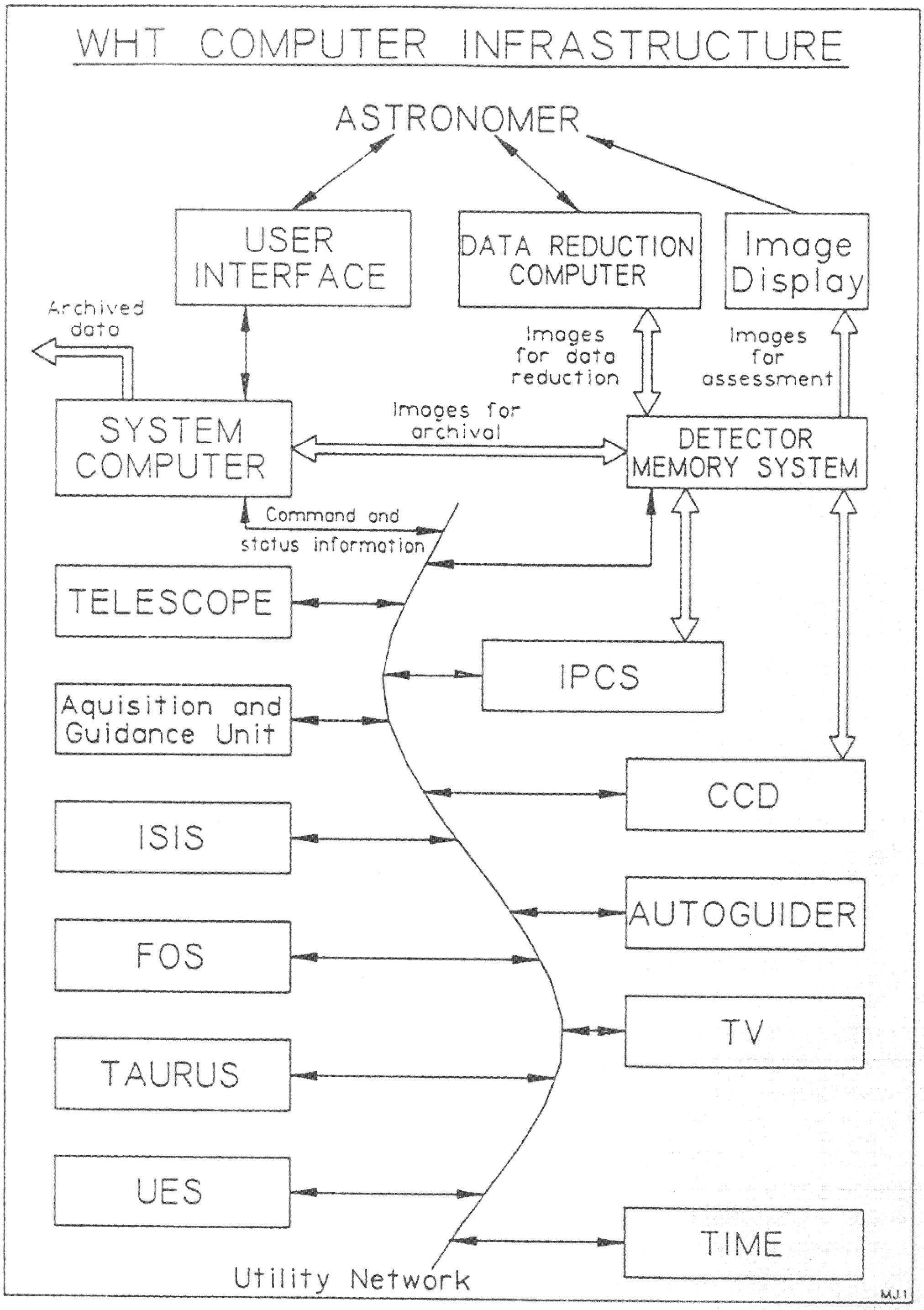

Figure 18: Schematic representation of the WHT instrument control system

- SAOIMAGE, used for display and mouse-controlled examination of the image;
- IRAF command language, used for running other applications e.g. `imexamine`;
- IRAF (Tek), used for displaying line graphics;
- Console window, where UNIX error messages appear;
- DMS control

The interface for transferring data from DMS memory to the Sparcstation local disks is controlled graphically on the Sparcstation itself. To transfer a specific buffer to the Sparcstation the user simply moves the pointer to the name or number of that buffer, selects it with the mouse, then selects with the mouse the SAVE option in the interface window. An IRAF format file is then created in a scratch area on one of the Sparcstation discs, and the name of the file created is displayed in the interface window. At present no header information at all is stored with the data files. The images can then be displayed in the SAOIMAGE window with the IRAF command `display`.

IRAF contains many facilities for rapid analysis of data of all types, users who require specialised facilities are advised to refer to the KPNO user manuals and cook-books, which are kept in dark blue loose leaved binders in the control room. For quick-look analysis of images and simple spectroscopic data the IRAF command `imexamine` has many of the required facilities. Typing `help <commandname>` at the IRAF interface produces a detailed description of the command, and typing `help <commandname> | lpr` will produce a hard copy of the help file on the Sparc laser printer.

By the end of 1993, the DMS display functions should have been transferred to the SPARC, making the DMS monitor superfluous. Header examination and FITSOUT from the SPARC should also be available.

The mountain-top SPARC cluster currently includes 7 SPARCs, 3 exabyte and a laser printer. There is a SPARC plus exabyte in each telescope building.

7.4 The Utility Network

The Utility Network is a local Ethernet, running between the various focal stations of the WHT, and the control room, over which the microprocessor systems (the 4ms systems which control the instruments and the Engineering Mimic; the VME computers which control the Autoguider, and the DMS; and the CCD controllers) communicate. Each device communicates via a Network Interface Unit (NIU), and each NIU can connect up to 4 devices to the Ethernet link. The system computer is also connected to the Utility Network via an NIU; this allows the transmission of messages from the User Interface to the devices. The Utility Network Ethernet is physically separate from the Ethernet which connects the Vaxcluster and various other computers around the site. Utility Network messages conform to a local protocol set out in *Johnson 1986 (Electronics report 412, 4.2m WHT Utility Network: Instrument Control Recommendations).*

7.5 The System Computer and User Interface

The system computer has two principal roles as part of the data-acquisition system:

- The system computer, running the ADAM control system, is responsible for coordinating the entire data acquisition process. The commands for doing this are listed in Part VI.
- The data acquisition system writes the data to files on the system computer datadisk, ready to be archived.

On completion of an exposure, the data is normally transferred from the DMS to the system computer, via a DR-11W interface. The header information associated with that data will have been collected by the system computer, either during the exposure, or on completion of the exposure. Data and headers are then merged into a datafile on the system computer disk. The datafile is in HDS NDF format, the header information being stored in the standard FITS extension to this format. Finally, two copies of the data are written to tape; a FITS format tape for the La Palma archive, and either a FITS tape or a VAX backup tape for the observer.

The system computer is networked to various data reduction computers (currently a VAX 4000 plus several VAXstations). Data can be copied across to these machines for immediate processing.

7.6 The MIMIC display

The MIMIC display running on the VAXstation 3100 gives mainly-graphical representations of the current status of the telescope, instruments and detectors. There are a number of pages, which can be selected using the mouse. Current pages include:

- **TELESCOPE:** Current position on sky, airmass, parallactic angle, etc.
- **CAGB:** Light path and status of mechanisms in the A&G box only.
- **ISIS SUMMARY:** Light paths and status of mechanisms in the acquisition and guidance unit, slit area and spectrograph, including TV, comparison lamps, autoguider, main filters, auxiliary-port filters, dekker slide, slit unit, above- and below-slit polarimetry modules, ISIS filters, Hartmann shutters, collimators, gratings and detectors.
- **CCDs:** Focal station, chip name, size, windows, binning, temperature (and difference from nominal), readout speed, exposure status, shutter status, requested exposure time, exposed time, UT start, for each CCD.
- **CCDs SUMMARY:** Temperature, exposure times, times to go, windows for each CCD.
- **IPCS:** Status of the IPCS
- **IPCS-WINDOW:** Size and position of the IPCS window.

A small version of the CCD summary page is permanently displayed. There are in addition individual pages for CAGB, AUTOguider, ISIS_SLIT and FOS, but the information from these has been incorporated into the ISIS SUMMARY page.

The current state of any mechanism or light path is identified by its represented colour on the MIMIC screen. The colour scheme is:

WHITE	mechanism is ok although not in use
RED	mechanism is in error
BLUE	mechanism is moving
GREEN	mechanism is successfully in use
YELLOW	the current selected light–path

The following ICL commands relate to the MIMIC (they are only normally needed when problems occur):

`MIMIC PAGES`	List names of available MIMIC pages (screens)
`MIMIC UPDATE`	Refresh current screen if it seems out of date
`MIMIC_START`	Start–up. Normally done in `START-UP` in ICL
`MIMIC_STOP`	Close down. Normally done in the ICL `EXIT` command
`SCREEN`	Select a screen (*e.g.*, ISIS). Normally done with the mouse.

7.7 Generating Data Tapes

ING telescope data are recorded to disk in .NDF format, and to tape in FITS format. The preferred medium is Digital Audio Tape (DAT), the second choice is Exabyte tape. It is the responsibility of the observer, or the support astronomer if present, to generate the archive tape (D-tape), and operations staff will normally provide a copy tape (C-tape) in FITS format on 9-track tape, Exabyte or DAT at the request of the observer. Alternatively the observer can create his or her own copy of the data in FITS format, or with the VMS BACKUP utility, on any of these media.

D-tapes can be created on any Vax in the cluster which has access to the required storage device, but the normal procedure is to do this on the main data reduction Vax LPVE. The observer should log onto this machine in the OBSERVER account, mount the tape on the required drive, then use the utilities `FITSINIT` and `WRITE_FITS`, which are described in Part VI to create the D-tape. A Tape Copy request form should then be filled out, indicating what kind of C-tape is required.

7.8 Engineering terminals

In addition to the DMS and the Autoguider terminals, which are located on the control desk, there are three other terminals which allow access to various subsystems. These are located on a table behind the data reduction vaxstation (LPVS3), and close to the door which leads to the dome area. One of the three terminals is a network monitor which should only be used by La Palma technical staff. Use of the other terminals is normally restricted to technical staff and support astronomers, and with the increasing reliability of the Vax control system, should occur only rarely.

7.8.1 The Engineering MIMIC

The Engineering MIMIC is a 4ms computer which is used to run a schematic display representing the status of ISIS and the A&G box. There are three diagrammatic pages, representing the A&G box; the ISIS slit are; and the rest of ISIS. Commands are available to switch between these display pages, to examine a particular mechanism in detail, and to move mechanisms in these and other subsystems by issuing network commands. These are detailed in a guide called "The WHT Engineering MIMIC", a pale green loosely bound document of which there should be at least one copy in the control room. To use the engineering mimic select **MIMIC** on the rotary switch labelled "**A**".

7.8.2 Direct control of the Cassegrain Instruments

It is possible to communicate with any of a number of other 4ms microprocessors using terminal A, by selecting the appropriate position on the rotary switch marked "**A**". The microprocessors include:-

- The FOS 4ms microprocessor.
- The ISIS 4ms microprocessor (position labelled "**CASS INST**").
- The A&G box 4ms microprocessor.
- The IPCS 4ms microprocessor.

The last three should only be used by technical staff who have read the appropriate technical documentation, but until the FOS D-task has been fully commissioned it may be necessary to move some FOS mechanisms and interrogate the status of the mechanisms from this terminal. These commands are listed in Part VI.

7.8.3 The Detector engineering control terminal

The Detector engineering control terminal can be used to communicate with one of the CCD controllers, including the autoguider CCD controllers. A limited number of CCD commands, used for assessing the performance of the CCDs and for taking test exposures when the Vax 4000 system computer is not available, are available to users and are documented in Section 13.3 of this manual.

Part IV
SETUP AND OBSERVING PROCEDURES

8 Setup Procedures

8.1 Starting the computer systems

The mechanisms of ISIS and the A&G box, and the detectors, are under the control of a number of microprocessors which communicate with each other and with the Vax 4000 system computer via the Utility network. The primary interface from the user is a command language called ICL which runs on the Vax 4000, and the primary source of information for the user is the Mimic display, which is a graphical process running on the Microvax 4000 but displaying on a Vaxstation, usually a Vaxstation 3100, which runs DECWINDOWS MOTIF, which is a variant of X-Windows. In order to display the data in real time, and in order to control the Autoguider and DMS, it is necessary to run the Sparcstation (called **lpss3**), which is located to the left of the Vaxstation. The Sparcstation also runs MOTIF, but this is a slightly different implementation from that on the Vaxstation. The other important interface for the user is the Detector Memory System (DMS), running Imageforth/68K, which provides a display of the data and a number of setup routines. This section describes how to check that all of the necessary systems are running and are communicating over the utility network, and to get the user interfaces running.

Because the DMS local control does not run through terminals, but through a window on the Sparcstation, the observer account on the Sparcstation should be started up first. On the Sparcstation (lpss3) logon as **observer**, the password will be known to local support staff. *Note that the Sparcstation runs the UNIX operating system, which is case sensitive, and all commands typed in including usernames and passwords must be in the correct case.* MOTIF will start automatically, but the application to control the DMS must be started individually from the Applications menu. ¿From the Applications menu start the following applications:-

- **IRAF+DMS** - This application will start the SAOIMAGE display server; a terminal window running IRAF; and the graphical tool for controlling data transfer from the DMS to the Sparcstation. It is advisable to start this application first.
- **DMS WINDOW** - This application will start a terminal window for local control of the Detector Memory System, this is also a FORTH system, so should also respond "ok" if it is running.

Next, it is important to check that the Vax 4000 and the DMS are running. The Vax 4000 is at the far end of the control room from the control desk, and is clearly labelled. The operator console for the Vax 4000 is near the computer, and it will be fairly clear from the paper output of this whether the computer is running. The DMS is in a VME rack in the second of the four blue cabinets to the left of the control desk. Its user interface consists of a terminal, mouse, and display screen towards the left hand end of the control desk. If the DMS appears not to be running, or to be running in a non-standard configuration, or you are unsure of the configuration, toggle the switch labelled **RESET** on the module labelled **VMPU** of the DMS. The display

Table 9: Microprocessors on the Utility Network

DMS	The detector memory system itself
FOS	The 4ms microprocessor controlling the Faint Object Spectrograph
AGCA	The 4ms microprocessor controlling the Cassegrain A&G Box
ISIS	The 4ms microprocessor controlling the ISIS Spectrograph
TAUR	The 4ms microprocessor controlling the Taurus Fabry–Perot
UES	The 4ms microprocessor controlling the Utrecht Echelle Spectrograph
LDSS	The 4ms microprocessor controlling the Low-Dispersion Survey Spectrograph
CCD0	The spare CCD controller
CCD1	The controller for the Red Arm CCD
CCD2	The controller for the Blue Arm CCD
CCD3	The controller for the FOS CCD
CCD4	The controller for the UES CCD
IPCS	The 4ms microprocessor controlling the Image Photon Counting System
AUT1	The VME microprocessor controlling the CCD Autoguider
SYS	The Vax 4000 System Computer
ENGM	The Engineering Mimic, which is a 4ms microprocessor

screen will refresh, and the control window on the Sparcstation will display a system message, then leave a standard Forth prompt ("ok" and a carriage return).

When the DMS is running it is possible to check which other subsystems are communicating over the Utility Network. At the DMS control window type:–

```
?NET
```

The DMS will then attempt to communicate with each of the subsystems in turn, and after each attempt will report either:–

NO RESPONSE FROM <DEVICE>

or:–

Acknowledgement received from <DEVICE>.

The devices are:–

If the DMS does not receive an acknowledgement even from itself there is most likely a fault with the Network Interface Unit (NIU) connecting the DMS to the Utility network, or with the cables between the DMS and the NIU. If the DMS receives acknowledgements only from those devices which are connected to the same NIU as the DMS, then there is most likely a fault in the connection between that NIU and the Utility network Ethernet cable.

If any of the 4ms or VME microprocessors fail to respond, then it is most likely that they are either not running, or are not correctly cabelled to the NIUs. If a group of devices on the same NIU fails to respond then there may be a fault with that NIU, or the cables between that NIU and the utility network. NIUs have a recessed reset button at the rear, which can be pressed with the sharp end of a pencil.

If the System Computer fails to respond, then it is possible to restart the Utility Network software running on the Microvax. At the Operator's console log in to the captive account **UNET**, the password should be available near the console. This will stop and restart the Utility Network software on the Vax 4000.

If these simple remedies do not work then technical assistance should be sought. To run the observing and data taking system the minimum configuration is DMS, AGCA, ISIS, SYS, FOS if it is to be used, and whichever detectors are to be used. It is also convenient to have AUT1 and ENGM communicating via the network.

Once it has been established that the relevant devices are communicating over the network the user interface to the System computer can be started. The user interface is usually run on the Vaxstation located on the control desk, though it can be run on a spare Vaxstation elsewhere in the control room, or the alphanumeric interface can be run on a terminal with the MIMIC being displayed on a Vaxstation.

If using a Vaxstation for alphanumeric input the user should first log on to this Vaxstation as **OBSERVER**. The password will be known to local staff. On the Vaxstation type:–

```
LPVF
```

This is defined as `SET HOST/LOG LPVF` and a logon message from the Vax 4000 system computer will appear. The user should also log on to this computer as **OBSERVER**. The password is the same. If using a terminal for alphanumeric input the user should log straight onto this machine. The system computer will display various information about new software and about the system. Two items require particular attention:–

- The system will try to allocate the device **XAA0:** which is used for data transfer from the DMS. If it cannot do this it will display a message to this effect, this is usually because there is a terminal somewhere with observer logged on. In this case this XAA0: must be deallocated at that terminal, or the process logged out or deleted. Then XAA0: must be allocated at the observer's terminal.
- The system will display the amount of free disk space on the system and data disks. If the data disk is full some data from previous night should be deleted, after first checking that it has been backed up.

At the Vaxstation or terminal type:–

```
ICL
```

The ICL command language will start and the procedures and command definitions will be loaded. The user will then be invited to start the control tasks, to do this type:–

```
STARTUP
```

The user is then given the option of running up the tasks or not, the answer to this question is always `YES`. The user will also be asked which Vaxstation to run the MIMIC on, this is normally the same Vaxstation as is being used for alphanumeric input, although it can be the other one.

The user is then prompted for the configuration required; normally this will be one of the following options:–

- ISIS + A&G + CCDs
- ISIS + A&G + CCDs + IPCS
- ISIS + A&G + FOS + CCDs

The D-tasks will the be started and the various subsystems initialised. If the initialisation of one subsystem fails it is *possible* that other subsystems will not be initialised, if this appears to be the case the subsystems can be initialised explicitly with the commands `ISIS_BEGIN`; `DMS_BEGIN`; `CAGB_BEGIN`; `DCT_BEGIN`; `FOS_BEGIN`; `AUT_BEGIN` and `CCDINIT <ccdname>`.

Starting up ICL will also start up the telescope control system on the Microvax II telescope control computer.

8.2 Configuration of the A&G Box and Spectrograph

Gratings and other optical components must only be changed when the telescope is parked at the zenith, and whilst the change is being made an entry must be made in the telescope log to the effect that the telescope is not to be moved until the work on the spectrograph or A&G box is finished.

8.2.1 Changing Gratings

Although it is possible to change gratings without the ICL interface running this procedure is rather involved, and should only be performed with the advice of technical staff. With the ICL interface running the procedure is fairly straightforward.

The grating angle or angles must first be moved to the change position, in this position the grating cell is parallel to the back of the spectrograph, and to the access doors, and the gratings can be removed from their cells and lifted straight through the access doors. An interlock prevents the grating cells being unclamped with the gratings at any other angle.

The procedure for changing gratings is invoked by typing:–

```
CHANGE
```

at the ICL interface. A list of items which can be changed with this procedure is given, the relevant grating should be selected. The user will then be offered access to the spectrograph, if the response to this question is "YES" then the selected grating will be moved to the change position (grating angle 35000) and **both** grating doors will be unlocked.

It is now possible to open the grating doors, which are located on the face of the spectrograph opposite the long arm. The door for the blue grating is in the upper left hand corner of this face; and the door for the red grating is in the lower right hand corner. When the door is opened the grating should lie approximately parallel to this spectrograph face, with the handles towards the door.

The grating clamps are operated by nitrogen pressure, and are activated by a toggle switch. For the red grating the switch is situated above the grating cell, and for the blue grating below the grating cell. If this toggle switch is moved to the down position the grating clamps will release, this should only be done with the telescope at the zenith, and the user should keep one hand on one of the handles on the grating itself while releasing the clamps. The grating can then be withdrawn from the cell, and taken out of the spectrograph. All except the tallest of observers should use a set of steps while changing the blue grating, its cell is both higher off the ground and deeper inside the spectrograph than that of the red grating.

Gratings are normally kept in wooden boxes in a metal storage cabinet on the observing floor. The boxes are clearly labelled with the identifier of the grating they contain. The gratings should be kept in these boxes whenever they are not in use, and under no circumstances should they be left out on the observing floor. **Users should never touch the surface of a grating.** Any blemishes on the surface should be reported to the telescope manager, users should never attempt to clean them off.

Replacing a grating in the cell is the reverse of removing one. ISIS gratings are always used blaze-to-collimator, so the arrow showing the direction of the blaze angle should always point towards the centre of the spectrograph. The writing on the grating should be the right way up if it is in the red cell, and upside down if it is in the blue cell. The grating should be placed in the cell, ensuring that it is properly seated. The toggle switch should then be moved to the up position; the clamps will come on. If the clamps release immediately after coming on, then the grating is not properly seated.

After the change is completed the user should press the return key at the ICL interface. The grating doors will then be locked, provided that they are closed correctly. The user should then type in the name of the grating loaded in response to the question. The ISIS database will then be updated, and the name of the grating loaded should appear on the mimic. It is important that the correct grating identification is loaded in the database, otherwise the procedure `CENWAVE` will not work correctly.

Users should never rely on the information contained in the database, nor that on the whiteboard in the control room, being correct when they first take over the system. The database could be incorrect if a different version of the software has been in use, as different versions of the software have separate databases. The only way to check that the correct grating is loaded is to run the change procedure, open the grating door, and look.

8.2.2 Changing Filters in the Main (A&G box) slides

The main neutral density and colour filters are held in two 5-position slides in the lower section of the A&G box. To change a filter within these slides the filter should already be mounted in a holder, which can be obtained from RGO technical staff.

To access one of the filter slides the slide to be accessed should be moved to position zero (out of the beam), and the other slide should be moved into the beam. For instance to access a filter in the COLOUR slide type:–

```
MAINFILTC OUT
MAINFILTND 4.
```

The access door on the A&G Box can then be unlocked with:–

```
AGACCESS.
```

This command will unlock the access door and will not return control to ICL until the door is locked again. The door is on the lower half of the A&G box, and has a shiny metal latch which can be opened manually. To remove the filter slide from the drive shaft a 3mm Allen key will be required. With the access door open an Allen screw can be seen in the centre of a rectangular latch which holds the filter slide in place. This screw should be removed and the rectangular latch can be swung aside, to allow the filter slide to be withdrawn from the A&G unit. The filter holders can then be interchanged using the same Allen key. The slide can then be inserted; the latch and Allen screw replaced. The access door can then be closed and latched. The AGACCESS procedure should then return an ICL prompt; and the interlocks should then be released. However the microswitch which detects that the door is closed does not always operate, and it may be necessary to open and close the door again until it does.

8.2.3 Changing components in the slit area

The slit area contains the dekker slide; the dichroic and folding flat slide; and the four ISIS filter slides (two in the blue beam after the blue fold, and two in the red and FOS beams between the blue and red folds. Slides not in use are kept in a steel cupboard behind the WHT engineering console, or else in the grating cupboard on the observing floor.

Care must be taken when working in the slit area because it is possible to knock the slit jaws out of alignment. To realign the slit jaws it is necessary to remove ISIS from the telescope, and this is equivalent to an extra instrument change. The slit area access door is interlocked with the dekker slide, it is only possible to open the slit door when the dekker is in position 0, when it offers some protection to the slit unit. However with the door open it is then possible to move the dekker away from position 0, and it would then be easy to disturb the slit alignment. **Users must not do this, and if they require any mechanism moved when the slit access door is open they must contact RGO technical staff.** If the IPCS EHT supply is on then only a minimum of light can be used in the slit area with the door open, and in the dark it is more likely that mechanisms will be disturbed by accident. Under these circumstances users must either switch the IPCS EHT to standby, or else contact RGO technical staff for assistance before opening the slit door.

Before the slit door is opened the dekker slide must be in position 0. At the ICL interface type:–

```
DEKKER 0
```

wait for the dekker action to complete, this mechanism is slow.

```
SLIT_DOOR OPEN.
```

The slit access door can then be opened manually. The dekker slide is a horizontal slide at the top of the slit area, which can be withdrawn from an angled groove. When replacing the dekker slide care must be taken to locate the slide correctly in this groove.

The two blue beam filter slides are to the right of the slit area, and can also be withdrawn and replaced. However the grooves that the two slides run in are not identical and these slides cannot be interchanged. The same is true of the two red beam slides which are in the lower part of the slit area. All the filter slides are somewhat stiff, and changing these filters should normally be done by RGO technical staff.

The dichroic slide is in the centre of the slit area, and is rather larger than the filter slides. It contains the mounting cells for the dichroics and for the flat mirror, these have the shape of a right angled triangle. The dichroic slide is held in place by a sprung loaded locator pin, this can be released by lifting the plastic knob on the slide. The knob can be twisted through 90 degrees, when the locator pin will be held out, and the slide can then be withdrawn carefully through the slit access door. When the slide is replaced the user must ensure that the locator pin is correctly engaged.

The slit door should be closed and latched; and is then locked by the command:–

```
SLIT_DOOR CLOSE.
```

The procedure `CHANGE` has been written to take the user through the process of changing the below slit filters. The procedure will move the dekker to position 0, unlock the slit door, and when the change has been completed will lock the door and update the database.

8.2.4 Directing light to the right cameras

The light path is shown on the CAGB; ISIS; and ISIS_SLIT screens of the Mimic display. The spectrograph can be configured for any combination of channels with the `ISIS_CONFIG` command, or the folding mirrors moved explicitly with `BFOLD` and `RFOLD`. To get light from the comparison lamps to the cameras the user must ensure that the ACQCOMP mirror is in place in the A&G box; that nothing else is between the mirror and the slit (particularly that the Lid Cover is open); that a comparison lamp is on, and if the IPCS is in use that an appropriate neutral density filter is in the comparison beam. A typical sequence of commands is:–

`ISIS_CONFIG BLUEANDRED`	Both blue and red channels
`AGMIRROR ACQCOMP`	
`COMPLAMPS CUAR`	Copper-Argon Lamp
`COMPFILTA ND3.0`	If the IPCS is in use
`COMPFILTB ND1.8`	If the IPCS is in use
`LID OPEN`	

It may be necessary to move any of MAINFILTND; MAINFILTC; FLENS_CALC_POL; HW_POLAR; QW_POLAR; ANAMORPHOTIC and any of the four ISIS filters to the appropriate position.

8.2.5 Setting Grating Angles

The procedure CENWAVE allows the user to set the grating angles to appropriate values for a specified central wavelength, however the zero point of the grating angle is not known precisely and has been known to change. Observers are recommended to check their central wavelength with an appropriate comparison spectrum, and report any discrepancy to the WHT Telescope manager. If the exact grating angles are known they can be set with the commands REDGRAT and BLUEGRAT.

8.2.6 The Slit Area

Unless the spectrograph is being used with multi-slits or fibres the slit carriage should be in the long-slit position. If it is not in the correct position it can be driven there with the ICL command LSLIT. The commands SLIT <width(μm)> and DEKKER <position> allow the user to determine the width and length of the slit, in general for setting up one requires DEKKER 6 (long slit) or DEKKER 2 (20 arcsec) for focus and tilt adjustment; and dekker 1 (narrow) for rotation adjustment and determining the s-distortion correction for the IPCS. It is a mistake to make the slit too narrow for determining focus, if it is less that 120μm then it will project to less than 2 CCD pixels, and the line profiles will be undersampled for the Hartmann test. A value in the range 120 to 180μm is recommended.

8.2.7 Configuring the Spectrograph for Spectropolarimetry

The ISIS spectrograph is fitted with polarisation optics which allows the observer to rapidly convert the instrument into a spectropolarimeter capable of measuring both linear and circular polarisation. The polarisation assembly basically consists of two units: above the slit a halfwave and a quarterwave plate can be inserted, and immediately below the slit either a calcite plate or a polaroid are available as a polarisation analyser.

In some more detail the following components comprise the ISIS polarisation system, in the order the light passes them:

- Halfwave plate, 40 mm diameter, effective λλ 300-1100 nm, mounted so that it can be inserted/retracted and set to any position angle or rotated continuously at a speed of several revs/sec. Rotating the halfwave plate through n degrees results in a rotation of $2n$ degrees of the polarisation vector of the light.

- Quarterwave plate (at present borrowed from the People's Photometer), mounted similarly to the halfwave plate. The quarterwave plate converts circular into linear polarisation, so that the calcite plate (linear beamsplitting polariser) can detect its presence.

- Standard ISIS slit unit with polarisation dekkers mounted. A comb-type dekker mask is employed to avoid overlap between the two spectra produced by the calcite slab analyser (see below).

- Choice of analyser:
  (i) calcite slab, 2 beams, 330-1100nm. (actually, a Savart plate, which equalizes focus for both polarisations). The calcite is located immediately below the slit and gives two beams which are both 100 % polarised, but orthogonally; the *o* and *e* ray. The relative intensity of these beams depends on the polarisation vector (size and orientation) of the incoming

beam.
(ii) Polaroid (HNP'B; 300-800 nm approx.), for when full spatial detail is mandatory.

For linear spectropolarimetry, after setting up the spectrograph and acquiring the object, one only needs to move the halfwave plate into the beam at a specific angle, move the calcite slab into the beam and select the appropriate dekker mask. The calcite slab affects the spectrograph focus which is corrected by adding 9200 units to the standard collimator positions. The slit-view TV camera looks through the halfwave plate, which causes the TV image to be highly vignetted and also affects the TV focus. The optimal TV focus (at scale 5) is about 1500 units less than the standard setting without the halfwave plate. If your object is faint it will be necessary to remove the halfwave plates and the dekker in order to put the object on the slit.

The instrumental setup for circular spectropolarimetry is similar, but the quarterwave plate must be used in stead of the halfwave plate. For further details see Section 9.5 of this manual and the *ISIS Spectropolarimetry Users' Manual*.

8.3 Setting up the CCD Detectors

The CCD setup is carried out with the comparison lamps, and these give a reasonably high signal. A large number of exposures may be necessary, and it is possible to save time by running the CCD in quick mode, in which the readout is speeded up.

At the ICL interface type:–

```
SPEEDY <channelname>
```

This will put the appropriate CCD into quick mode. At the end of the setup procedures the CCD should be returned to the standard readout speed. At the ICL interface type:–

```
SLOUCH <channelname>
```

8.3.1 Rotation

The long axis of the CCD should be aligned fairly precisely with the dispersion direction of the spectrograph, with care it should be possible to do this to an accuracy of 1 minute of arc, which corresponds to 0.3 pixels slope of the spectrum from one end to the other. The value of doing this alignment well is in the signal-to-noise ratio of the final spectrum when extracting spectra of faint point sources, and in the effective spatial resolution of long slit spectroscopy of extended objects in good seeing. This alignment will probably only have to be done when the cryostat has just been put on the spectrograph, but it should be checked more frequently. As the dispersion direction depends upon the angle of the grooves on the grating this alignment could in principle be grating dependent, although with the current set of gratings it is thought not to be.

To check the alignment take an exposure with `GLANCE` of the tungsten lamp through the narrow dekker (dekker 1). Filters, exposure time and grating angle should be adjusted to give a fairly uniform count level along the spectrum. The count level should not exceed 32767 anywhere along the spectrum. If the spectrum displayed on the DMS screen is vertical, as it will be for an EEV P88200 chip, the X position of the spectrum should be measured as near as possible to each end with the DMS command `X-FIND`. If the spectrum on the DMS screen is horizontal, as it will be for an EEV P88300 chip, the Y position of the spectrum should be measured at each end with the DMS command `Y-FIND`.

At the DMS control window type:–

`X-FIND` or `Y-FIND`

Locate the cursor on one end of the spectrum with the DMS mouse, then press the space bar on the keyboard **not one of the mouse buttons** to accept the cursor position. A profile across the spectrum will be displayed on the DMS display screen, and on the alphanumeric screen the position, which is the raw cursor position in the spectral direction and the centroid in the spatial direction will be displayed. For the centroiding algorithm to work well the peak of the profile should be near the centre of the display, if it is not then press the space bar to return to the main display and repeat the process. This should be repeated at the other end of the spectrum, and the difference between the two centroids noted. If this is more than about 0.3 pixels then the rotation alignment should be adjusted.

The CCD mounting ring is fixed to the mounting ring on the spectrograph by seven 6mm Allen screws which pass through slots in the CCD mounting ring into the spectrograph mounting ring. **There are two further Allen screws which hold the spectrograph mounting ring to the spectrograph, these lie on a horizontal line through the centre of the mounting ring, and are recessed more deeply than the other screws. These two screws should not be loosened.** If the seven screws are loosened the cryostat and mounting ring can be rotated a small amount, the limit is set by the length of the slots in the CCD mounting ring. There is a micrometer gauge fixed to the CCD mounting ring to the left of the cryostat; this can be brought against a block which is fixed to the spectrograph mounting ring to give a measure of the relative position angle of the two rings.

The cryostat should be rotated by backing off the micrometer; loosening the screws; rotating the cryostat manually; tightening at least three of the screws; and then measuring the position angle with the micrometer. The micrometer gauge should not be used to push the cryostat around. The mounting ring on the red arm is stiffer than that on the blue arm, and needs to be pushed around quite hard.

A 1 pixel slope from end to end on the CCD will require a movement of the cryostat position angle equivalent to slightly under 0.2mm on the micrometer. The direction of the slope on the DMS display will depend upon which CCD on-chip amplifier is being used, so this will have to be established by trial and error. Getting the rotation right is largely a matter of trial and error, and can be a time consuming process.

When the rotation is correct all seven screws holding the two rings together should be tightened.

8.3.2 Tilt and coarse Focus

The tilt of the cryostat can be adjusted in two dimensions to ensure that the CCD is coplanar with the focal plane of the spectrograph. The cryostat is held to the mounting ring by three clamps on the mounting ring which each hold a capstan attached to the cryostat flange against the mounting ring. The height of the cryostat can be adjusted by rotating the capstans, and can be measured with three micrometers, mounted on the cryostat flange alongside each capstan, which can be brought against a metal stud in the surface of the mounting ring. The capstans can be locked by tightening the thread that they run through with an Allen screw in the cryostat flange.

The tilt of the CCD can be checked with the FOCUS procedure on the DMS. With a slit width of around 150μm and a long slit dekker position set the exposure time, filters and central wavelength to give a uniform distribution of line from one of the comparison lamps; make sure that there are reasonably strong lines near each end of the spectrum. The exposure time should be set to give a reasonably strong signal, but the lines to be used must not exceed 32767 adu at any point along their length. Set up a CCD window about 600 pixels wide with the ICL procedure `WINDOW`; close the left Hartmann shutter by typing:–

`BHART 1` or `RHART 1`

at the ICL interface and take an exposure with `GLANCE` When it has read out, at the DMS control window type:–

```
FOCUS
```

Select three strong lines evenly spaced from the one end of the spectrum to the other by placing the cursor on each in turn and pressing the space bar on the DMS keyboard. Each line profile will be shown on the DMS display, and the line can be rejected if it appears too weak, or blended with or close to another line. The best results will come from strong isolated lines. When three lines have been selected type:–

```
FOCUS-LEFT
```

at the DMS control window. The programme will then list the centroid and an estimate of the full width half maximum at three positions along each line. The arrangement of the listed positions on the alphanumeric screen maps to the DMS display, so the first position listed is in the top left hand corner of the image as displayed on the DMS display.

Now open the left Hartmann shutter and close the right by typing:–

`RHART 2` or `BHART 2`

at the ICL interface and take another exposure. At the DMS control window type:–

```
FOCUS-RIGHT
```

This routine will list the positions and the full width half maxima of the lines together with the shifts since the first exposure. These Hartmann shifts indicate how far from the focal plane the CCD is at each point, and the aim of the tilt adjustment is to make all of the shifts the same. If the shifts are more than 3 pixels then the spectrograph is probably too far out of focus for this procedure to succeed, and it will be necessary to adjust the collimator position with `BCOLL` or `RCOLL`, or else to move all three capstans so that the spectrograph is closer to focus.

The *relative* Hartmann shift from one end of the spectrum to the other, or from one end of the slit to the other, should be no more than about 0.2 pixels. If they are more than this then the capstans will need to be adjusted. There are three capstans, labelled A, B and C. The dispersion is horizontal when the telescope is parked at the zenith; moving capstan B affects the tilt along the slit, whereas moving capstan A or C affects both the tilt along the spectrum and that along the slit. For this reason it is easier to adjust the tilt along the spectrum first, and then the tilt along the slit.

To move a capstan the micrometer should be read, then backed off. The small Allen screw should be loosened until the capstan is free to rotate. It may be possible to rotate the capstan without releasing the clamp, this is probably the best thing to do if the amount of capstan rotation is less than one complete turn. If it is larger the clamp should be released; the capstan turned by an appropriate amount with one hand, and the clamp applied again; all the while the other hand should be used to hold the cryostat firmly in place. After the clamp has been tightened the micrometer can be read again. **The micrometers should never be used to take the weight of the cryostat, and should only be brought into contact with the studs when the capstans are firmly clamped.**

One complete turn of a capstan will result in a change in the micrometer reading of 0.5 millimetres. A one pixel differential shift along the spectrum will require a movement of capstan A or C of 4 complete turns, or 2 turns of each in opposite directions, which will keep the focus in the centre of the chip the same. A one pixel differential shift along the slit (600 CCD pixels) will require 7 complete turns of capstan B to correct it.

The sign of the differential Hartmann shift measured by this procedure will depend upon the way that the CCD is mounted in the cryostat, and which on-chip amplifier is being used. The telescope manager or technical staff may know the direction, but if they are not available it can be established by trial and error.

The Hartmann test should be repeated after every move of the capstans; it should not be necessary to run the `FOCUS` routine each time because the lines should not shift very far. If `FOCUS-LEFT` gives widely different centroids or widths for what should be the same line then it may be necessary to run `FOCUS` again. When the differential shifts are satisfactory the micrometer readings should be noted in the ISIS log, together with the date and details of the cryostat used. The micrometers should then be backed off, and the firmness of the clamps checked. It is not normally necessary to tighten the small Allen screws, unless the capstan is particularly loose

8.3.3 Collimator Focus

The final focus is achieved by moving the ISIS collimators, in practice this is all that most users will have to do. The grating setting, set by the ICL procedure `CENWAVE`, and the CCD window, set by the ICL procedure `WINDOW`, should be appropriate for the observations of the coming night.

The collimator position can be set from the ICL interface by typing:–

`BCOLL <position>` where the position is in the range 0-52000
`RCOLL <position>` where the position is in the range 0-30000

The spectrograph works best with the collimators near 8000, except if the blue camera is in use with the folding prism, in which case the focus position should be near 30000. If focus is obtained far from these values the spectrograph will be astigmatic, and although the comparison lines may be in focus the resolution along the slit will be degraded. In this case it will be necessary to rotate the three capstans by the same amount to bring the CCD into approximate focus near the optimum value of the collimator position. Movement of the capstans is described in section 8.3.2. One complete turn of each capstan will move the CCD with respect to the focal plane of the spectrograph by 0.5 mm, which will cause a Hartmann shift of 3.5 CCD pixels. This is equivalent to approximately 10000 units of collimator movement. A clockwise rotation of the capstans will be compensated by a negative collimator movement on either arm.

8.3.4 Hartmann test using the DMS

Set the slit width and dekker with:–

```
SLIT 150
DEKKER 6
```

The comparison lamp filters and the exposure time should be set to give a reasonably strong comparison spectrum but the intensities in the lines to be used, as measured with the CALCULATE option on the DMS STATISTICS menu, should not exceed 32767. Close the left Hartmann shutter by typing:–

`BHART 1` or `RHART 1`

at the ICL interface and take an exposure by typing:–

`GLANCE RED ARC <time>` or `GLANCE BLUE ARC <time>`

When it has read out, at the DMS control window type:–

```
FOCUS
```

Select three strong lines evenly spaced from the one end of the spectrum to the other by placing the cursor on each in turn and pressing the space bar on the DMS keyboard. Each line profile will be shown on the DMS display, and the line can be rejected if it appears too weak, or blended with or close to another line. The best results will come from strong isolated lines. When three lines have been selected type:–

```
FOCUS-LEFT
```

at the DMS control window. The DMS will then list the centroid and an estimate of the full width half maximum in CCD pixel units at three positions along each line, and store these values. The arrangement of the listed positions on the alphanumeric screen maps to the DMS display, so the first position listed is in the top left hand corner of the image as displayed on the DMS display.

Now open the left Hartmann shutter and close the right by typing:–

`BHART 2` or `RHART 2`

at the ICL interface and take a similar exposure. At the DMS control window type:–

```
FOCUS-RIGHT
```

This routine will list the positions and the full width half maxima of the lines together with the shifts since the first exposure. These Hartmann shifts indicate how far from the focal plane the photocathode is at each point. The amount of collimator movement required can be calculated from the mean Hartmann shift; a Hartmann shift of 0.5 pixels implies that the collimator needs to be moved about 1000 microns. The direction of the shift will depend upon which on-chip amplifier is being used, and will have to be determined by trial and error.

After each move of the collimator the Hartmann test should be repeated. After a move of the Blue collimator it probably will be necessary to run `FOCUS` again as unclamping and clamping this collimator can cause line shifts of several pixels.

The final FWHM of the lines with a narrow slit should be in the region 1.5 to 2 pixels, although with the 150μm slit recommended they will be somewhat broader.

At the end of the focus procedure both Hartmann shutters should be opened by typing:–

`BHART 0` or `RHART 0`

The focus is somewhat temperature dependent, but unless there is a sudden change of ambient temperature the spectrograph, once in focus, should remain so for several days.

8.3.5 Hartmann test using the Vax

Using the command `ARC` or `RUN` obtain 3 or 5 pairs of Hartmann left and right arc-lamp exposures at different values of the collimator position. Copy them onto a scratch area on one of the Vaxcluster scratch disks as files `HART_Li.DST` and `HART_Ri.DST` where `i` takes values e.g. 1 - 3 or 1 - 5. Type `FIGARO`, then `FOCUS_HART` and respond to the prompts.

The parameters which may be changed by the user are: the number of left-right pairs of images; the wavelength direction (X or Y); the first and last pixels in the orthogonal direction to be used; the start collimator position; the increment in collimator position; and whether the maximum pixel-value is to be determined for each of the images (so that the user can check for saturation).

The cross-correlation between spectra extracted from left and right images is performed by the FIGARO routine `SCROSS`. In-focus position is determined in two ways: by linear interpolation between two values flanking zero line-shift, and by fitting a least-squares straight line to the relation between focus position and line shift. The program plots this relation on a device of the user's choosing e.g. `PERICOM_MG, IKON_1, CANON_P`, VAXstation `TEK_4010` window.

8.3.6 Minimum-FWHM using the VAX

The correct position of the collimator may also be determined (not as accurately) from a plot of line FWHM vs collimator position. Take a series of regularly-spaced exposures, copy them to `SCRATCH` as files `FOCUSi.DST`, type `FIGARO`, then `FOCUS_FWHM` and respond to the prompts.

The parameters which may be changed by the user are: the number of images; the wavelength direction (X or Y); the first and last pixels in the orthogonal direction to be used; the start collimator position; the increment in collimator position; whether the maximum pixel-value is to be determined for each of the images (so that the user can check for saturation); whether the region of the spectrum to be used is cursor-selected or defaults to the whole spectrum; and the number of brightest lines to be used to determine the mean FWHM.

A version of FIGARO's `EMLT` program is used to determine the mean FWHM for the brightest lines on each extracted spectrum. In-focus position is estimated by determining the minimum in a parabola fitted to the 3 points flanking the lowest-measured FWHM in the relation FWHM *vs* focus position. The program plots this relation on a device of the user's choosing e.g. `PERICOM_MG, IKON_1, CANON_P`, VAXstation `TEK_4010` window.

8.4 Setting up the IPCS

Instructions for starting up the IPCS are given in "*The IPCS-II Users' Manual, by J.S.B. Dick*" and these instructions should be obeyed exactly to ensure safety for the IPCS image intensifier. Ensure also that the raw video display in the control room is working, and that the "Panic Button", closes the shutter immediately it has been pressed.

The ICL commands to open and close the blue arm shutter when the IPCS is on the spectrograph are:–

`IPCSOPEN` or `IPO` to open the shutter;

and:-

`IPCSCLOSE` or `IPC` to close the shutter.

If the "Panic Button" is pressed to close the shutter then `IPCSCLOSE` must be issued before attempting to open the shutter again.

The IPCS is easily damaged by bright light, so care must be taken when setting up and observing. Particular care is necessary when using the tungsten lamp for the rotation and scan correction setup, as this lamp is very bright. A substantial amount of neutral density is required to reduce the intensity of the lamp to a safe level, and it is recommended that users begin with at least ND4.2 (`COMPFILTA ND3.0` and `COMPFILTB ND1.2`) in the beam and reduce it slowly if necessary.

8.4.1 Camera Head Rotation

The camera head of the IPCS should be rotated until the spectral direction is aligned with the camera pixel direction of the IPCS. **At present the camera head mechanism is unreliable, and this adjustment should only be done by RGO technical staff, who should then disconnect the power to the motor which drives the camera head to stop it from rotating of its own accord.**

Set up the spectrograph and comparison lamp unit to give a narrow tungsten spectrum with reasonably uniform illumination along the spectrum:–

`DEKKER 1`	to give a narrow dekker
`AGMIRROR ACQCOMP`	
`CENWAVE BLUE 6500`	illumination is more uniform in the red
`COMPFILTA ND3.0`	
`COMPFILTB ND1.2`	
`SLIT 200`	
`COMPLAMPS W`	

Open the shutter carefully in `OVERSCAN` mode to check the count rate, and adjust the comparison filters, slit width and grating angle if necessary.

Set up the IPCS using the ICL procedure `IPCSFORMAT` to have a window about 30 camera pixels wide with the spectrum from the narrow dekker in the centre, and with full (x8) resolution in the X direction and x2 or x4 resolution in the Y direction. Alternatively the ICL procedure `IPCSSDC` should do the automatically, although it may be necessary to adjust the start pixel of the window in the Y direction; see the "*IPCS-II Users' Manual*" for details of how to do this.

Open the shutter and take an exposure of at least 200 seconds to a reasonable count level. When the exposure has finished, at the DMS control window type:–

```
Y-FIND
```

Using the DMS mouse put the cursor a little way in from one end of the spectrum and press the space bar. The DMS will determine the centroid in the Y direction of the spectrum. Press the space bar again and repeat the process at the other end of the spectrum.

If the spectrum is clearly tilted then the camera head should be rotated. First, check that the power lead to the motor which drives the camera head rotation is connected. The camera head can then be rotated from the ICL interface by typing:–

```
IPROT <value>
```

where value in an integer between 0 and 65535 which represents the amount the camera head is to be rotated. Each step represents 4.4 seconds of arc, and the value is biased by 32768, so that 32760 rotates 8 steps in a negative direction and 32778 rotates 10 steps in a positive direction. A value of 32768 stops the rotation.

As a rough guide, a slope of 1 pixel over the length of the spectrum at x2 resolution implies that a rotation of 25 units is required, and to rotate the spectrum clockwise on the DMS display a negative rotation of the camera head is required.

This process should be rotated until the spectrum is straight to an accuracy of about 0.5 pixel slope at x2 resolution (or 1 pixel at x4 resolution). When the rotation is correct it is advisable to disconnect the power lead to the rotation drive motor.

8.4.2 S–Distortion Correction

The IPCS-II S-distortion correction is a rebinning operation performed by the DMS, and the parameters for the correction are determined by the DMS.

Set up the spectrograph and comparison lamp unit to give a narrow tungsten spectrum with reasonably uniform illumination along the spectrum:–

```
DEKKER 1                 to give a narrow dekker
AGMIRROR ACQCOMP
CENWAVE BLUE 6500        illumination is more uniform in the red
COMPFILTA ND3.0
COMPFILTB ND1.2
SLIT 200
COMPLAMPS W
```

Open the shutter carefully in `OVERSCAN` mode to check the count rate, and adjust the comparison filters, slit width and grating angle if necessary.

The s-distortion correction must be calculated at full (x8) resolution in both X and Y directions, even if this resolution will not be used for the observations. Run the ICL procedure:–

```
IPCSSDC
```

which will set up a full resolution window 30 camera pixels wide centred on the spectrum. If, after running this procedure the tungsten spectrum is not in the centre of the window the value of the Y starting pixel of the CCD window must be changed, this can be done with:–

```
SEND IPCS OBEY Y_CCD_WIN MOVE <ystart> 30
```

The existing s-distortion correction must be turned off by typing at the DMS control window:–

```
0 ESD
```

At the ICL terminal take a fairly long exposure, it is important to have a strong signal in the S-curve:–

```
IPCSOPEN
EXPOSENP IPCS 1000
```

After this exposure has finished, close the IPCS shutter with:–

```
IPCSCLOSE
```

then at the DMS control window type:–

```
CALC-SDC
```

This calculates the s-distortion correction, and takes about 80 seconds during which time the DMS will not respond. After the correction has been calculated it must be loaded and enabled on the DMS control window with:–

```
LOAD-SDC
1 ESD
```

S-distortion corrections can be stored on the DMS disk with:–

```
PUT-SDC-ARRAY
```

and recalled with:–

```
GET-SDC-ARRAY
```

After recalling an s-distortion correction it is necessary to load and enable it as described above. Unlike the first generation IPCS on the INT the s-distortion correction is a digital process, and no “tweaking” is necessary or possible.

8.4.3 Collimator Focus

As with the CCD detectors the final focus is achieved by moving the ISIS collimator, and determined by using the remotely operated Hartmann shutters. Again two methods of determining the Hartmann shifts are provided.

The collimator position can be set from the ICL interface by typing:-
`BCOLL <position>` where the position is in the range 0-52000

If a dichroic or the flat mirror are in use the spectrograph works best with the collimator near 8000, if the folding prism is in use the collimator should be near 30000. If focus is obtained far from these values it will be necessary to move the image tube in the solenoid to bring the focus near to its nominal value. *This adjustment should only be attempted by RGO technical staff.*

8.4.4 Hartmann test using the DMS

The focus should be determined with a grating setting and data format appropriate for the observations of the coming night. Set the slit width and dekker with:–

```
SLIT 100
DEKKER 6
```

A comparison lamp, usually the Copper-Argon lamp is used for the focus. The neutral density filters should be set to give a count rate of no more than one photon/pixel/second at x8 resolution along the spectrum and x2 resolution alongthe slit. The ICL procedure `IPCSFORMAT` should be used so set up an appropriate data window. Close the left Hartmann shutter by typing:–

```
BHART 1
```

at the ICL interface and take an exposure of at least 200 seconds by typing:–

```
IPCSOPEN
EXPOSENP IPCS 200
```

at the ICL interface.
When it has finished, at the DMS control window type:–

```
FOCUS
```

Select three strong lines evenly spaced from the one end of the spectrum to the other by placing the cursor on each in turn and pressing the space bar on the DMS keyboard. Each line profile will be shown on the DMS display, and the line can be rejected if it appears too weak, or blended with or close to another line. The best results will come from strong isolated lines. When three lines have been selected type:–

```
FOCUS-LEFT
```

at the DMS control window. The DMS will then list the centroid and an estimate of the full width half maximum in DMS pixel units at three positions along each line, and store these values. The arrangement of the listed positions on the alphanumeric screen maps to the DMS display, so the first position listed is in the top left hand corner of the image as displayed on the DMS display.

Now open the left Hartmann shutter and close the right by typing:–

```
BHART 2
```

at the ICL interface and take a similar exposure. At the DMS control window type:–

```
FOCUS-RIGHT
```

This routine will list the positions and the full width half maxima of the lines together with the shifts since the first exposure. These Hartmann shifts indicate how far from the focal plane the photocathode is at each point. The amount of collimator movement required can be calculated from the mean Hartmann shift; a Hartmann shift of 1 pixel implies that the collimator needs to be moved about 1000 microns. A positive Hartmann shift implies that the collimator must be moved to lower values.

As the IPCS data builds up in the DMS you can type `FOCUS-RIGHT` part way through the exposure to see how it is going, then repeat it at the end.

After each move of the collimator the Hartmann test should be repeated. It probably will be necessary to run `FOCUS` again as unclamping and clamping this collimator can cause line shifts of several pixels.

The final FWHM of the lines should be around 3.5 pixels, it is rather better in the red and rather worse in the blue. If, with the spectrograph in focus and a narrow slit in place the FWHM is much greater than this then the Image Tube focus is incorrect and should be adjusted. This must only be done by RGO technical staff.

At the end of the focus procedure both Hartmann shutters should be opened by typing:–

```
BHART 0
```

The focus is somewhat temperature dependent, but unless there is a sudden change of ambient temperature the spectrograph, once in focus, should remain so for several days.

8.4.5 Hartmann test using the Vax 4000

Using the command `EI` obtain 3 or 5 pairs of Hartmann left and right arc-lamp exposures, and copy them onto a scratch area on the Vaxcluster as files `HART_Li.DST` and `HART_Ri.DST` where `i` takes values e.g. 1 - 3 or 1 - 5. Type `FIGARO`, then `FOCUS_HART` and respond to the prompts.

The parameters which may be changed by the user are: the number of left-right pairs of images; the wavelength direction (X or Y); the first and last pixels in the orthogonal direction to be used; the start collimator position; the increment in collimator position; and whether the maximum pixel-value is to be determined for each of the images (so that the user can check for saturation).

The cross-correlation between spectra extracted from left and right images is performed by the FIGARO routine `SCROSS`. In-focus position is determined in two ways: by linear interpolation between two values flanking zero line-shift, and by fitting a least-squares straight line to the relation between focus position and line shift. The program plots this relation on a device of the user's choosing e.g. `PERICOM_MG, IKON_1, CANON_P`, VAXstation `TEK_4010` window.

8.4.6 Minimum-FWHM using the VAX

The correct position of the collimator may also be determined (not as accurately) from a plot of line FWHM vs collimator position. Take a series of regularly-spaced exposures, copy them to `SCRATCH` as files `FOCUSi.DST`, type `FIGARO`, then `FOCUS_FWHM` and respond to the prompts.

The parameters which may be changed by the user are: the number of images; the wavelength direction (X or Y); the first and last pixels in the orthogonal direction to be used; the start collimator position; the increment in collimator position; whether the maximum pixel-value is to be determined for each of the images (so that the user can check for saturation); whether the region of the spectrum to be used is cursor-selected or defaults to the whole spectrum; and the number of brightest lines to be used to determine the mean FWHM.

A version of FIGARO's `EMLT` program is used to determine the mean FWHM for the brightest lines on each extracted spectrum. In-focus position is estimated by determining the minimum in a parabola fitted to the 3 points flanking the lowest-measured FWHM in the relation FWHM *vs* focus position. The program plots this relation on a device of the user's choosing e.g. `PERICOM_MG, IKON_1, CANON_P`, VAXstation `TEK_4010` window.

8.5 Installation and Setup for Fibre observing

8.5.1 Fibre slit mounting

In order to use ISIS with fibres, it is necessary to mount the fibre bundle slit end in a special structure. This structure is required to take into account the mechanical performance of the spectrograph and to allow the slit alignment with its optical axis.

As can be see in Figure 9, the fibres slit is placed such that the optical axis of the fibres is orthogonal to the optical axis of the spectrograph. A prism is used to make both optical axes coincide. This prism is mounted on a holder. The incoming light from the fibres crosses the holder through two 2mm wide slots. Several clips fix the prism to the holder. The slit is mounted onto a plate ; three kinematic seats allow the fibre slit to be aligned with the prism.

The prism - slit system is mounted onto a rotating plate which permits alignment between the slit image and the detector's spatial direction. Another plate, placed onto kinematic seats, holds the prism - slit mounting and allows it to be aligned with the optical axis of the spectrograph.

Finally, all these mechanisms are supported by the standard mounting to the ISIS slits but with two peculiarities: On the one hand, a stop piece is employed to centre the slit image in the detector. On the other, two pieces to clamp the protective cover of the slit are supported by the plate.

The bundle exits the mechanical structure of the spectrograph through a window opened in the ISIS box (Figure 9). Two portable plates were manufactured to adjust the bundle to the window. THe plates are joint to the bundle through a cable-gland of type GEWISS/GW52006.

8.5.2 Fibre slit alignment

Two steps are required in order to align the fibre optic system. First, the slit and the prism are aligned together and, next, the slit - prism subset is aligned with the optical axis of the spectrograph.

The slit - prism alignment is conveniently performed in the laboratory. The focal plane bundle end is illuminated with a laser beam; the output light at the other end of the bundle enters the prism. The screws at the kinematic seats are adjusted in such a way that the output light from the slit does not become vignetted by the two slots of the prism holder.

In order to align the slit - prism set with the axis of the spectrograph, ISIS must not be mounted on the telescope. In this process, basically, the bundle slit must be aligned and centred on the detector, and also the optical axis of the central fibre of the bundle must be centred with the collimator's axis. The following steps are required:

- The Dekker must be placed in position zero with the command `DEKKER 0`.
- The bundle slit is placed in position on the spectrograph. In order to do so, the software command `SLIT_DOOR OPEN` is used to open the door giving access to slit units. The command `MSLIT` gives access to the unit supporting the slit mounting. This mounting is put on the unit by introducing the bundle through the ISIS window above mentioned.
- The diffraction grating is removed, using the `CHANGE` procedure from ICL. From this position, one of the collimator mirrors can be see. Either the blue or red arm can be used for the alignment.
- The focal plane bundle end is illuminated with white light. From the grating position, the image of the fibre slit can be seen on the collimator mirror. Its centering and orientation can be checked this way.
- ISIS long slit can be positioned with the software command `LSLIT`. Looking at the collimator mirror the movement of both the fibre slit and long slit can be followed. Then, differences in their centering and orientation can be seen.
- For a correct centering, the position of the fibre slit must coincide with that of the long slit. This can be achieved by sliding the slit mounting on the slit unit.

- The white light illumination of the bundle is removed and, instead, the focal plane end of its central fibre (number 31) is illuminated with a laser beam.
- The output light cone illuminates the collimator mirror. Since the FRD of this cone is larger than the mirror, the mechanical mirror holder becomes illuminated as well.
- The light cone can be centred on the collimator by moving the screws on the kinematic seats of the slit supporting plate. This way, the alignment between the optical axis of the fibres and the one of the spectrograph is obtained.

The alignment process described up to now can be checked by means of a method which is similar to the autocollimation one. This method is as follows: a flat mirror is placed at the diffraction grating position, facing the collimator mirror – the grating encoders position for the red arm to reach this situation is 35500. When a laser beam illuminates the focal plane end of one of the fibres at one slit edge, the output light is reflected by the collimator mirror. This beam will be reflected by the flat mirror and returned onto the collimator mirror, which will focus it (if the alignment is good) onto the opposite edge on the slit from where the light started.

8.5.3 Guide fibre bundle focussing

In order to focus the guiding system, the ends of the bundles must be focused onto the CCD camera. This can be done during daylight and it requires two people speaking to each other; one of them must be in the control room viewing the bundles image on the screen, while the other remains in the dome to perform the focusing.

The bundles are mounted on an interface which connects them to the CCD camera. After illuminating the aperture plate bundles ends, the image of the camera bundles ends can be see on the TV monitor in the control room. In the dome, the micrometric positioning screw can be adjusted until the TV image appears focused. The amount of incoming light onto the bundles must be controlled in order to avoid saturation or fine detail loss.

This focusing method is simple and fairly accurate. However, if better precision is required, a transparency with a fringe pattern can be illuminated behind the coherent bundle, the image of this can be focussed accurately on the TV screen.

8.5.4 Spectrograph set up

The spectrograph setup procedures for long slit observing are described above. The plane and tilt of the fibre slit can in principle be different from those of the long slit, the difference in the plane of the slits causes a difference of the distances from the fibre and long slits to two collimators. Because spatial resolution is important, the spectrograph should be set up to provide a collimated beam onto the grating. The nominal values of the collimator settings *for long slit observing* to provide such a situation are 7000μm for the Blue arm, and 9000μm for the red arm. The procedure to ensure that the spectrograph is correctly set up for fibre observing is as follows:-

- With the slit unit in the long slit position, set the two collimators to their nominal values.
- Ensure that the spectrograph can be focussed with the collimators near these values, by making adjustments to the capstans on the CCD cryostats, as described in Section 8.3.2.

- Ensure that the tilts of the focal planes are correct, again by adjusting the capstans as described in Section 8.3.2.
- Ensure that the rotation of the CCDs is such as to align the long axis of the chip with the dispersion direction, again as described in Section 8.3.1.
- Move the slit carriage to the multislit position with the command `MSLIT`, and remove the Acquisition and Comparison mirror.
- Switch on the fibre calibration lamp.
- Using the Hartmann procedures, focus the spectral lines from the fibres onto the CCDs by moving the collimators.
- Correct for any residual tilt along the fibre slit by making balanced moved of the CCD capstans, i.e always keeping the centre of the focal plane in the same case.

The difference between the collimator position for best focus for the long slit and for the fibres should be the same, and of the same sign, for both red and blue arms.

8.6 Setting up FOS

The fixed format of FOS makes it a very stable instrument. However, it is a good idea occasionally to check the focus and alignment. Moreover the best focus setting will need to be reset if either a below-slit filter, or more particularly the field lens, are used with FOS in any mechanism below the slit.

To check the focus, set the ISIS slit width to 40μm, turn on an arc lamp, put in the comparison-lamp mirror and take a short exposure. Select a strong but unsaturated line and use the DMS command `10 Y-FIND` to measure its FWHM. If the line is in focus, the FWHM should be about 1.6 pixels, slightly better in the blue. If the FWHM exceeds 1.8 pixels, the focus must be adjusted by control of the motor-micrometers (see below). A more accurate check of the focus can be made by comparing exposures taken with either the left or right Hartmann shutter closed, these exposures can be analysed with the Hartmann routines described in Section 8.3.3

For data-reduction routines to work well, the slit must be aligned with the CCD rows to within $\sim$ 0.2 pixel over the full slit length. This can be checked using the data frame obtained for focus, by measuring the line centres with 10 Y-FIND at opposite ends of the slit.

The focus and tilt of the FOS CCD are determined by the positions of 3 push rods on which the ring bearing the CCD is supported. These push rods are moved along their axes by 3 motor-micrometers, which are controlled from the engineering terminal. The commands available are:

`HELP` - lists all available commands
`STATS` - lists status of Hartmanns, motor-micrometers, focus and tilt
`xxx FOCUS` - adjusts focus to position xxx (0 - 511). Each motor-micrometer moves by the same amount
`ALLSTOP` - stops all mechanisms immediately
`xxx 1MOVE` - moves motor-micrometer 1 to position xxx (0 - 511)
`xxx 2MOVE` - moves motor-micrometer 2 to position xxx (0 - 511)
`xxx 3MOVE` - moves motor-micrometer 3 to position xxx (0 - 511)

`xxx HANGLE` - sets horizontal tilt to xxx (-255 - 255)
`xxx VANGLE` - sets vertical tilt to xxx (-255 - 255)
`a b HARTS` - operates Hartmann shutters (a, b = OPEN or CLOSED)

The most-recent setting of the motor-micrometers, focus and tilt is recorded in the FOS instrument logbook. Check whether this is for FOS in the configuration that is required.

9 Observing Procedures

9.1 Observing with one or two CCDs

9.1.1 TV Focus

Normal practice is for the telescope operator to focus the telescope on the TV image reflected from the slit jaws. The slit image is of course focussed onto the detector. However for the telescope focus to be correct it is crucial that the TV camera itself is focussed correctly onto the slit. TV focus does not normally change very much unless a change is made to the TV camera itself, and the current value of the TV focus is normally written on the white board in the control room. However if there is any doubt about the value of the TV focus it is necessary to measure this, which can be done during the day:-

1. Obtain the key to the TV override switch from the technical staff. This is normally kept out of the control room and will have to be signed for.
2. Override the interlock on the slit viewing TV camera, and only this camera. This will allow the TV and the lights to be on at the same time.
3. Put on a low level of lighting in the dome; the drum lights are quite sufficient. Ensure by means of a notice than nobody will switch any other lights on in the dome.
4. Switch on the TV controller for the slit viewing TV and the TV system VME computer. These are in the furthest of the four blue cubicles from the left hand end of the control desk.
5. Ensure that the slit viewing mirror is in, type `AGSLIT` at the ICL interface if it is not.
6. Switch on the slit viewing TV camera only; wait for the delay lights to go out, and turn up the gain on the TV **SLOWLY** until the slit jaws are visible on the small TV direct monitor. Watch this monitor all the time while turning up the gain.
7. Adjust the TV focus with the `TVFOCUS` command until the edges of the slit jaws are sharpest.
8. Note the new value on the whiteboard.
9. **TURN THE TV OFF AND RETURN THE OVERRIDE SWITCH TO NORMAL STATUS.** Failure to do this could result in the destruction of a TV camera.

Note that the correct value of TV focus for direct viewing (i.e. with the ACQCOMP mirror in) is very different from that for slit viewing. The telescope should not normally be focussed on the direct image when using ISIS or FOS. However TV focus will be approximately the same for the two different scales when the slit viewing optics are in. The normal slit viewing mode is at a scale of 4.5 arcsec/mm.

9.1.2 Instrument Calibration Data

The standard observing mode with ISIS is to observe with one or more CCDs. Decisions which have to be made before the beginning of an observing run include:–

- The grating or gratings to be used, and the central wavelengths they will be used at.
- The dichroic to be used if both arms are required. Plots of the reflection and transmission curves of the mounted dichroics should be available in a folder in the control room.
- The size of the data window. The ISIS slit illuminates about 700 pixels on the spatial direction on an EEV CCD; slightly less on the Tektronix CCD. Windowing the chip saves readout time, and observers should not normally use more pixels than the slit illuminates. Many observers, particularly those interested in point sources, will require much less of the slit, and in many cases a hundred pixels (33 arcsec) will suffice.
- Whether on-chip binning is required to reduce the effect of readout noise. it is possible using the BIN procedure to set any binning factors in either direction; binning factors of up to 4 in each direction are normal.

Procedures for configuring the spectrograph for the beginning of observing are described in Part IV. The centre of the slit on the CCD can be determined by taking a short exposure of a tungsten lamp through the narrow dekker (dekker position 1); and measuring the centre in pixels with the DMS command `Y-FIND`. Before beginning to take exposures with a CCD it is necessary to set the CCD up with the ICL command `SETUP` <`ccdname`>. This will prompt the user for the size of the CCD data array; this includes underscan and overscan regions and is 400 by 590 for the FOS and GEC5 CCDs; 1280 by 1180 for EEV P88300s; and 1124 by 1124 for the Tektronix CCD. If windowing or binning is required this can then be set up with the ICL procedures `WINDOW` and `BIN`. There are a number of faults that can occur when reading CCD data into the DMS buffers:

- If the CCD fibre optic interface card (at the top of the second blue cabinet from the left hand end of the control desk) displays a light labelled **G.O.A.T.** then there is probably a fault with an optical fibre cable. A duty tech should be called.
- If there is an error light on the DICI card; or a **FIFO FULL** light on the CCD fibre optic interface card; then the DICI should be reset and the exposure repeated.
- If the data are clearly scrambled; or show a series of diagonal stripes then the CCD controller thinks the data frame is a different size to the DMS. The DMS should be reset, and the `SETUP` and `WINDOW` commands should be repeated at the ICL interface **FOR EVERY CCD IN USE**.
- If the previous procedure does not work then the CCD controller should be rebooted (with the `REBOOT` command rather than switching it off and on) and the procedure repeated.
- If the CCD shutter fails to open this will send a message to the ICL interface. This could be due to a fault on a shutter cable; to low nitrogen pressure to the telescope; or to a mechanical failure of the shutter. However before calling for technical assistance it is worth typing `UNJAM` at the relevant CCD controller to see whether this cures the fault.

Once the CCD has been set up to obtain images of the correct format, and the spectrograph has been set up correctly then the observer can begin taking calibration exposures. Normally the following calibration exposures are required:-

- A number of "Bias" frames, which are dark exposures with zero exposure time. These can be taken with the `BIAS` command. These are often not required because the bias is structureless, and its absolute level can be determined from the overscan and underscan regions associated with each exposure.

- A single long dark exposure, which can also be taken with the `DARK` command. The dark count is very small, and a dark frame is usually used to measure the cosmic ray rate.

  If the ICL interface is not running, dark frames can be taken with the following procedure:–

  1. Set up the correct buffer with the correct size in the DMS with one of the commands `CRUN`, `GRUN` or `OPN`; if the latter then the correct arguments must be used.
  2. At the CCD controller invoke the Network vocabulary with the command:-
`NETWORK`.
  3. At the CCD controller set the exposure time with the command:-
`<headno> <exposuretime> SEX`,
where the time is in milliseconds.
  4. Begin the dark exposure with the command `<headno> 0 DAR`. Note that although the network command to take a dark frame is `DRK`, the CCD controller command is `DAR`.
  5. The exposure will read out into the DMS buffer, and can be stored with `KEEP` from ICL.

  It is very difficult to setup windows or binning without access to the ICL interface.

- A number of flat fields taken with the Tungsten lamp. The grating can be moved to give uniform illumination along the spectrum, because the tungsten flatfield should not be used to take out large scale sensitivity variations. It cannot be used to take out the large scale variations along the slit because the illumination of the slit by the calibration optics is not exactly the same as the illumination by the sky. A flatfield taken with a wide slit can be used for correcting for small scale sensitivity variations along either dimension of the CCD. A flatfield taken with a narrow slit will contain additional small scale variations of illumination in the spatial direction, which will appear as horizontal stripes on the image. These are due to variations in the slit width; the slit jaws are not precisely straight and parallel.

  To obtain flatfield exposures the following steps must be followed:-

  1. Put the acquisition and comparison mirror into the beam with the ICL command `AGCOMP` or `AGMIRROR ACQCOMP`.
  2. Turn on the tungsten lamp with the ICL command `COMPLAMPS W`.
  3. Adjust the comparison neutral density filters with the ICL commands `COMPFILTA` and `COMPFILTB`.

4. Turn out the lights in the dome if possible.
5. Take trial exposures with GLANCE and adjust the exposure time and filters to give a maximum level in the region of 20000 - 40000 ADU.
6. Take the final exposures with RUN or FLAT or keep the trials if the level is right.

- An exposure of the twilight sky, with the spectrograph set up precisely as it is intended to use it during the night. In particular the slit width should be the same as that intended for the night-time observations. Twilight sky exposures can be taken about 20 minutes after sunset, with the telescope pointing at the zenith. They are used for calibrating the sensitivity variations in the spatial direction.

  To take twilight sky exposures:-

  1. Take the acquisition and comparison mirror out of the beam if it is in with the ICL command AGSLIT or AGMIRROR SLITVIEW or AGMIRROR OUT. If a comparison lamp is on you will need to turn it off with COMPLAMPS OFF first.
  2. Verify that the dome and primary mirror covers are open.
  3. Take trial exposures with GLANCE and adjust the exposure time and main filter slide filters, with the ICL command MAINFILTND to give a maximum level of no more than 40000 ADU. The twilight sky exposures do not require a very high signal level, because they will be collapsed in the spectral direction before being used anyway.
  4. Take the final exposures or keep the trials if the level is right.

- Exposures of comparison sources (usually copper-argon or copper-neon) interspersed with observations on the sky. The comparison lamps are really rather faint in the blue, and exposure times of between one and five minutes, depending upon the dispersion and slit width, will be required to give adequate signal in the blue. The copper argon lamp usually gives the most usable lines here.

  At wavelengths longer than 5850 Å the copper-neon lamp has a number of strong clean lines, and at wavelengths longer than 6965 Å the copper-argon lamp does too. Thus it is usually possible to obtain a high signal-to-noise comparison spectrum, containing a number of good lines, using one or both of these lamps in an integration time of between 5 and 30 seconds.

  When using both arms it is possible to make the best of the disparity in the required exposure times for comparison lamps in the blue and red channels by completing the entire red exposure, including clearing, exposing and reading out the CCD and keeping the file to the Vax disc while the blue CCD is integrating. At the ICL interface:-

  1. Ensure that the acquisition and comparison mirror is in, if it is not put it in by typing AGCOMP.
  2. Switch on the required comparison lamp(s) with the command COMPLAMPS.
  3. Start the blue exposure with ARC BLUE <exposuretime>, where the exposure time is 100-300 seconds.

4. When the packet collection is complete start the red exposure with:-
   `ARC RED <exposuretime>`,
   where the exposure time is in the range 10-30 seconds.
5. Wait for the red exposure to finish reading out; when it has finished the icon for the red CCD frame will appear on the DMS display screen; and the message "PICTURE action complete" will appear at the ICL interface.
6. Wait for the blue frame to finish reading out; again waiting for the icon to be redrawn and the "PICTURE action complete" message to appear at the ICL interface.

If the difference between the two exposure times is less than about 60 seconds then the blue frame will begin reading out before the transfer of the red data to disc has taken place. This is not a problem at all; the DMS is capable of having data written to one buffer by a CCD controller whilst data is being read from another.

9.1.3 Acquiring data on the sky

The commands for controlling the telescope are detailed in the WHT manual; and any of these commands except use of the handset can be issued from the ICL interface instead of the Telescope Control System (TCS) interface. If these commands are typed at the ICL interface the telescope D-task relays them to the TCS, and they are echoed on the TCS control terminal. The position information is input to the TCS by one of the methods described in the WHT manual. If a particular sky position angle is required, for an extended object or for two or more objects in a line this is specified by the TCS command `ROT SKY <position angle>`. When observing point sources for which the sky position angle is not important, the command `ROT VFLOAT` will ensure that the sky position angle is set to the parallactic angle when the object is acquired. If spectrophotometric accuracy is of prime importance, and the observer does not wish to autoguide, the command `ROT VERTICAL` will put the slit vertical and leave it there, i.e. the rotator will not track. The sky position angle and the parallactic angle will then always coincide. All position angles are measured in the conventional sense: from North through East.

If the observer has very precise positions, and the pointing of the telescope has been calibrated correctly with the TCS `CALIBRATE` procedure then the objects should appear close to the Cassegrain rotator centre. In this case it is best to define an aperture with the TCS `ENTER APERTURE` command, and move the objects directly into the slit with the TCS `APERTURE` command.

It is normally best to acquire directly onto the slit at a scale of 4.5 arcsec/mm. If the TV focus has been set correctly it should be possible to check the focus on the slit if the object is bright enough. If there are two objects which are further apart than the TV field of view at this scale it may be necessary to go to 12 arcsec/mm to get both onto the slit. When acquiring more than one object on the slit it is best to use the TCS `TWEAK` command, which will allow small adjustments of position and position angle, whether the telescope is autoguiding or not.

9.1.4 Acquiring faint objects

If the objects are two faint to see on the slit viewing TV then they should be acquired using the TCS `BLIND_OFFSET` command. For each object the observer should bring accurate positions of the object, and of an offset star which will be visible on the slit viewing TV. Each position should be entered as a catalogue entry in the TCS. The procedure for acquisition is as follows:-

1. Acquire the offset star on the rotator centre by typing `GOCAT <offsetstar>`.
2. Centre the star up on the rotator centre using the handset.
3. Move the star into the slit with the `APERTURE` command.
4. Move to the programme object by typing `BLIND_OFFSET <objectname>`.

Once the object is centred on the slit it is possible to begin the CCD integrations. The WHT tracks well enough that it is standard procedure to begin the integrations before acquiring a guide star. Integrations are started with `RUN`, and can be the same length or different lengths. If they are the same length, and the frames are large, then the two CCDs may be reading out into the DMS buffers simultaneously; the DMS is capable of handling this, although the message "Reading CCD" on the DMS screen may disappear after the first CCD has finished reading out, although the second has not yet finished. The DMS command `?REGS` allows one to check whether the CCDs have all finished reading out.

9.1.5 Acquiring guide stars

Guide star acquisition is facilitated by the Guide Star Server (GSS), with which it is possible to predict the probe co-ordinates for a star from the Hubble Space Telescope Guide Star Catalogue using software running on a Vaxstation in the La Palma cluster. The catalogue itself is on two CD-roms attached to this Vaxstation. To run the GSS, star a session on any VAX computer and type:–

```
@DISK$USER3:[GSS]GSS_INIT
GSS
```

This will invoke the GSS programme, which is characterised by the prompt `GSS>`. The following string of commands input to the GSS programme will generate a file, `OUTPUT.GS`, with a list of suitable guide stars and their predicted `AUTORADIAL` and `AUTOTHETA` values:-

```
CONFIG WHT CASS
ROTATOR <rotatorposition>
SEARCH <objectposition>
EXIT
```

Where the rotator position is the sky position angle in degrees, and the object position is specified as RA, Dec and Equinox in the same format as is used by the Telescope Computer. The file `OUTPUT.GS` can then be typed or printed, and the guide star acquired.

To find a guide star, search the autoguider field by typing:–

`FIELD` at the ICL interface, or:
`1 FIELD` at the autoguider interface.

The autoguider will scan the field three times, then look for a star on the final readout. If a suitable star is found then a white cursor appears on the star image. It is then possible to guide on that star. If the star appears too faint it is possible to increase the guiding integration time by typing:–

`GUIINT` <time> at the ICL interface, or:
<time> `GUIINT` at the autoguider interface,

where the time is in milliseconds. Guiding integration times can be as short as half a second, and a sensible maximum is 10 seconds.

If no sufficiently bright star is found in the field the procedure is to move guide probe with the ICL `AUTOTHETA` or `AUTORADIAL` commands by about the field size. The field size is approximately 8000 millidegrees in AUTOTHETA (it depends somewhat upon the radial position), and about 10000 microns in AUTORADIAL. **Beware of low values of AUTOTHETA; at values below about 35000 the guide probe vignettes the slit viewing optics**.

Once a suitable star has been found by the autoguider, you can start the autoguider guiding and sending error signals to the TCS by typing:

`FON` at the ICL interface, or:
`GUIDE ON` at the autoguider interface.

The TCS needs the guide probe co-ordinates in order to convert these errors into corrections in Altitude and Azimuth, so to start guiding you need to type:

```
PROBE <autoradial> <autotheta>
AUTOGUIDE ON
```

at the TCS console, or the ICL interface. There is a programmed function key on the TCS terminal for `AUTOGUIDE ON`.

To stop guiding at the end of an exposure type:

`AUTOGUIDE OFF` at the TCS or ICL terminal:
`FOFF` at the ICL interface, or `GUIDE OFF` at the autoguider interface.

9.1.6 Wavelength Calibration

It is necessary to intersperse sky observations with comparison lamp observations for wavelength calibration. Because of the flexure of ISIS it is necessary to do this rather more often than with, for instance, the IDS on the INT. For observers who need high wavelength accuracy, for instance for absolute radial velocity measurements of stars, it is advisable to take comparison lamp exposures about every 15 minutes. For observers who wish to measure less precise radial velocities (for instance in most extragalactic systems), or line ratios, then comparison lamp exposures every hour should suffice. Separate comparison lamp exposures are definitely required for objects separated by more than 5 degrees in elevation, and for observations at different mount position angles. In particular observations of extended objects at different position angles must be calibrated separately.

The procedure for taking calibration lamp exposures is described in section 9.1.2. It may be possible to autoguide through a wavelength calibration exposure; this depends upon the brightness of the guide star and the probe co-ordinates. If not it will be necessary to switch the autoguider off during the calibration exposure; and re-acquire the guide star afterwards.

9.2 Observing with IPCS only or with CCD and IPCS

Procedures for setting up and using the IPCS are described in full in *The IPCS-II Users' Manual, by J.S.B. Dick* and it is important that observers who intend to use the IPCS read this manual.

The IPCS is easily damaged by bright light. Thus it is important that before opening the shutter the observer should be aware of the degree of illumination which will fall on the detector. If the observer is unsure of this, then they must insert neutral density into the beam with `MAINFILTND` (or alternatively with `COMPFILTA` or `COMPFILTB` if the exposure is of a comparison lamp, and gradually reduce the level of neutral density until the level of illumination is the maximum that can be tolerated. Unlike the CCD systems, starting and ending IPCS exposures is independent of the operation of the shutter. The shutter can be opened with the command `IPO`, and closed either with the command `IPC`, or by pressing the "Panic Button", but this does not mean that an exposure has been taken. An exposure should be started with the command `EXPOSE IPCS` *after* the shutter has been opened; and the shutter should be closed with the command `IPC` *immediately* an exposure has ended.

The "Panic Button" is present to enable the user to close the shutter immediately if the level of illumination is too high. If this is used, the software does not know that the shutter has been closed, and the observer must *also* close the shutter in software with `IPC` before the software will allow the shutter to be opened again.

If the shutter is opened and the level of illumination is much too high an overillumination trip will occur. This causes the shutter to close, and an overillumination status to be set in the IPCS 4ms; the shutter cannot be opened until this status has been cleared. This can be done with:-

```
OVERILLUM_INIT
```

It is important to establish the cause of the overillumination trip before opening the shutter again. **An overillumination trip does not affect the EHT supply, and thus does not provide any protection in case of shutter failure, and provides only limited protection if the cause of the overillumination is lights in the dome.**

9.2.1 TV Focus

The TV focus must be set as described in Section 9.1.1, with the added proviso that this must be done with the IPCS EHT supply off, as no lights are permitted in the dome with the EHT on.

9.2.2 Switching on the IPCS EHT voltage

The procedure for running up the IPCS EHT voltage is given in *The IPCS-II Users' Manual*, and it is important that the instructions for doing this are followed exactly. In particular it is vital that the observer monitors the real time video display **in the IPCS electronics cubicle on the telescope** as the voltage runs up, and is prepared to set the IPCS to "STANDBY" if the level of illumination is too high.

The observer should also check on the IPCS-II chassis in the blue instrument cabinets, that the corrections for dither and S-distortion are enabled. These are enabled if three green lights on a module towards the right hand end of the chassis are lit. If the dither correction is not enabled, at the ICL interface type:–

```
SEND IPCS OBEY DITH_SWITCH MOVE 1 1
```

If the S-distortion correction is not enabled, at the DMS control window type:–

```
1 ESD
```

9.2.3 Instrument Calibration Data

Decisions which have to be made before beginning an observing run with the IPCS include:–

- The grating to be used, and the central wavelength that it will be used at.
- The dichroic, flat mirror, or folding prism to be used.
- The format of the IPCS data window, in terms of area and resolution. If the window is larger the frame time will be longer, and thus the linearity at high count rates worse. Each CCD pixel is subdivided into a number of smaller pixels which is a power of 2 up to a maximum of 8 in each direction, these factors are known as X- and Y-resolution factors. The X-resolution factor is normally set to 8, which offers the maximum sampling in the spectral direction, and gives 2560 pixels along the spectrum. In normal use the Y-resolution factor will be either 2 or 4, giving a spatial pixel size of 0.7 or 0.35 arcsec respectively.

At the beginning of the setup, and when moving to a new target whose brightness is unknown, it is advisable to run the IPCS in full frame readout mode. To do this type `OVERSCAN`, but note that unlike IPCS-I on the INT, there is no way of observing the whole of the output of the image intensifier tube; the "overscan" mode on IPCS-II simply offers a readout of the whole of the CCD. To resume observing after running in full frame readout mode it will be necessary to repeat the setup of the detector format with `IPCSFORMAT`.

Procedures for configuring the spectrograph for the beginning of observing are described in Part IV. The centre of the slit on the detector can be defined by observing the tungsten lamp through a narrow Dekker **and appropriate neutral density filters**. The IPCS data window format can be set with the interactive ICL procedure `IPCSFORMAT`, and adjusted until the narrow dekker spectrum falls in the centre of the data window. Note that there are some restrictions upon the parameters supplied to `IPCSFORMAT`, these are detailed in the description of the procedure given in Part VI of this manual, and explained in detail in Chapter 4 of the *IPCS-II User's Manual.*

The IPCS-II dark count is negligible in use on ISIS, and any attempt to measure it will result instead in a measure of the light leaking into the detector. Three types of calibration exposure are useful when observing with the IPCS:-

- Flat field exposures. Because of the low granularity of the current IPCS image intensifiers, the introduction of "dither", and the low count rate limit imposed by the hardware; it is very hard to get sufficient counts in a flatfield actually to improve the data. An integration time of at least three hours would be required to give 1000 photons/pixel in normal observing format (in which each CCD pixel is divided into 16 or 32 data frame pixels). To obtain a flatfield:–

    1. **ENSURE THAT THE IPCS SHUTTER IS CLOSED WITH** `IPC`.
    2. Insert the acquisition and comparison mirror in the A&G box with `AGCOMP`
    3. Switch on the tungsten lamp with `COMPLAMPS W`
    4. Set the grating angle to about 6000Å. The illumination is more uniform in the red.
    5. Set the Dekker to a long slit position, such as 6, but not to position 0.
    6. Set the slit width to around 500 μm.
    7. Insert neutral density (at least ND3.0 is required initially) with `COMPFILTA`, `COMPFILTB`, or MAINFILTND.
    8. Ensure that the dome lights are out and that it is dark in the dome.
    9. Cautiously open the shutter with `IPO`. Be prepared to close immediately with the "Panic Button" if the level of illumination is too high.
    10. If the level or uniformity of illumination are too high then cautiously adjust the grating angle and the amount of neutral density. The count rate should not exceed about 3 Hz/CCD pixel, which is equivalent to 0.1 Hz/data pixel. **THE SHUTTER MUST BE CLOSED WHILE MOVING EITHER THE GRATING OR THE FILTER WHEELS OR SLIDES**.
    11. Begin a long exposure with `EI`. It is your duty to ensure that the level of illumination in the dome remains low during the flatfield exposure. The dome lights are interlocked so that they should not come on with the IPCS EHT on, you must check that this interlock is not overridden. You must also ensure that nobody will open the dome before dark if a flatfield is in progress.

- Twilight sky exposures. These are used to determine the uniformity of illumination along the slit. It is safer to obtain these at the end of the night, when the sky brightness gradually increases, rather than at the beginning when it is difficult to estimate the level of illumination. Twilight sky exposures should be taken with the comparison mirror out (`AGSLIT`), and with the slit width set to the value that has been used during the night. They should be taken with the telescope tracking and pointing at a blank area of the sky; there is a list of these in the *WHT Users' Manual*.

- Calibration lamp exposures. These should be interspersed with observations of astronomical targets throughout the night. The normal comparison lamps are Copper-Argon and Copper-Neon; to maintain a safe level of illumination it may be necessary to use these in conjunction with neutral density filters, especially when working at low dispersion. To obtain sufficient counts for a good wavelength fit a comparison lamp exposure time of at least 100 seconds is required.

9.2.4 Acquiring data on the sky

The procedures for acquiring data with the IPCS are basically the same as those for acquiring data with CCDs, set out in Section 9.1.3. However the data acquisition commands `EXPOSE IPCS` or `EI`, and `KEEP IPCS` or `KI` must be used instead of the CCD commands `RUN`, `ARC`, `GLANCE` etc. If the IPCS and a CCD are being used simultaneously then the old version of the software (S0-3) will be running, and the old CCD commands (e.g. `EXPOSE RED` and `KEEP RED`) will need to be used to control the CCD. *This situation is expected to change by early 1993.*

When acquiring data with the IPCS some additional precautions should be observed:–

- Always close the IPCS shutter with `IPC` immediately after a run has completed, and never allow the telescope to be moved while the IPCS shutter is open.
- If you are not sure about the brightness of a new target then set the IPCS to full frame readout mode, and insert neutral density, removing it gradually whilst keeping a safe level of illumination. Use the real time video display to estimate a safe level of illumination.
- Never move a filter or the blue grating with the IPCS shutter open.
- If observing in cloud always watch the real time video display whilst integrating, in case the target brightens suddenly.
- If observing comparison lamps simultaneously always set the illumination to a safe level for the IPCS, increasing the exposure time for the CCD if necessary.

As with the CCDs, calibration lamp exposures should be taken approximately every 15 - 30 minutes, or on a 5 degree change in elevation, or on any change of the rotator position angle.

If observing simultaneously with the IPCS and a CCD, the DMS is capable of handling both detectors simultaneously. It is not necessary to ensure that the IPCS integration finishes before CCD readout begins; the DMS can be integrating in an IPCS buffer while a CCD reads out into a different buffer, and it can also handle data transfer from a CCD buffer to the Vax or the Sparcstation whilst an IPCS integration is in progress.

9.3 Time-resolved observations with ISIS

Time-resolved observations can be defined as those in which one is studying an astrophysical phenomenon which varies in time. The timescales may vary from milliseconds to years, depending on the object under study. Clearly, inefficiencies in observing procedure and instrumentation are of far greater importance when studying short-timescale variability than when studying long-timescale variability. Therefore, this section is primarily aimed at observers studying objects which vary on a timescale of seconds or minutes. However, many of the principles discussed are simply means of maximising observing efficiency and should therefore be of interest to all observers.

9.3.1 Sources of dead-time

Dead-time can be defined as the interval between exposures during which the detector is not actually detecting photons from an object. There are numerous sources of dead-time, both instrumental and human. In the following discussion we shall restrict ourselves to the instrumental, but it should be emphasized that a great deal can be gained by simply having a carefully prepared observing programme. The following list details the most common sources of dead-time and the amount of time they each contribute to the total figure. The list is in chronological order, from typing the exposure command to receiving the data on disk.

Typing commands – This is the most obvious form of dead-time and occurs due to the inevitable delay involved in typing a `RUN` command and its associated parameters. Depending on typing speed, this can take up to 10 seconds. This may sound pedantic, but the use of the `MULTRUN` command (see section 9.3.2) actually represents one of the largest and most straightforward reductions in dead-time that can be made.

The control system – Once the command has been typed, it is passed over the Utility Network to the specified CCD controller and the chip is then cleared in preparation for the exposure. The travel time of the command from ICL to the CCD controller is of order a few seconds and, for the time being, represents an irreducible minimum in dead-time.

Clearing the chip – This is a surprisingly large contributor to dead-time – a full EEV chip takes approximately 15 seconds to clear. At present, other than windowing or binning the chip (and hence reducing the number of pixels) there is little that can be done to reduce this.

Reading out the chip – When an exposure has completed, a process known as *clocking* is used to transfer the charge from the chip. Once this process is complete, each charge packet is detected as a voltage across a capacitance, the voltage is amplified by an on-chip amplifier and then digitised. The data is then passed from the CCD controller through optical fibres to the FOX card in the control room and onto the DMS via DICI. This process, which we will refer to as *read-out*, is the dominant source of dead-time when observing. It takes approximately 110 s to read-out a full EEV chip, although this can be reduced significantly by windowing, binning and changing the read-out speed (see section 9.3.2).

Archiving the data to disk – Once on the DMS, the usual procedure is to transfer the data to disk on the VAX. This process takes approximately 45 s for a full EEV chip and also involves the writing of file headers (or packets). Clearly, by reducing the number of DMS-VAX transfers and the size of the transferred frames the dead-time can be reduced (see section 9.3.2).

9.3.2 Reducing dead-time

There are a number of ways in which dead-time can be reduced. Below we list the methods currently available and give some indication of how effective they each are.

Using `MULTRUN` – This is a useful ICL command which should be used when it is necessary to take repeated exposures of a single object. The procedure does not do anything particularly clever – it simply sets up an exposure loop which removes the dead-time involved in typing repeated `RUN` commands. The loop can be aborted by typing `KILLMULT`. The saving in dead-time is surprising, particularly towards the end of a night!

Windowing the chip – By windowing a CCD, only a subset of the chip is read-out and transferred to the VAX. This significantly reduces read-out time by an amount which scales with the number of pixels in the window. It makes little difference if this window is chosen at the top, middle or bottom of the chip. The only disadvantages of this method are that one obtains a reduced field of view and reduces or removes entirely the bias strip. The former is not really a problem for spectroscopy and the latter can be resolved by allocating multiple windows, so that one window contains the spectrum and another the bias strip (although the multiple windows option will not be available until next year).

Binning the chip – With the CCD controller it is possible to change the clocking routines to provide on-chip binning in which the summed charge from several adjacent pixels is read out as a single charge. This reduces the number of pixels which are read out and transferred and therefore also reduces the read-out time by a factor which depends on the number of pixels in the binned chip. An added advantage of binning is that the summed charge from the adjacent pixels is measured with the read-out noise corresponding to a single pixel. Hence the effective read-out noise is reduced by a factor equal to the square root of the number of pixels in the bin. The disadvantage of binning is that it reduces spatial resolution and the dynamic range of the chip, since the larger pixels still have the count limit of a single pixel. If neither of these is a problem then the use of on-chip binning on its own or in combination with windowing should be considered.

Selecting the read-out speed – There are currently two read-out speeds available when using ISIS – `READOUT_SPEED FAST` and `READOUT_SPEED STANDARD`; the speed must be typed in upper case. For an EEV chip, the full-frame read-out time in standard mode is approximately 110 s with a read-out noise of approximately 4 electrons. The equivalent figures for fast mode are 70 s and 5 electrons. The fast read-out speed also gives a slightly larger dynamic range. Clearly, if the observations are sky limited there is little to gain in terms of signal-to-noise by using `STANDARD`, although there is evidence that the charge transfer may be poorer; please consult your support astronomer for details.

Accumulating the data in the DMS – It is possible to accumulate data in the DMS using *datacubes*. These are three-dimensional data structures in which individual frames form the planes. This removes the significant dead-time due to transferring data from the DMS to the VAX. Using datacubes it is possible to obtain dead-times of approximately 5 s with a CCD in fast read-out mode and windowed 100×100. The DMS can hold datacubes of up to 32 MBytes in size and hence approximately 800 frames of 100×100 pixels. There are two drawbacks to this method: Firstly, no file headers and hence exposure start times are saved, and secondly, there is a large overhead when the datacube is transferred to the VAX. At the present time, the datacube option is not offered on a routine basis and any users who are interested in employing this method should first contact their support astronomer.

Using the IPCS – In terms of signal-to-noise, there are few occasions when it is advisable to use the IPCS on the blue arm of ISIS instead of the TEK CCD. However, the IPCS does have the advantage of a lower dead-time. The IPCS is not an integrating detector. This means that as the individual photons are recorded, their positions are immediately passed to the DMS. At the end of an exposure, there is no chip read-out, only the normal overhead of writing the data to the VAX (and even this can be overcome by using datacubes in the DMS). It is even possible to time-tag each photon, so that one can choose the time-resolution and signal-to-noise per frame at the data reduction stage. However, this mode is still to be fully tested. If the IPCS can produce an acceptable signal-to-noise and the very-highest time resolution is required, it should be considered as the detector for the blue arm of ISIS.

9.3.3 Future developments

By reprogramming the CCD controller it should be possible to reduce dead-times still further. For example, at present the CCDs are cleared prior to all exposures. The charge is transferred to the output but not digitised. This operation takes approximately 10 μs per pixel, and hence 15 seconds for a full EEV chip. There are alternatives. It is possible to flush the charge out almost instantaneously by using all of the CCD clocks simultaneously instead of one-by-one, as in the normal horizontal clocking process. Alternatively, since each full-frame read-out essentially clears the CCD anyway, we could avoid clearing the chip altogether, assuming that the previous frame was not over-exposed and there is not much light leakage or dark current since the last read-out. In addition, since the read-out noise is known to be a function of read-out speed, it should be possible to offer a greater variety of read-out speeds and noise levels.

For even greater reductions in dead-time, it should be possible to store a series of short exposures on-chip. The interval between exposures can be very short, especially if the image-window is almost one-dimensional, *ie.* spectroscopic. A small box, defined by a dekker, consisting of N rows at the top of the CCD is illuminated. On completion, the box is moved quickly down the chip and the clear area can be exposed again. This can be repeated until the chip is full. The whole frame can then be read-out from the bottom of the CCD. The exposure time T per box can be in the range 1 – 65535 ms. For an EEV chip it takes about 0.04 ms to shift down one row of data; thus the total time per box = $T + N \times 0.04$ ms. For a box of size 10 rows, and a 60 s exposure, the total time interval between boxes would be 60.0004 s. Even if such a system were available now, it would still be impaired by the relatively slow DMS-VAX link. However, work is in progress to replace this next year with a system which saves the data directly onto the observing SPARCstation. This should provide an order of magnitude improvement in the dead-time due to archiving data on disk.

It should be noted that most of the above enhancements are still at the drawing-board stage and it is by no means clear when, if ever, they will become available to the community; this will depend on demand from users and the availability of engineering effort.

9.3.4 A note on accurate time and ISIS

A long-standing problem with ISIS has been the lack of accurate shutter timings. The current system uses clocks on the CCD controllers to write shutter opening and closing times to the file headers. The clocks are relatively inaccurate and can drift by a few seconds over the course of a night. The present solution is to synchronise the clocks with UTC at the start of each night, using the commands `.DATE`, `.TIME`, `HH:MM:SS SET-TIME` and `DD:MM:YY SET-DATE` on the engineering terminal. This system is clearly inadequate, especially when accurate times are required. On the JKT and INT, the shutter timings are obtained directly from the time service. Work is currently underway to create a similar system on the WHT and we expect it to be fully operational by the end of 1993. Until then, we advise all observers who require accurate timings to contact their support astronomer for further details.

9.4 Observing with FOS

Procedures for observing with FOS are in general similar to those used when observing with CCDs on ISIS (Section 9.1). FOS is a simpler spectrograph, and has no moving parts. A consequence of this is that it is not necessary to take wavelength calibration exposures so frequently, indeed for many observers one calibration exposure at the beginning of each night will suffice. Apart from this the calibration exposures required are the same as are required for ISIS CCD observing.

Data acquisition procedures are again the same as for ISIS observing, except that it is much more likely that the observer will seek to observe objects which cannot be seen on the slit viewing TV with FOS. Such objects should be acquired by the `BLIND_OFFSET` procedure os the Telescope Control Computer, outlined in *The WHT Users' Manual*.

The approximate positions of the first- and second-order spectra on the CCD are shown in Figure 8. There are two main observing modes: with 20-arcsec dekker, both orders; and long-slit, with the FCP-tray field lens inserted. The anamorphotic field lens improves illumination of the grating (without it, light spills over the edge of the grating, and illumination on the detector is reduced at each end of the slit). It also incorporates a GG495 (yellow) filter, which blots out the second order. The field lens is inserted with ICL command `FIELD_LENS`. During routine FOS observing, this and the dekker are the only components that need moving. Exposures longer than, say, half an hour, should be split to allow identification of spurious features due to cosmic rays.

The efficiency of the system (atmosphere at zenith + telescope + instrument + detector) is shown in Fig 16. In first order, it peaks at 17% at 7000Å.

9.4.1 Data reduction

Data reduction typically involves the following steps:
- Debiassing and flat-fielding the data frames. Flat-fielding is particularly important for removing the many poorly-resolved sky lines redward of 7200 Å (for this reason, the resolution of ISIS is preferred if wavelength coverage and throughput are adequate). The tungsten lamp is so red that flats are saturated in the red before enough signal is obtained in the blue; twilight flats are better.
- Correction of curvature, extraction and sky-subtraction of first- and second-order spectra for each object on slit. Sky-subtraction can be 'top-hat', using a few equally-weighted columns (preferably on either side of the object spectrum) for sky and a few equally-weighted columns for object; ot it can be optimal, with the software weighting each object column according to the strength of the signal. In practice, optimal extraction typically yields only a few 10s of % extra signal-to-noise for an unresolved object.
- Wavelength calibration, via arc exposures (CuAr or CuNe, former probably better, has lower density of lines). FOS is very stable, and wavelength calibration can anyway be checked against the numerous sky lines, but it's a good idea to take a few arcs per night.
- Correction for absorption bands due to the atmosphere (especially the Fraunhofer A and B bands at 7594 and 6867 Å), via observation of a star with a featureless spectrum, usually a B

star such as Feige 34.
- Correction for atmospheric extinction at the airmass observed, using the theoretical curve from La Palma technical note 31.
- Correction for the spectral response of FOS, via observation of a spectrophotometric standard star with a wide slit, to give e.g. μJy through the slit as a function of wavelength. FOS' wavelength response is surprisingly bumpy, with features of strength $\sim$ 5% on a scale of $\sim$ 200Å.
- Smoothing of second-order spectrum to resolution of first-order, and merging of first- and second-order spectra into one.

Thus, as well as spectra of targets, observers may want to take bias frames, twilight flats, tungsten-lamp flats, arc-lamp exposures and spectra of B-stars and spectrophotometric standards.

Much of the above can be carried out using FIGARO software. The software available for spectrum extraction (SCP and SAM) is described in Starlink User Notes 148 and 149.

9.5 Spectropolarimetry

Different modes of using the polarisation optics are conceivable; here we will describe what may be considered a common-user mode for measuring linear polarisation, which is adequate for most purposes. This so-called "staring" mode uses the calcite plate analyzer to separate the light into an ordinary and an extra-ordinary beam which results in two spectra on the detector. One component of the polarisation vector (e.g. the Stokes Q parameter) of the incoming beam is converted to an intensity difference between the two spectra. Since both spectra are taken under exactly the same conditions, the intensity *ratio* is independent of sky transparency. In order to account for differences in the response of the spectrograph and the detector to the highly polarised o and *e* rays a second exposure with the halfwave plate rotated by 45 degrees is required. This offset of 45 degrees in the halfwave plate position angle results in a rotation of the incoming polarisation vector by 90 degrees. Due to this rotation, on passing the calcite plate, the intensity difference will be inverted relative to the first exposure while leaving the instrumental response identical; the instrumental response can then be taken out by comparing the two exposures.

To measure the full linear polarisation vector (i.e. both Stokes Q and U) a second set of two exposures is required with the halfwave plate set at 22.5 and 67.5 degrees.

A standard sequence of exposures is:

exposure 1 with halfwave plate at 0.0 degrees
exposure 2 with halfwave plate at 45.0 degrees
exposure 3 with halfwave plate at 22.5 degrees
exposure 4 with halfwave plate at 67.5 degrees

Exposures 1 and 2 yield the Stokes Q spectrum, and exposures 3 and 4 the Stokes U spectrum. The angle of the (linear) polarisation vector, as defined by its Q and U components, is given relative to some instrumental coordinate system. The halfwave plate positions angle may be given any (constant) offset which will only affect the instrumental reference system. The orientation of the instrumental reference system relative to the N-S meridian has to be calibrated by observing a polarisation standard star. It is important to keep the orientation of the instrument fixed relative to the sky (*e.i.* set Cassegrain rotator tracking). Be sure to write down the position angle of the halfwave plate and of the Cassegrain rotator and to understand the exact definitions.

Since the calcite plate produces two slit images slightly offset in the spatial direction (the *o* and *e* rays) a dekker mask has to be used to prevent confusion between different parts of the slit. This implies that continuous long-slit observations are not feasible in this observing mode. To facilitate semi long-slit observations a comb Dekker may be used to observe a series of regularly spaced apertures along the slit simultaneously. For a more detailed description of observational considerations see the *ISIS Spectropolarimetry Users' Manual.*

The ISIS polarisation module has been proven to be capable of measuring polarisation reliably to an accuracy better than 0.1 %. High-accuracy polarimetry requires many photons: as a rule of thumb, for planning observations, the uncertainty in one Stokes parameter $\sim 1/\sqrt{N}$, where N is the total number of photons –per resolution element– obtained in two exposures. The generally high count rates necessary for spectropolarimetric observations (and certainly for the usually bright polarimetric standard stars) a CCD is strongly preferred as a detector over the IPCS.

Currently the polarisation optics have been used with the red and blue cameras of ISIS. In principle the polarisation module also functions with FOS but this option has not been tested extensively.

Note that experiments with the dichroic beamsplitter in position showed reflected light from the rear of this component. Such light is displaced along the slit, partly into the spectrum of the other polarisation; this spoils the polarimetry, so for the time being we must, reluctantly, advise against use of the dichroic.

9.5.1 How to derive the Stokes parameters

The staring mode uses the calcite plate, which yields 2 spectra (of opposite polarization). The polarization information (one Stokes parameter per exposure) is contained in the ratio, at each wavelength, of the intensities in the 2 spectra but it is mixed up with the system gain ratio for the pixels concerned. The effect of the unknown gain is eliminated by inverting the sign of the polarization effects in a second exposure, while leaving the gain ratios identical. Inversion of (linear) polarization effects and therefore of the Stokes parameters is accomplished by rotating the halfwave plate by 45 degrees; while the polarization effects are inverted, the system gains remain the same since these are determined by the built-in polarization of the o and e exit beams of the calcite plate. All instrumental conditions (grating parameters, filters, dichroics, Dekker, slit etc) must be the same in both exposures; image centering on the slit is the most difficult to control in this respect.

The derivation of Stokes parameters from the recorded spectra is presented below. We factorise the conversion 'constant' for input flux to detector signal into a polarization-dependent, time-independent part G and a time-dependent, polarization-independent part F:

$G_{||}$ and $G_{\perp}$ refer to the o and e-spectra on a single frame; they include grating efficiencies and reflection coefficients of mirrors, and the sensitivity of the pixel considered to the polarized light striking it.

F_0 and F_{45} refer to the two separate frames (halfwave at 0 and 45 degrees) and include atmospheric transmission, seeing, image wander and variations in shutter timing.

I and Q refer to total and polarized flux input and the i refer to signals recorded by the detector.

$P_Q = Q/I$ is the Q-component of the degree of polarization.

In this notation, we obtain:

$$
\begin{array}{lcllll}
i_{0,||} & = & \frac{1}{2}(I+Q) & \cdot & G_{||} & \cdot & F_0 \\
i_{0,\perp} & = & \frac{1}{2}(I-Q) & \cdot & G_{\perp} & \cdot & F_0 \\
 & & & & & & \\
i_{45,||} & = & \frac{1}{2}(I-Q) & \cdot & G_{||} & \cdot & F_{45} \\
i_{45,\perp} & = & \frac{1}{2}(I+Q) & \cdot & G_{\perp} & \cdot & F_{45}
\end{array}
$$

To derive Stokes parameters from these spectra, first divide the o and e ray spectra in each frame to take out the scaling factors F. Dividing these ratios again cancels the G factors. The Q Stokes parameter, in degree-of-polarization scale, is:

$$P_Q = \frac{R-1}{R+1} \qquad \text{with} \qquad R^2 = \frac{i_{0,||}/i_{0,\perp}}{i_{45,||}/i_{45,\perp}}$$

Note that by multiplying the intermediate ratios, instead of dividing them, the G ratio (relative flat field) is obtained.

The other Stokes parameter, P_U, is obtained similarly from the pair of exposures with the halfwave plate at 22.5 and 67.5 degrees. The raw degree of polarization P and polarization angle θ, are then given by:

$$P = \sqrt{P_Q^2 + P_U^2} \qquad \text{and} \qquad \theta = 0.5 \arctan\left(P_U/P_Q\right)$$

Note that this schematic procedure neglects CCD bias, sky background and calibration for instrumental parameters. Bias may be subtracted from the data frames as a first step or be treated as part of the sky background; sky subtraction and calibration are treated in separate subsections below.

9.5.2 Imaging Polarimetry

ISIS can be used as an orthodox focal reducer, with a convenient plate scale of 0.3 arcsec per 22μm pixel. The optical quality of the instrument is excellent on-axis, although towards the edges of the field there is some chromatic distortion (this does not matter in a spectrometer). The mirror which replaces the grating in this mode is silver-coated, and so the throughput of the red channel is good (5 reflections at 98% each). The mirror should be used at the angle appropriate for the channel in use (55500 for the red arm or 53250 for the blue arm).

The important use of the instrument in this mode is as a specialised imaging polarimeter, as the existing modulator as used for spectropolarimetry, can be employed. The analyser is a Savart plate which is placed in the multi-slit slide, with a field of 80 arcsec diameter. As in the case of spectropolarimetry, a dekker mask is necessary whose duty fraction is fixed by the angular throw of the below-slit analyser, and by cross-talk (scattered light) between the separated images in each plane of polarisation. The instrument has been successfully used with a dekker consisting of a series of slots 1.2 mm wide with an occulting bar 3.5 mm wide in between. This accommodates wavelengths as far as R – the throw of the analyser decreases with increasing wavelength. This dekker arrangement, gives slots on the sky 5 arcsec wide, limited in the other direction by the 80 arcsec diameter field of the Savart plate. separated by 15 arcsec. This pattern is repeated in the narrow direction six times before the field is vignetted by the modulator (the half-wave plate). This dekker is rather conservative and a larger duty fraction could probably be used.

The principal limitation in practice is that filters have to be changed manually, as the small below-slit filter slides in ISIS have to be used. Likewise swapping from red to blue channels involves manual operations.

9.6 Observing with Fibres

In order to set up the telescope when optical fibres are employed, the telescope must be focussed on the aperture plate and the rotator axis and orientation must be adjusted.

9.6.1 Telescope focusing on the aperture plate.

This focusing is performed using the coherent guiding bundle in the following way: a bright star is observed with this bundle, in order to follow the image variations on the TV screen. This process is best done if the coherent bundle can be put in the centre of the aperture plate (ie, focal plane centre). If this is not possible, the bundle coordinates must be known accurately so that the telescope can be offset to put the star onto the coherent bundle. It is advisable to use the high quality zone of the fibre bundle for focussing

9.6.2 Adjustment of the rotator axis and orientation.

The rotator axis - aperture plate alignment and the orientation of the rotator are crucial when fibre optics are employed. An error in the rotator orientation translates to a difference between the North direction of the focal plane and that of the aperture plate. For multi-object spectroscopy, this, in turn, means a bad field acquisition, together with a drastic efficiency decrease. In extreme cases, the field can even not be seen. For this reason it is very useful to perform these adjustments as accurately as possible before using the instrument on the first night. It is also advisable to check them at the beginning of every subsequent observing night.

The aperture plates have several holes to allow connection of the semi-coherent bundles at 400" North and 400" South from the plate centre, and the coherent bundle at the field centre. The North-East orientation of plate is fixed at the time the holes are manufactured. In order to adjust the rotator, then, the following steps are required:

- Place the coherent bundle in the centre of the aperture plate.
- Because of the orientation of the Auxiliary port with respect to the ISIS slit, the nominal sky position angle of the Cassegrain rotator to align plate and sky axes is 315°, and this the Sky Position angle should be set to this as an initial estimate.
- Acquire a bright star with the telescope and place it on the coherent bundle. Determine the rotator centre, which should be on the coherent bundle. It may be easiest to determine the rotator centre on the direct TV with the `ACQCOMP` mirror in place, then to place the star on the rotator centre, move the `LARGEFEED` mirror in and mark that point as the rotator centre. It is very important to determine the rotator centre accurately, as otherwise target acquisition will be extremely difficult.
- Calibrate the telescope pointing with the TCS procedure `CALIBRATE`. Again this can be done either on the coherent bundle, or with the direct viewing TV.

- Move the star to the centre of the aperture plate and define a telescope Aperture there.The coherent bundle centre and the plate centre do not coincide. The centre of the aperture plate (origin of the coordinates for the plate holes) should be X=71μm and Y=559μm (0.32 arcsec W and 2.52 arcsec North on the sky for a plate drilled with North at the top) from the centre of the coherent bundle.

- The telescope is moved South 400", so that the star drifts 400" North away from the field centre. In general, the pseudo-image of the star does not appear at once in the semi-coherent bundle placed there. This is due to the fact that the telescope's North and the plate's North do not coincide. The rotator angle must be adjusted until the star appears in the semi-coherent bundle. This way, a preliminary adjustment of the rotator angle is performed.

- If the field centre is not perfectly determined, the star will not appear perfectly centred in the semi-coherent bundle. In order to centre the star, the telescope must be moved in RA and Dec (or X and Y).

- After centering of the star in the semi-coherent bundle, the telescope is moved 400" North. The star appears in the coherent bundle. A new aperture (APE1) is created to define that point as the new field centre.

- The telescope is moved 400" North and the same process, as described above, is repeated for the other semi-coherent bundle.

All these steps can be repeated as many times as desired, in order to obtain a very precise adjustment of the rotator.

As a reference, if the plate is manufactured at sky position angle zero then the cassegrain rotator angle fibres are employed at the auxiliary focus is 314°57'36", and typical offset values between APE0 and APE1 are X= 4.2 and Y= -4.2.

9.6.3 Field acquisition

The first step to do when performing fibre optic multi-object spectroscopy is to select a field and to put the observing fibres on the aperture plate. To insert the fibres in the corresponding holes is an easy task but it must be performed with caution in order to avoid damaging the fibres ends. Also, it must be taken note of to which star in the field each fibre corresponds. Although it is not strictly needed it can be useful as well to order the stars by magnitudes, in such a way that –to avoid contamination– two adjacent spectra do not produce large luminosity differences onto the detector. 10 to 15 minutes are required in order to insert 61 fibres in the plate.

Briefly, the field acquisition consists of pointing of the telescope towards the coordinates of the centre of the field to be observed. It is then expected that the 3 guide stars will appear correctly centred on the TV screen. Step by step this process is as follows:

- Point the telescope towards the RA and Dec of the field centre.

- Perform an aperture offset to aperture APE1.

- If the rotator is well centred and oriented, the image of the guide stars for the coherent bundle and two patterns for the two semi-coherent ones, will be seen on the guiding monitor.

- In order to correct the telescope pointing, the telescope must be moved in RA and Dec or X and Y until the semi-coherent bundles illumination patterns are well centred. When the seeing is good ($\sim$ 1.5"), this centering is easy to obtain as the 7 central fibres of each bundle must appear uniformly illuminated. If the seeing is between $\sim$ 1.5 and 4", the centering can be performed by means of the uniform illumination of the external ring in each bundle. If the seeing is worse, the centering becomes more difficult although basically it still relies on an uniform illumination of the fibres in the semi-coherent bundles.

- If an optimal adjustment has not been obtained for both semi-coherent bundles, the telescope rotator must be moved until a better centering of the three guide stars is achieved.

- Finally, when the field has been properly acquired, guiding can begin on the TV image of the star on the coherent bundle with the `GUIDE` or `IGUIDE` functions of the TV system, and Autoguiding can be started with the TCS command `TVGUIDE ON`. The first time this is done it is necessary to verify that the X and Y handset functions of the TCS drive the star along the correct X and Y axes of the TV image. If they do not, then some adjustment will have to be made. Field reversals can be corrected with the Scan Reverse switches on the Westinghouse control panel on the control desk; and the angle of the coherent fibre bundle can be rotated at the TV end. It is only necessary to set this angle to an accuracy of about 5°.

9.6.4 Calibration

The calibration lamp for the fibre system is not yet driven from the A&G box 4ms microprocessor, although it is planned to implement this diring 1993. At present the power to the calibration lamp will need to be switched on by the observer, usually from one of the power points on the inside of the telescope fork. To take a calibration exposure all of the A&G box mirrors must be withdrawn with the ICL command `AGMIRROR OUT`. The frequency recommended for calibration exposures depends upon the specific application, and is the same as that for normal CCD observing. The calibration lamps are bright, and only short exposures (1-5 seconds) are required. The gain of the TV systems must be turned down while calibration exposures are in progress.

9.6.5 Data reduction

Fibre data can be reduced in the FIGARO data reduction system using the spectrum following and extraction procedures `FINDSP` **OVERPF** and `POLEXT`. More detail on data reduction procedures is given in *The ISIS Fibre system Technical Report and User Manual*, by J.-L. Rasilla *et al.*, and in the Starlink FIGARO documentation.

Part V
QUICK REFERENCE GUIDE

10 Quick Reference Guide

This section is intended to provide a guide for the experienced user, and contains one line summaries of some of the most commonly used commands, arranged approximately in the order of an observing session. More detail of the individual commands is given in Part VI. In this section some abbreviations (set up as Defstrings under ICL) are used. If in doubt about a particular function please refer to Part VI.

10.1 Starting Up

– Create a DECTERM window on the observing VaxStation (usually, LPVS2) and login as OBSERVER

– Now type `LPVF` and login to LPVF (the VAX 4000) with the same username and password

– Read the news and the see the diskspace available on the datadisk displayed

– Type `ICL` to start the observing system. Answer the prompts – the MIMIC displays are usually put on LPVS2.

– As the MIMIC screens fill with mechanism positions and settings, check for any 'bad status' colours. The colour coding is as follows:

Green:	set ok	Blue:	mechanism moving
Red:	error status	White:	not in use

– During 3pm handover tests, SA or observer should check for bad status, and move some mechanisms in ISIS, A&G Box, Autoguider and AuxPort (if being used). Also, `SETUP` and `WINDOW` all the CCDs to be used, and take quick arc or test exposures on ISIS/FOS/AuxPort to check optical paths are clear and data flow to the DMS is ok. The Duty Tech will test the Telescope, and jointly you should fill in the handover log.

10.2 Taking Data - the Data Acquisition System

A typical command specifies a *channel* (`RED`, `BLUE`, `FOS` or `AUX`); an exposure time *t* (sec); a *title*; an observation type *obstype* (e.g., `ARC`, `BIAS`, `TARGET`, etc); and sometimes the number *num* of the output file in a scratch area. The DAS commands are:

`RUN`	*chann*	*t*	*title*	Take an exposure of an astronomical target
`TARGET`	*chann*	*t*	*title*	Same as `RUN`
`FLAT`	*chann*	*t*	*title*	Take a flat-field exposure
`SKY`	*chann*	*t*	*title*	Take a sky-flat exposure
`ARC`	*chann*	*t*	*title*	Take an arc (doesn't control the lamps)

MAP	*chann*	*t*	*title*	Take a dekker-map exposure
DARK	*chann*	*t*	*title*	Take a dark exposure (shutter not opened)
BIAS	*chann*		*title*	Take a 0-sec exposure
FLASH	*chann*		*title*	Ditto with preflash
GLANCE	*chann*	*obstype*	*t*	A 'quicklook' - put data in DMS only (no headers)
KEEP	*chann*		*title*	Keep a GLANCE file
SCRATCH	*chann*	*num*	*obstype*	*t title*. As RUN, but data saved as file *num* in scratch area
WINK	*chann*	*num*	*obstype*	*t title*. As SCRATCH, but no headers are collected
PROMOTE	*num*			Promote scratch file *num* to normal RUN file status

It is possible to take a set of *n* identical exposures with the command

MULTRUN *chann* *n* *title*

and there are similar commands MULTFLAT, MULTARC, etc.

DAS commands to modify or end exposures are:

PAUSE	*chann*		Pause an exposure
CONTINUE	*chann*		Continue a paused exposure
FINISH	*chann*		End an exposure and save the data
ABORT	*chann*		End an exposure and discard the data
NEWTIME	*chann*	*t*	Set a new exposure time

The command

DIR

lists the RUN and SCRATCH files taken during the night.

10.3 Setting Up The CCDs

The typical configuration is CCD1=RED, CCD2=BLUE, CCD3=FOS (or AUX).
This may change; DET_SHOW_CONF shows the actual configuration.

Check when CCDs were last filled with liquid N_2 and fill if necessary. Check CCD temperatures are correct (see MIMIC screen for CCD1, etc).

SETUP RED/BLUE/FOS/AUX	to setup the default formats: 1280 in X, 1180 in Y for EEV3 & EEV6; 1124×1124 for Tek
WINDOW RED/BLUE/FOS/AUX	to window, just answer the questions.
DISABLE_WINDOWS RED/BLUE/FOS/AUX	to disable windows (and ENABLE_WINDOWS to restore).
SEND CCDn OBEY CANCEL_WINDOWS MOVE *h*	to clear windows completely (*h*=head number)

To change CCD readout speeds:

`SLOUCH RED/BLUE/FOS/AUX`	set slow readout speed
`SPEEDY RED/BLUE/FOS/AUX`	set fast speed (NB slightly higher readout noise)
`BIN RED/BLUE/FOS/AUX`	set on-chip binning factors in X and Y

To manually open and close the CCD shutters, use:
`OP`n, `CL`n, where n=R, B, F or A.

10.3.1 Rotation and Focus

Rotation: Use the narrow (`1.2"`) dekker, and tungsten lamp. On the DMS measure the position of the left & right ends of the narrow spectrum with `Y-FIND` command. Rotate cryostat manually (as described in section 8.3.1) if shift exceeds 0.3 pixels.

Focus: Setup a wide window on chip, with `WINDOW` params:

RED (CCD1; EEV3 chip) 1,210,1278,720
BLUE (CCD2; Tek chip) 1,160,1122,680

Use arc lamps: CuNe is usually best around 7000Å for the RED arm, CuAr around 4500Å for the BLUE arm. The 'focus-loop' is:

`SLIT 200`	Set slit width of 200 μm
`DEKKER 6`	Select the long–slit dekker
`B(R)HART 1`	Close blue (or red) arm left Hartmann shutter only
`GLANCE BLUE(RED) ARC` t	Take a t sec test exposure
DMS> `FOCUS`	and select 3 strong unblended lines with the cursor
DMS> `FOCUS-LEFT`	See the 9 centroid positions & FWHM values listed
`B(R)HART 2`	Close the blue (or red) arm right shutter only
`GLANCE BLUE(RED) ARC` t	Take a second t sec test exposure
DMS> `FOCUS-RIGHT`	List new positions, FWHMs and Hartmann shifts
	If average shift >0.1pixel, move collimator and loop back to `B(R)HART 1` line

Moving the BLUE or RED collimator position (`RCOLL, BCOLL` command) by 1000 units will change the Hartmann shift by 0.5 pixels. See Whiteboard for the *direction* to go.

Current collimator settings are on the white-board.

10.4 Setting Up The IPCS

10.4.1 Starting Up and Scan Correction

Check the N_2 supply is ok, the shutter is closed and lights are out.
'Fast start' the EHT supply, on the IPCS rack mounted on the Cassegrain cage.

As of February 1993, the 'old' data acquisition system is needed with IPCS (*i.e.*, use `EXPOSE` and `KEEP` commands). Perform scan correction on the DMS by typing `IPCSSCAN` and following

Table 10: Some default IPCS Formats

	on-axis	*on-axis*	*Full frame*	*On-axis*
Rows read out	64	64	255	64
Start of window	70	70	1	81
Read into buffer	50	30	254	50
Y-res (spatial)	4	8	1	2
Spectral	320	320	320	320
X-res (spectral)	8	8	8	8
PROC	IPCSY4	IPCSY8	OVERSCAN	IPCSY2

instructions (use `CALC-SDC`);
or load previous one with:
`EAGLE`
`GET-SDC-ARRAY`
and enable it with
`1 ESD`
all on the DMS terminal.

N.B. *Always* check IPCS with OVERSCAN first. There can be a bright ghost that appears at the top of the IPCS field and which is believed to be caused by reflection off the ANAMORPHOTIC slide if it is not fully out.

10.4.2 Setting up the IPCS Format, and Focussing ISIS

$ `LOAD IPCSFORMAT`
Use default formats from the following table:

(The IPCSY2 settings put the 1.2 arcsec dekker in the centre of the frame, as of 28.10.90)
Or make your own format with `IPCSFORMAT`.
(N.B. Current size limit for DMS IPCS buffer is 2560×480.)

Note that the number of rows read into the DMS buffer must be less than the number of rows read out of the IPCS.

To change the Y window only, use `IPCSWIN`. (Max. rows = 64; spectral direction fixed at 320, X8).

Focus: Setup for CuAr arc with λ_{cen} ~4500Å, slit-width ~ 150 microns and COMPFILTA ND1.8 (depends on grating). A typical focus procedure would be:

`OVERSCAN`	use full IPCS frame
`BHART 1`	Left Hartmann shutter in; Right out

`EI 120`	120 sec exposure (short for `EXPOSE IPCS`)
DMS>`FOCUS`	choose 3 strong, unblended lines (left, middle & right end)
DMS>`FOCUS-LEFT`	
`BHART 2`	Right shutter in; Left out
`EI 120`	
DMS>`FOCUS-RIGHT`	which will give centroid differences at 3 points along each line.

The centre positions at each point indicates rotation and can be analysed with `FOCUS`.
Also check line rotation with DMS command `X-FIND`.
Then use

`IPROT` n	to rotate IPCS camera head to position n

where n is 32768 $\pm$ *rot*; and *rot* is 50/IPCS-pix displacement from top to bottom (+ve to move line anticlockwise).

To reduce centroid differences to 0, change collimator by 600 units for 0.5 IPCS-pix (+ve to make shift go +ve).
(N.B. if you use the DMS command l_1, l_2, l_3 `FOCUS-SET` the line positions are in **screen** pixels, not IPCS pixels.
Write them down when you first choose them.)
Best IPCS focus is currently 2–2.5pixels (check with the Local IPCS Expert)

The last BCOLL setting will be written on the whiteboard.

10.4.3 Observing with IPCS

OVERSCAN mode should always be used for a new objects/arc, etc., and then return to normal format with default proc, `IPCSWIN` or `IPCSFORMAT`.

Always observe new objects with your finger on the PANIC button. If used it is necessary to `IPC` before `IPO` will work.
If the IPCS *Overillumination* circuit is tripped, then it must be cleared with the command:-
`SPO OVERILLUM INIT`

`IPO`	opens IPCS shutter
`IPC`	closes IPCS shutter
`EI` *t*	performs a *t* secs IPCS exposure (short for `EXPOSE IPCS`
`KI`	'keeps' the exposure (transfers it from DMS to the 4000)
`IPPAUSE`	pauses the exposure
`IPCONT`	restarts the exposure
`IPSTOP`	stops (aborts) the exposure
`IPNEWT` *t*	changes the exposure time during the integration
`IPUPDATE`	causes exposure time to update on MIMIC
`IPWIN` *r w*	changes Y window to *w* rows read out starting from *r*
`IPCLEAR`	clears DMS IPCS buffer

10.5 The DMS Display

- Both CCD and IPCS images are read out into the DMS and displayed on the screen.
- The first CCD exposure read out after startup (or a DMS reset) will just be displayed as a small ikon. Click the cursor on this ikon (with the LH mouse button) for a full size display. You can switch between CCDs (and between CCD & IPCS) in this way.
- The mouse is disabled during CCD readout or when the IPCS display is being updated (when a BUSY message is displayed).

10.6 ISIS Commands

10.6.1 Slit area

`SLIT` *w*	sets slit width to *w* microns
`LSLIT`	selects long slit unit
`MSLIT`	selects multi-slit unit
`DEKKER` *n*	moves dekker to position *n*, where 0=out; 1=narrow(`1.2"`); 2=20"(for FOS); 6=long slit observing
`SLIT_DOOR OPEN`	releases slit area access door N.B. the DEKKER should be in position 0 for access to the slit area.
`SLIT_DOOR CLOSE`	locks slit area access door

10.6.2 Folds and Filters

`RFOLD` *n*	moves red fold to position *n* (0=flat mirror; 1=out)
`BFOLD` *n*	moves blue fold to position *n* (0=out; 1=flat; 2=dichroic) N.B. As of Oct 91, the BFOLD flat only reflects the central 2.5 arcmins of the field (or from 100-700 on the CCD). Important limit for Multislit users.
`RHART` *n*	moves Red Hartmann shutter to position *n* (0=both out; 1=L in,R out; 2=L out,R in; 3=both in)
`BHART` *n*	moves blue Hartmann to position *n* (same convention as for RHART)
`RCOLL` *n*	moves red collimator to setting *n*
`BCOLL` *n*	moves blue collimator to setting *n*
`RFILTA` *n*	moves red filter A to position *n* N.B. Check whiteboard & mimic for current filter slides loaded
`RFILTB` *n*	moves red filter B (see whiteboard)
`BFILTA` *n*	moves blue filter A to position *n*
`BFILTB` *n*	moves blue filter B to position *n*
`CHANGE`	to change grating & to update MIMIC database on gratings & ISIS filters

10.6.3 Gratings and Wavelength Settings

`REDGRAT` θ	moves red grating to angle θ (units of 0.001 degs)
`BLUEGRAT` θ	moves blue grating to angle θ
`CENWAVE RED` λ	moves red grating to wavelength λ Å
`CENWAVE BLUE` λ	moves blue grating to wavelength λ Å
`CHANGE`	use this to change a grating and then to enter the new item in the MIMIC's database. MANDATORY for a grating change.
`GRATING_DOOR OPEN`	unlocks both grating doors N.B. Do *not* issue this command until gratings have reached 35000.
`GRATING_DOOR CLOSE`	locks both grating doors. NB: Use CHANGE to change gratings; these commands to reset the doors only.

10.6.4 Polarisation Module

The main commands used for operating the polarisation elements are:

`FCP_OUT`	Remove calcite block or polaroid from the beam
`FCP` *pos*	Move FCP tray to *pos*. Options are: `CLEAR` - remove from beam `FIELD_LENS` - the old position of the FOS field lens `POLAROID` - select the Polaroid analyser position `CALCITE` - move to the Calcite analyser position.
`CALC`	Inserts calcite block into the beam
`POL`	Move Polaroid analyser into the beam
`HW_POLAR MOVE IN or OUT`	Moves the HW plate into or out of the beam
`HW_POLAR ANGLE` n	Sets angle of HW plate to n (in tenths of a degree)
`HW_POLAR ROTATE` n	Rotates the HW plate at n Hz
`HW_POLAR STOP ROTATE`	Stops the rotation of the HW plate, sets angle to 0
`HW_POLAR INIT`	Initialize the halfwave plate
`QW_POLAR MOVE IN or OUT`	Moves the QW plate into or out of the beam
`QW_POLAR ANGLE` n	Sets angle of QW plate to n (in tenths of a degree)
`QW_POLAR ROTATE` n	Rotates the QW plate at n Hz
`QW_POLAR STOP ROTATE`	Stops the rotation of the QW plate, sets angle to 0
`QW_POLAR INIT`	Initialize the quarterwave plate.

10.6.5 Initialising mechanisms

`INSLIT`	initialises slit unit (*not* the slit width)
`INRG`	initialises red grating
`INBG`	initialises blue grating
`INRFOLD`	initialises red fold slide
`INBFOLD`	initialises blue fold slide
`INRCOLL`	initialises red collimator
`INBCOLL`	initialises blue collimator
`INHW`	initialises 1/2 wave plate
`INQW`	initialises 1/4 wave plate
`INFCP`	initialises FCP tray
`INDEK`	initialises dekker
`ISIS_INIT` *mechanism*	for any ISIS mechanism.
mechanism `INIT`	for some ISIS mechanisms.

ISIS mechanism names include:-
`DEKKER, SLIT_JAWS, SLIT_UNIT, HW_POLAR, QW_POLAR, FLENS_CALC_POL, BLUE_FOLD, RED_FOLD, BLUE_FILTER_A, BLUE_FILTER_B, RED_FILTER_A, RED_FILTER_B, BLUE_COLLIMATOR, RED_COLLIMATOR, BLUE_GRATING, RED_GRATING.`

The slit jaws cannot be initialised - get technical help if they stick.
Updating the MIMIC for ISIS: use `ISIS_UPDATE ALL`.

10.7 A&G Box Commands

`AGMIRROR OUT`	removes all mirrors (e.g. for Hitch-Hiker to operate)
`AGCOMP`	moves mirror to acquisition/comparison lamp position
`AGSLIT`	moves mirror to slit-viewing position
`AGAUX`	equivalent to `AGMIRROR SMALLFEED` (for Auxiliary Port imaging)
`AUXFILTER` *n*	chooses auxiliary focus filter *n*, 0–5 (usually UBVRIZ) but check whiteboard for details of last filter set used. N.B. offsets to telescope focus (wrt ISIS/FOS slit) are : U Filter: -0.24mm; R Filter: -0.17m; Hα (8.2mm) Filter: -0.28mm and change AUTOFOCUS by approx -500.
`MAINFILTND` *number*	main filter slide to OUT, 2, 3, 4, 5, 6 (see whiteboard)
`MAINFILTC` *number*	main filter colour to OUT, 2, 3, 4, 5, 6 (see whiteboard)
`TVFOCUS` *n*	moves TV focus to *n* (range 0–18,000) Typically 14000 for 5"/mm, 12750 for 12"/mm for slit viewing
`TVFILT` *name*	TV filter to CLEAR, B, V, R or EMPTY

Beware of position empty, it may not be!!

`TVSCALE` *s*	selects TV scales of *s* = 5 or 12"/mm (1.5 or 4 arcmin field)

N.B. The two TV scales need slightly different TV focus settings.

Initialising:

`AGINIT` *mechanism*	where *mechanism* can be :–

`ACQCOMP, AUTOFILT, AUTOFOCUS, AUTORADIAL, AUTOTHETA, AUXFILTER, COMPFILTA, COMPFILTB, LARGEFEED, MAINFILTC, MAINFILTND, SLITVIEW, SMALLFEED, TVFILT, TVFOCUS, TVREDUCER` (to init `TVSCALE`)

Updating the MIMIC for A&G Units:

`AGUPDATE` *mechanism*

10.7.1 Comparison lamps

Only the lamps in the horns (usually CuAr and CuNe) and Tungsten currently give enough light to be useable.

`COMPLAMPS` *name*	turns on lamp (CUAR, CUNE, CUAR+CUNE, W) or OFF
`COMPFILTA` *name*	puts in CLEAR, ND0.2, ND0.6, ND0.8, ND1.8, ND3.0, GG375, GG495
`COMPFILTB` *name*	puts in CLEAR, ND0.3, ND0.5, ND0.9, ND1.2, ND2.0, BG24, OPAQUE

10.7.2 Autoguider

To start or stop, type START-UP and SHUT-DOWN on the autoguider keyboard. Check N_2 flow on start up (On ball meter immediately above red-ccd cryostat, reading should be at least 60) .

`AUTORADIAL` n	n=0–40000 microns
`AUTOTHETA` n	n=0–180000 millidegrees N.B. for values below 35000, the probe may vignette the slit
`AUTOFOCUS` n	n=0–6000 microns (typically 1500-2500)
`AUTOFILT`	selects EMPTY, CLEAR, OPAQUE, B, V or I
`ACQINT` n	Sets acquisition time (n= 1000–50000 msec)
`GUIINT` n	Sets guiding time (n=1000–50000 msec); typical 1-2s)
`FIELD`	takes exposures and finds guide star
`FON`	initiates 'following' by autoguider
`PROBE` r θ	inform T/S of probe position (get from CAGB mimic) N.B. MANDATORY - otherwise the object may move off the slit!
`AUTOGUIDER ON`	tell T/S to initiate closed-loop autoguiding
`AUTOGUIDER OFF`	tell T/S to stop autoguiding
`FOFF`	terminates the autoguider 'following'

Other commands available on the autoguider keyboard :

n `ACQINT`	sets integration time for the field in millisecs
n `GUIINT`	sets guiding time for the field in millisecs (usually 1000-4000)
`1 FIELD`	does 4 pictures and marks brightest star, excluding edge region
`GUIDE ON`	to start guiding, averaging over i integrations
`GUIDE OFF`	to stop guiding
n `GUISIZE`	to change the size of the guiding box
`>> and <<`	to rotate colour look-up table
`+TAU and −TAU`	to change horizontal scale of guide error display
`+SCALE and −SCALE`	similarly vertical scale

To use the artificial star:
ICL>`AUTOFILT OPAQUE`
Autoguider>`4000 GUIINT`
ICL>`COMPLAMPS W`
ICL>`COMPFILTA ND0.3`
Autoguider> `1 FIELD`
Autoguider> `GUIDE ON`

this gives a 'star' of magnitude 10.4.

10.8 Typical Observing Sequence

- Move telescope to target.
- ICL> `DEKKER 0` ... for a good image of the field with the TV
- ICL> `AGSLIT` and centre star on slit.
- ICL> `FIELD` ... take a field & find guide star.
- ICL> `PROBE` r θ
- ICL> `FON` ...begin following star
- ICL> `AUTOGUIDER ON` ...close guiding loop
- ICL> `DEKKER` n ... select dekker to be used (6 for long-slit spectra)
- ICL> `RUN/GLANCE/SKY`, etc ... take exposure on-sky
- If arc exposure is needed:
  ICL> `AUTOGUIDER OFF`
  ICL> `FOFF`
  ICL> `AGCOMP`
  ICL> `COMPLAMPS CUNE (or CUAR)`
  ICL> `ARC RED/BLUE/FOS etc` ... take arc exposure

- When arc exposure is completed:
  ICL> `COMPLAMPS OFF`
  ICL> `AGSLIT`

- To reacquire guide star return to `1 FIELD` command. Otherwise: next object !

10.9 Observing With FOS

- Fill with liquid N_2 in the early evening before observing.

- If all mechanisms are initialised you can set the system for FOS by entering :-
  `ISISCONFIG FOS` (or, set `RFOLD` and `BFOLD` mirrors clear
  `SETUP FOS` (answer x:400 y:590)

- As standard FOS dekker is only 20" long (Dekker 2), take a test exposure with this dekker to determine where the slit centre is (or, use bright sky or tungsten lamp to illuminate the dekker)

10.10 Offsetting the Telescope

10.11 Blind Offsets

`BLIND` is best for blind offsets to invisible targets, whereas `OFFSET` is okay for small offsets only. Use of `BLIND` ensures that the WHT keeps the correct rotator centre, etc. during long exposures. Proceed as follows :

- Enter coords of *standard* (PPM recommended) and faint *blind target* into the observing catalogue (on TCS keyboard).

- Make sure that `CALIBRATE` and a check for rotator centre position are done at start of night.

- `GOCAT` *offset star*

- Set desired position angle on sky, and centre star on slit.

- `BLIND` *blind target*

- Try to find a guide star and start guiding as quickly as possible now.

10.11.1 Small Offsets

This is used e.g. to move a few tens of arcsecs from the nucleus of a galaxy. The offsets may either be in the form $\Delta x, \Delta y$ (arcsecs) or $\Delta(\alpha), \Delta(\delta)$ (co-ord differences). Proceed as follows :

- Acquire main target

- Set desired position angle on sky and centre target on slit

- `OFFSET` *type da dd* where *type* is either ARC (units are arcsecs on sky) or SEC (secs of time and arcsecs), *da,dd* are the offsets in α, δ in the above units.

- do `FIELD` and find a good guide star but don't start guiding yet
- `PROBE` $r\ \theta$ on TCS console.
- `OFFSET` *type* 0 0 to return to main target to check it's still centered on the slit
- `OFFSET` *type da dd* and start exposures
- do `FIELD` again and quickly start closed-loop autoguiding

10.11.2 Data Files

- To see what files have been saved on the 4000 look in the directory: DISK$WHTDATA:[OBSDATA.dd-mm-yyyy].

  ¿From ICL use: `DCL DIR DCT_OBSDIR:[dd-mon-year]`.

- To write a FITS tape from the 4000 :-

  - Login to LPVE as OBSERVER in an independent session.
  - `ALLOCATE MUD0: or MUE0:` Allocate one of the tape drives that are connected to LPVE
  - `MOUNT/FOR/DENS=6250 MUD0: or MUE0:` Mount the tape
  - `FITSINIT` and answer the questions
  - `WRITE_FITS` ditto.

  To write an EXABYTE in FITS format:

  - Login to LPVE as OBSERVER
  - Allocate the exabyte (`ALLOC MUC0: or MUE0:`)
  - `MOUNT/FOREIGN MUC0: or MUE0:`
  - `FITSINIT` ... answer the questions
  - `WRITE_FITS` ... ditto.

  To write DAT in FITS format:

  - Login to LPVE as OBSERVER
  - Allocate the DAT (`ALLOC MUC3:`)
  - `MOUNT/FOREIGN MUC3:`
  - `FITSINIT` ... answer the questions
  - `WRITE_FITS` ... ditto.

10.12 Shutdown

- `STANDBY` shuts down IPCS. Then set the switch on the electronics cubicle to OFF.
- `SHUT-DOWN` the Autoguider (type this on the autoguider keyboard).
- `COMPLAMPS OFF`
- `EXIT` and then logoff from LPVF and the Vaxstation.
- Fill CCDs with liquid N_2.
- Enter requests for next day in the Telescope Log book, and enter faults in the FAULT database on LPVS3.

Part VI
COMMAND LISTS

11 Commands entered at the ICL interface

This section describes commands which can be entered at the ICL interface to control one or more subsystems.

Notation:

- Examples of commands entered at the terminal are in typewriter font: `REDGRAT 35000`;
- Angle brackets denote parameter values or character strings: `<angle>`;
- Square brackets denote optional input: `[x,y]`; all other parameters are obligatory;

11.1 A&G Box Commands

11.1.1 AGACCESS

Unlocks the access door for the main filter slides

Format:	`AGACCESS`
Comments:	The door must be opened and the closed manually. The command does not give control back to the user until this has been done. The door will be locked when it is closed, there is no separate command for this.

11.1.2 AGBARCODES

Reads the barcodes on the filters in the main A&G box filter slides.

Format:	`AGBARCODES <function>`
Example:	`AGBARCODES UPDATE`
Comments:	*function* can have one of three values: READ which reads the barcodes and stores the information in the 4ms; TRANSFER, which transfers the information from the 4ms to the system computer; and UPDATE, which performs both of these function, and is the usual option.

11.1.3 AGINIT

Initialises one of the mechanisms in the Cassegrain A&G box.

Format:	`AGINIT <mechanism>`
Examples:	`AGINIT COMPFILTA` `AGINIT ALL`
Comments:	Mechanisms which can be initialised include: COMPFILTA; COMPFILTB; AUTOFILT; AUTOFOCUS; AUTOTHETA; AUTORADIAL; AUXFILT; TVFOCUS; TVFILT; TVSCALE; ACQCOMP; SLITVIEW; LARGEFEED and SMALLFEED. To initialise all of the A&G box mechanisms type `AGINIT ALL`.

11.1.4 AGMIRROR

Moves a specified A&G box mirror into the beam, or all mirrors out of the beam.

Format: `AGMIRROR <mirrorname>`
Example: `AGMIRROR SLITVIEW`
Synonyms: `AGCOMP` (≡ `AGMIRROR ACQCOMP`)
`AGSLIT` (≡ `AGMIRROR SLITVIEW`)
Comments: Valid parameters are: ACQCOMP; SLITVIEW; LARGEFEED; SMALLFEED and OUT.

11.1.5 AGUPDATE

Updates the status of a mechanism as displayed on the MIMIC display.

Format: `AGUPDATE <mechanism>`
Examples: `AGUPDATE COMPLAMPS`
`AGUPDATE ALL`

11.1.6 ARCOFF

Turns off all comparison lamps and moves the mirrors to the slit viewing position.

Format: `ARCOFF`

11.1.7 AUTOFILT

Sets the position of the Autoguider filter wheel.

Format: `AUTOFILT`
Example: `AUTOFILT CLEAR`
Comments: Possible values are: B; V; I; CLEAR; EMPTY and OPAQUE. Note that AUTOFOCUS will need to be adjusted when moving from B, V, or I to EMPTY, but not when moving from B, V, or I to CLEAR.

11.1.8 AUTOFOCUS

Sets the Autoguider focus.

Format: `AUTOFOCUS <focusvalue>`
Example: `AUTOFOCUS 3500`
Units: Microns.
Range: 0 to 6000.
Comments: The autoguider focus must be adjusted after the telescope focus has been set to focus on a guide star.

11.1.9 AUTORADIAL

Sets the radial position of the guide probe.

Format: `AUTORADIAL <radialposition>`
Example: `AUTORADIAL 10000`
Units: Microns.
Range: 0 to 40000.

11.1.10 AUTOTHETA

Sets the angular position of the guide probe.

Format:	`AUTOTHETA <thetaposition>`
Example:	`AUTOTHETA 50000`
Units:	Millidegrees.
Range:	0 to 180000.
Comments:	Note that values less that 35000 may cause the probe to vignette the slit viewing optics.

11.1.11 AUXFILTER

Moves the auxiliary port filter wheel to a given position.

Format:	`AUXFILTER <filterposition>`
Example:	`AUXFILTER 3`
Range:	0 to 5.
Comments:	The filter wheel has positions 0 to 5, and the names of the filters mounted in each position are usually listed on the white board in the control room.

11.1.12 COMPFILTA

Moves the comparison lamp filter wheel A so that the named filter is in the beam.

Format:	`COMPFILTA <filtername>`
Example:	`COMPFILTA ND3.0`
Comments:	Possible values for *filtername* are: ND3.0; ND1.8; ND0.8; ND0.6; ND 0.2; GG375; GG495; and CLEAR.

11.1.13 COMPFILTB

Moves the comparison lamp filter wheel B so that the named filter is in the beam.

Format:	`COMPFILTB <filtername>`
Example:	`COMPFILTB ND3.0`
Comments:	Possible values for *filtername* are: ND2.0; ND1.2; ND0.9; ND0.5; ND0.3; BG24; OPAQUE; and CLEAR.

11.1.14 COMPLAMPS

Switches on or off comparison lamps.

Format:	`COMPLAMPS <lampname(s)>`
Examples:	`COMPLAMPS CUAR+CUNE` `COMPLAMPS OFF`
Comments:	More than one comparison lamp may be switched on, the names being joined together with plus signs. Possible comparison lamps are: CUAR; CUNE; W; FEAR; FENE; NAK; and ALMGCA. Another allowed parameter is OFF, which may not be joined with a plus sign to any other allowed parameter.

11.1.15 COMPND

Sets the comparison lamp neutral density to a specified value.

Format: `COMPND <ndvalue>`

Example: `COMPND 1.5`

Comments: Selects the combination of neutral density values in the COMPFILTA and COMPFILTB wheels, whose sum is closest to the *ndvalue*, moves the filter wheels to those positions.

11.1.16 CUARON

Moves the mirrors to the ACQCOMP position and switches on the copper-argon lamp.

Format: `CUARON`

Comments: This command currently will only work if the IPCS is in use.

11.1.17 CUNEON

Moves the mirrors to the ACQCOMP position and switches on the copper-neon lamp.

Format: `CUNEON`

Comments: This command currently will only work if the IPCS is in use.

11.1.18 MAINFILTC

Moves the main colour filter slide to a given position.

Format: `MAINFILTC <filterposition>`

Examples: `MAINFILTC 3`
`MAINFILTC GG395`

Comments: The position can be specified as a filter position number in the range 2-6; as the name of a filter which has been identified by its barcode; or as OUT to remove the filters from the beam.

11.1.19 MAINFILTND

Moves the main neutral density filter slide to a given position.

Format: `MAINFILTND <filterposition>`

Examples: `MAINFILTND 3`
`MAINFILTND ND2.0`

Comments: The position can be specified as a filter position number in the range 2-6; as the name of a filter which has been identified by its barcode; or as OUT to remove the filters from the beam.

11.1.20 TV_DIRECT_12

Selects the direct viewing position at a scale of 12 arcsec/mm.

Format: `TV_DIRECT_12`

Comments: Procedure which moves the mirrors to the ACQCOMP position, selects a scale of 12 arcsec/mm and the correct value of TVFOCUS.

11.1.21 TV_DIRECT_5

Selects the slit viewing position at a scale of 5 arcsec/mm.

Format: `TV_DIRECT_5`

Comments: Procedure which moves the mirrors to the ACQCOMP position, selects a scale of 5 arcsec/mm and the correct value of TVFOCUS.

11.1.22 TV_SLIT_12

Selects the slit viewing position at a scale of 12 arcsec/mm.

Format: `TV_SCALE_12`

Comments: Procedure which moves the mirrors to the SLITVIEW position, selects a scale of 12 arcsec/mm and the correct value of TVFOCUS.

11.1.23 TV_SLIT_5

Selects the slit viewing position at a scale of 5 arcsec/mm.

Format: `TV_SCALE_5`

Comments: Procedure which moves the mirrors to the SLITVIEW position, selects a scale of 5 arcsec/mm and the correct value of TVFOCUS.

11.1.24 TVFILT

Moves the filter wheel in front of the TV camera to a named filter.

Format: `TVFILT <filtername>`

Example: `TVFILT R`

Comments: Possible values are: B; V; R; CLEAR and EMPTY. The TV focus must be adjusted when changing from EMPTY to one of the other positions. **Note that there may be an opaque mask in position EMPTY; if so position CLEAR should be used instead.**

11.1.25 TVFOCUS

Sets the TV focus.

Format: `TVFOCUS <focusvalue>`

Example: `TVFOCUS 15000`

Units: Microns.

Range: 0 to 17500.

Comments: To adjust the TV focus so that the TV is focussed on the slit, or so that a star is in focus on the TV in direct mode.

11.1.26 TVSCALE

Sets the TV scale.

Format: `TVSCALE <tvscalevalue>`

Example: `TVSCALE 5`

Comments: Puts the correct focal reduction optics (or no optics at all) in front of the TV camera for a specified scale (in arcsec/mm), either in slit viewing or direct mode. Allowed values of the TV scale are 5 and 12.

11.2 Autoguider Commands

11.2.1 ACQINT

Changes the Autoguider integration time when acquiring.

Format: `ACQINT` <`integrationtime`>
Example: `ACQINT 4000`
Units: Milliseconds.
Comments: Equivalent to <`integrationtime`> `AIT` at the Autoguider terminal.

11.2.2 FIELD

Causes the CCD autoguider to read out its whole field of view and look for a suitable guide star.

Format: `FIELD`
Comments: Does not return control to the user until this process is complete. Equivalent to `1 FIELD` at the autoguider interface.

11.2.3 FOLLOW

Causes the CCD Autoguider to follow a star image and to send error signals to the Telescope Control Computer, or to stop doing so.

Format: `FOLLOW` <`onoroff`> <`n`>
Examples: `FOLLOW ON 1`
Synonyms: `FON` (≡ `FOLLOW ON 1`)
`FOFF` (≡ `FOLLOW OFF 1`)
Comments: Valid values of the first parameter are ON and OFF; the second is the number of Autoguider integrations per guiding error is normally 1. Equivalent to `n 1 GUI` and `GUI-OFF` at the Autoguider terminal. `FOLLOW` does not start the telescope autoguiding, it is necessary to issue the `PROBE` and `AUTOGUIDER` commands to the TCS, either through the ICL interface or at the TCS terminal, to do this. For details of these commands refer to THE WHT USERS' MANUAL.

11.2.4 GUIINT

Changes the Autoguider integration time when guiding.

Format: `GUIINT` <`integrationtime`>
Example: `GUIINT 4000`
Units: Milliseconds.
Comments: Equivalent to <`integrationtime`> `GIT` at the Autoguider terminal.

11.3 ISIS Commands

11.3.1 ANAMORPHOTIC

Moves the Anamorphotic lens in or out.

Format: `ANAMORPHOTIC <direction>`
Example: `ANAMORPHOTIC IN`
Comments: Valid parameters are IN or OUT. **NOTE THAT THE ANAMORPHOTIC LENS HAS NOT YET BEEN ACQUIRED, AND THIS MECHANISM HAS BEEN DISABLED UNTIL IT HAS.**

11.3.2 BCOLL

Controls the Blue collimator.
Format: `BCOLL <position>`
Example: `BCOLL 14800`
Units: Microns.
Range: 0 to 52000.
Comments: Moves, stops or initialises the Blue collimator. Valid parameters are a position in microns; STOP and INIT.

11.3.3 BLUEGRAT

Controls the Blue grating.
Format: `BLUEGRAT <angle>`
Example: `BLUEGRAT 48912`
Synonym: `BGRAT`
Units: Millidegrees.
Range: 0 to 110000.
Comments: Moves, stops or initialises the Blue Grating, or reprograms the SMDM which controls it. Valid parameters are an angle in millidegrees; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.4 BLUEXDISP

Controls the blue cross-disperser.
Format: `BLUEXDISP <position>`
Example: `BLUEXDISP IN`
Comments: Moves, stops or initialises the Blue cross-disperser, or reprograms the SMDM which controls it. Valid parameters are: IN; OUT; STOP; INIT; and REPROGRAM. The last option should only be used in exceptional circumstances. **THIS ITEM HAS NOT YET BEEN DELIVERED AND THIS COMMAND WILL NOT BE IMPLEMENTED UNTIL IT HAS.**

11.3.5 BFILTA

To move filter slide A in the Blue beam to a given position.
Format: `BFILTA <position>`
Example: `BFILTA 2`
Range: 0 to 2, or a named position.
Comments: Moves, stops or initialises Blue Filter A. Valid parameters are a position in the range 0 to 2; a named filter (listed on the ISIS MIMIC page); OUT; STOP;

INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.6 BFILTB

To move filter slide B in the Blue beam to a given position.

Format: `BFILTB <position>`
Example: `BFILTB 2`
Range: 0 to 2, or a named position.
Comments: Moves, stops or initialises Blue Filter B. Valid parameters are a position in the range 0 to 2; a named filter (listed on the ISIS MIMIC page); OUT; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.7 BFOLD

Controls the slide containing the folding flat for the blue camera and the dichroic mirror.

Format: `BFOLD <position>`
Example: `BFOLD DICHROIC`
Synonym: `BLUE_FOLD`
Comments: Moves, stops or initialises the slide containing the folding flat for the blue camera and the dichroic mirror. Valid parameters are a number in the range 0 to 2; MIRROR ($\equiv$ 1); DICHROIC ($\equiv$ 2); CLEAR ($\equiv$ 0); STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.8 BHART

Controls the position of the Blue beam Hartmann shutters.

Format: `BHART <position>`
Examples: `BHART 1`
`BHART BOTH_IN`
Range: 0 to 3, with named equivalents.
Comments: Valid parameters are a number in the range 0 to 3; BOTH_IN ($\equiv$ 3); LEFT_IN ($\equiv$ 2); RIGHT_IN ($\equiv$ 1) and BOTH_OUT ($\equiv$ 0).

11.3.9 CENWAVE

Sets a grating to give a specified central wavelength on the detector.

Format: `CENWAVE <gratingname> <wavelength>`
Example: `CENWAVE RED 6563`
Synonym: `ISIS_CENWAVE`
Units: *wavelength* is specified in Ångstroms.
Comments: A procedure to work out the grating angle required to give a given central wavelength on the detector, and then to set the grating angle to that wavelength. The grating name, which must be RED or BLUE, and the required central wavelength in Ångstroms are specified on the command line. The grove spacing on

the grating must be correct in the database, this can be checked on the mimic screen.

11.3.10 CHANGE

An interactive procedure to allow the user to change gratings or filters and to update the database.

Format: `CHANGE`

Comments: The change procedure allows the user to change gratings or filters. It prompts the user for the item that requires changing, then moves that mechanism to its change position, moves the dekker to the change position if a filter is to be changed, and unlocks the relevant door. After the change has been made it locks the door and updates the database.

11.3.11 DEKKER

Moves the Dekker slide.

Format: `DEKKER <position>`

Examples: `DEKKER 2`
`DEKKER BARRED`

Range: 0 to 8, or named dekkers.

Comments: Moves, stops or initialises the dekker slide, or reprograms the SMDM which controls the dekker slide. Valid parameters are a dekker position in the range 0 to 8; a named dekker as listed on the MIMIC display; OUT; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.12 FCP

Moves the slide which contains the Field Lens; Calcite block and Polaroid Filter.

Format: `FCP <position>`

Example: `FCP CALCITE`

Synonyms: `FIELD_LENS (≡ FCP FIELD_LENS)`
`FIELDLENS (≡ FCP FIELD_LENS)`
`POLAROID (≡ FCP POLAROID)`
`CALCITE (≡ FCP POLAROID)`
`FCP_CLEAR (≡ FCP CLEAR)`
`FCPCLEAR (≡ FCP CLEAR)`

Range: 0 to 3, or named positions.

Comments: Moves, stops, or initialises the Field Lens, Calcite and Polaroid slide or reprograms the SMDM which controls it. Valid parameters are a position in the range 0 to 3; FIELD_LENS ($\equiv$ 2); CALCITE($\equiv$ 3); POLAROID ($\equiv$ 1); OUT ($\equiv$ 0); STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.13 GRATING_DOOR

Locks or unlocks the grating access doors.

Format: GRATING_DOOR <position>
Example: GRATING_DOOR OPEN
Comments: This is an interactive procedure to unlock and lock both grating doors. Valid parameters are OPEN and CLOSE, LOCK and UNLOCK. GRATING_DOOR OPEN or GRATING_DOOR UNLOCK will unlock the doors and invite you to open them manually. GRATING_DOOR CLOSE or GRATING_DOOR LOCK will invite you to check that they are closed, and lock them when you have verified this.

11.3.14 HW_POLAR

Controls the Half Wave Plate.
Format: HW_POLAR <function> <parameter>
Examples: HW_POLAR MOVE IN
HW_POLAR ROTATE 25
HW_POLAR ANGLE 1800
HW_POLAR STOP ROTATE
Synonyms: HWIN ≡ HW_POLAR MOVE IN
HWOUT ≡ HW_POLAR MOVE OUT
HWP ≡ HW_POLAR ANGLE
HWPROT ≡ HW_POLAR ROTATE
Units: Angles are specified in units of a tenth of a degree.
Rotation rates are specified in units of a tenth of a Hz.
Range: Angle in range 0 to 3600.
Rotation rate in range -7 to 118.
Comments: *function* can have the values ROTATE, ANGLE, MOVE or STOP.
The parameter for HW_POLAR ROTATE is a rotation rate in units of a tenth of a Hz, this sets the plate in continuous rotation.
The parameter for HW_POLAR ANGLE is an angle in units of a tenth of a degree, this sets the plate to a fixed angle.
The parameter for HW_POLAR MOVE can be IN or OUT, this moves the plate in or out.
The parameter for HW_POLAR STOP can be ROTATE or MOVE, this stops the plate rotating or moving.
Notes:- The wave plate must be in before continuous rotation is started; and the if the wave plate is rotating it must be stopped before sending it to a fixed angle.

11.3.15 ISIS_CONFIG

Configures the folding mirror slides for observing with a named combination of arms.
Format: ISIS_CONFIG <configuration>
Example: ISIS_CONFIG BLUEANDRED
Comments: Valid parameters are RED; BLUE; FOS; BLUEANDRED and BLUEANDFOS.

11.3.16 ISIS_INIT

Initialises a named mechanism
Format: ISIS_INIT <mechanism>

Example: `ISIS_INIT RED_GRATING`
Comments: Mechanisms which can be initialised include:-
RED_GRATING; BLUE_GRATING; RED_COLLIMATOR;
BLUE_COLLIMATOR; RED_FILTER_A; RED_FILTER_B;
BLUE_FILTER_A; BLUE_FILTER_B; DEKKER;
SLIT_UNIT; HW_POLAR; QW_POLAR; RED_FOLD;
BLUE_FOLD and FLENS_CALC_POLAR.

11.3.17 ISIS_MOVE

Moves a specified mechanism
Format: `ISIS_MOVE <mechanism> <position>`
Example: `ISIS_MOVE RED_GRATING 45789`
Comments: The list of mechanisms which can be moved includes those which can be initialised with `ISIS_INIT`, plus ANAMORPHOTIC; LID_COVER and SLIT_JAWS.

11.3.18 ISIS_UPDATE

Updates the status of a mechanism on the MIMIC display.
Format: `ISIS_UPDATE <mechanism>`
Example: `ISIS_UPDATE SLIT`
Comments: The list of mechanisms which can be updated is the same as that which can be moved with `ISIS_MOVE`.

11.3.19 LID

Opens or closes the Lid Cover.
Format: `LID <direction>`
Example: `LID OPEN`
Comments: Valid parameters are OPEN and CLOSE.

11.3.20 QW_POLAR

Controls the Quarter Wave Plate.
Format: `QW_POLAR <function> <parameter>`
Examples: `QW_POLAR MOVE IN`
`QW_POLAR ROTATE 25`
`QW_POLAR ANGLE 1800`
`QW_POLAR STOP ROTATE`
Synonyms: `QWIN` ≡ `QW_POLAR MOVE IN`
`QWOUT` ≡ `QW_POLAR MOVE OUT`
`QWP` ≡ `QW_POLAR ANGLE`
`QWPROT` ≡ `QW_POLAR ROTATE`
Units: Angles are specified in units of a tenth of a degree.
Rotation rates are specified in units of a tenth of a Hz.
Range: Angle in range 0 to 3600.
Rotation rate in range -7 to 118.

Comments:	*function* can have the values ROTATE, ANGLE, MOVE or STOP. The parameter for `QW_POLAR ROTATE` is a rotation rate in units of a tenth of a Hz, this sets the plate in continuous rotation. The parameter for `QW_POLAR ANGLE` is an angle in units of a tenth of a degree, this sets the plate to a fixed angle. The parameter for `QW_POLAR MOVE` can be IN or OUT, this moves the plate in or out. The parameter for `QW_POLAR STOP` can be ROTATE or MOVE, this stops the plate rotating or moving. Notes:- The wave plate must be in before continuous rotation is started; and the if the wave plate is rotating it must be stopped before sending it to a fixed angle.

11.3.21 RCOLL

Controls the Red collimator.

Format:	`RCOLL <position>`
Example:	`RCOLL 7500`
Units:	Microns.
Range:	0 to 30000.
Comments:	Moves, stops or initialises the Red collimator. Valid parameters are a position in microns; STOP and INIT.

11.3.22 REDGRAT

Controls the red grating.

Format:	`REDGRAT <angle>`
Example:	`REDGRAT 56478`
Synonym:	`RGRAT`
Units:	Millidegrees.
Range:	0 to 110000.
Comments:	Moves, stops or initialises the Red Grating, or reprograms the SMDM which controls it. Valid parameters are an angle in millidegrees; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.23 REDXDISP

Controls the Red cross-disperser.

Format:	`REDXDISP <position>`
Example:	`REDXDISP IN`
Comments:	Moves, stops or initialises the Red cross-disperser, or reprograms the SMDM which controls it. Valid parameters are: IN; OUT; STOP; INIT; and REPROGRAM. The last option should only be used in exceptional circumstances. **THIS ITEM HAS NOT YET BEEN DELIVERED AND THIS COMMAND WILL NOT BE IMPLEMENTED UNTIL IT HAS.**

11.3.24 RFILTA

To move filter slide A in the Red beam to a given position.

Format: `RFILTA <position>`

Example: `RFILTA 2`

Range: 0 to 2, or a named position.

Comments: Moves, stops or initialises Red Filter A. Valid parameters are a position in the range 0 to 2; a named filter (listed on the ISIS MIMIC page); OUT; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.25 RFILTB

To move filter slide B in the Red beam to a given position.

Format: `RFILTB <position>`

Example: `RFILTB 2`

Range: 0 to 2, or a named position.

Comments: Moves, stops or initialises Red Filter B. Valid parameters are a position in the range 0 to 2; a named filter (listed on the ISIS MIMIC page); OUT; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.26 RFOLD

Controls the slide containing the folding flat for the red camera.

Format: `RFOLD <position>`

Example: `RFOLD MIRROR`

Synonym: `RED_FOLD`

Comments: Moves, stops or initialises the slide containing the folding flat for the red camera. Valid parameters are a number in the range 0 to 1; MIRROR ($\equiv$ 0); CLEAR ($\equiv$ 1); STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.3.27 RHART

Controls the position of the Red beam Hartmann shutters.

Format: `RHART <position>`

Examples: `RHART 1`
`RHART BOTH_IN`

Range: 0 to 3, with named equivalents.

Comments: Valid parameters are a number in the range 0 to 3; BOTH_IN ($\equiv$ 3); LEFT_IN ($\equiv$ 2); RIGHT_IN ($\equiv$ 1) and BOTH_OUT ($\equiv$ 0).

11.3.28 SLIT

Sets the Slit jaws to a specified width.

Format: `SLIT <slitwidth>`

Example: `SLIT 200`

Synonym: SLITARC (also allows STOP as a parameter.)
Units: Microns.
Range: 25 to 5000.

11.3.29 SLIT_DOOR

Locks or unlocks the slit area access door.

Format: `SLIT_DOOR <position>`
Example: `SLIT_DOOR OPEN`
Comments: This is an interactive procedure to unlock and lock the slit access door. Valid parameters are OPEN and CLOSE, LOCK and UNLOCK `SLIT_DOOR OPEN` or `SLIT_DOOR UNLOCK` will unlock the door and invite you to open it manually. `SLIT_DOOR CLOSE` or `SLIT_DOOR LOCK` will invite you to check that it is closed, and lock it when you have verified this.

11.3.30 SLIT_UNIT

Selects whether the long slit unit or the multi-slit and fibre slit unit is in the beam.

Format: `SLIT_UNIT <position>`
Example: `SLIT_UNIT LONG_SLIT`
Synonyms: `LSLIT (≡ SLIT_UNIT LONG_SLIT)`
`MSLIT (≡ SLIT_UNIT MSLIT_FIBRES)`
Comments: Moves, stops or initialises the slit unit, or reprograms the SMDM which controls it. Valid parameters are a position in the range 0 to 1; LONG_SLIT (≡ 1); MSLIT_FIBRES (≡ 0; STOP; INIT and REPROGRAM. The last option should only be used in exceptional circumstances.

11.4 FOS Commands

11.4.1 FIFOCUS

Returns the status of the FOS Focus and updates the MIMIC.

Format: `FIFOCUS`
Synonym: `FIF`
Comments: **AT PRESENT THE FOS MIMIC DOES NOT WORK.**

11.4.2 FIGLOBAL

Returns status of all FOS mechanisms.

Format: `FIGLOBAL`
Synonym: `FIG`
Comments: **AT PRESENT THE FOS MIMIC DOES NOT WORK.**

11.4.3 FIHARTMANN

Returns status of the FOS Hartmann shutters.

Format: `FIHARTMANN`
Synonym: `FIHA`

Comments: **AT PRESENT THE FOS MIMIC DOES NOT WORK.**

11.4.4 FIHTILT

Returns status of the FOS Platform Horizontal Tilt.

Format: `FIHTILT`

Synonym: `FIHT`

Comments: **AT PRESENT THE FOS MIMIC DOES NOT WORK.**

11.4.5 FIVTILT

Returns status of the FOS Platform Vertical Tilt.

Format: `FIVTILT`

Synonym: `FIVT`

Comments: **AT PRESENT THE FOS MIMIC DOES NOT WORK.**

11.4.6 FMFOCUS

Controls the FOS Focus.

Format: `FMFOCUS` <`focusvalue`>

Example: `FMFOCUS 227`

Synonym: `FMF`

Units: The units are units of 4 microns.

Range: 0 to 511

11.4.7 FMHARTMANN

Controls the FOS Hartmann shutters.

Format: `FMHARTMANN` <`position`>

Example: `FMHARTMANN LEFT`

Synonym: `FMHA`

Comments: Valid parameters are: LEFT (left shutter in beam); RIGHT (right shutter in beam) and CLEAR (both shutters out of beam).

11.4.8 FMHTILT

Controls the FOS Platform Horizontal Tilt.

Format: `FMHTILT` <`value`>

Example: `FMHTILT 199`

Synonym: `FMHT`

Units: Each unit subtends a displacement of 4 microns across the diameter of the platform.

Range: 0 to 511

11.4.9 FMMONITOR

Turns FOS monitor mode on or off.
Format: `FMMONITOR <onoroff>`
Example: `FMMONITOR ON`
Synonym: `FMM`
Comments: Valid parameters are ON and OFF.

11.4.10 FMRESET

Software reset of the FOS 4ms.
Format: `FMRESET`
Synonym: `FMR`

11.4.11 FMVTILT

Controls the FOS Platform vertical Tilt.
Format: `FMVTILT <value>`
Example: `FMVTILT 199`
Synonym: `FMVT`
Units: Each unit subtends a displacement of 4 microns across the diameter of the platform.
Range: 0 to 511

11.4.12 FSGLOBAL

Stops all FOS mechanisms.
Format: `FSGLOBAL`
Synonym: `FSG`

11.5 Data Taking Commands - CCD Detectors

CCD data are taken and stored with the Data Acquisition System, which provides a large range of commands for taking data of various types, and storing the data with or without the header information in various forms on the Vax discs. A description of the system, together with a complete list of the commands, is given in "William Herschel Telescope Instrument control and data acquisition system user manual", by S.W. Unger & G.T. Rixon, and only a subset of the commands, relevant to observing with CCDs on ISIS, are listed here. Many commands do almost identical things, for instance the commands `RUN`, `FLAT`, `ARC`, and `SKY` differ only in one header item in the data file. The commands `SCRATCH` and `PROMOTE` are intended for use by automatic setup procedures yet to be written.

11.5.1 ABORT

Terminate an exposure early, abandoning the data.
Format: `ABORT <channel>`
Channel: The name of the CCD data acquisition channel to be used.
Examples : `ABORT RED`

Comments: This command terminates the current CCD exposure, throwing away the data.

11.5.2 ARC

This is equivalent to the RUN command, but intended for exposures of arc lamps rather than observations of astronomical targets.

Format: `ARC <channel> <time> ["<string>"]`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Title: A title for the observation (optional)
Examples : `ARC RED 1.5 "CuAr arc 5500 Angstrom"`
Comments: As for the RUN command, except that the observation type is set in the headers as being an arc exposure.

11.5.3 BIAS

Takes a single bias frame (a zero second exposure), and transfers the data plus headers to an HDS file on the system computer.

Format: `BIAS <channel> ["<string>"]`
Channel: The name of the CCD data acquisition channel to be used.
Title: A title for the observation (optional)
Examples : `BIAS RED "Bias frame 5"`
Comments: As for the RUN command, except that exposure time will be zero, and the observation type is set in the headers as being a BIAS exposure.

11.5.4 BIN

Bins a CCD detector

Format: `BIN <channel> <xbin> <ybin>`
Channel: The name of the CCD data acquisition channel to be binned.
Xbin: The binning factor in X. This must be an integer in the range 1 – 10.
Ybin: The binning factor in Y. This must be an integer in the range 1 – 10.
Examples : `BIN RED 2 2`
Comments: This command sets the binning factors on the named channel in both X and Y, and enables windowing and binning on the CCD.

11.5.5 CCDINIT

Initialises a CCD.

Format: `CCDINIT <detectorname>`
Example: `CCDINIT RED`
Comments: Initialises a CCD and updates the MIMIC display with data from the CCD controller. This is performed in the startup sequence, and this command is only required if the startup sequence fails.

11.5.6 CONTINUE

Continue a paused CCD exposure.

Format: `CONTINUE <channel>`

Channel: The name of the CCD data acquisition channel to be used.

Examples : `CONTINUE RED`

Comments: This command resumes a paused CCD exposure, opening the CCD shutter. The shutter will not be opened if it was closed when the exposure was paused (as in the case of a dark exposure). The command will be aborted if no exposure is in progress.

11.5.7 DARK

Takes an exposure without opening the CCD shutter, and transfers the data plus headers to an HDS file on the system computer.

Format: `DARK <channel> <time> ["<string>"]`

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Title: A title for the observation (optional)

Examples : `DARK RED 9999 "Measuring dark counts"`

Comments: As for the RUN command, except that the CCD shutter is not opened, and the observation type is set in the headers as being a DARK exposure.

11.5.8 DIR

Lists the run and scratch files taken during the night.

Format: `DIR`

Comments: Lists the files in the directories to which run and scratch files are currently being written. Normal DCL qualifiers (e.g. `/SIZE`) are accepted.

11.5.9 DISABLE_WINDOWS

Disables windows and binning factors previously set up on a CCD detector

Format: `DISABLE_WINDOWS <channel>`

Channel: The name of the CCD data acquisition channel.

Examples : `DISABLE_WINDOWS FOS`

Comments: This command disables windowing and binning of the CCD. The command does not delete the systems memory of window parameters and binning factors, it only stops the system applying it. The windows and binning can be reenabled with the command ENABLE_WINDOWS.

11.5.10 DISKSPACE

Reports the available diskspace on the data disk and on the home disk of the OBSERVER.

Format: `DISKSPACE`

11.5.11 ENABLE_WINDOWS

Enables windows and binning factors previously disabled on a CCD detector

Format: `ENABLE_WINDOWS <channel>`

Channel: The name of the CCD data acquisition channel .

Examples : `ENABLE_WINDOWS FOS`

Comments: Where windowing and binning of the CCD have been disabled using the DISABLE_WINDOWS command, this command reenables them.

11.5.12 FINISH

Terminate an exposure early, saving data and headers to disk.

Format: `FINISH <channel>`

Channel: The name of the CCD data acquisition channel to be used.

Examples : `FINISH RED`

Comments: This command terminates the current CCD exposure, saving the data to disk as if the exposure had completed normally.

11.5.13 FLAT

This is equivalent to the RUN command, but intended for exposures of flat fields rather than astronomical targets

Format: `FLAT <channel> <time> ["<string>"]`

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Title: A title for the observation (optional)

Examples : `FLAT BLUE 1.5 "Tungsten flat 5500 Angstrom"`

Comments: As for the RUN command, except that the observation type is set in the headers as being a flatfield exposure.

11.5.14 GLANCE

Takes an exposure and transfers the data into the Detector Memory System for inspection, but not to the system computer.

Format: `GLANCE <channel> <obstype> <time>`

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Obstype: The observation type. Valid observation types are ARC, BIAS, DARK, FLAT, and TARGET.

Examples : `GLANCE RED ARC 5`

Comments: This command is intended for a quick–look at the data, to verify for example that the intensity level is as expected before carrying out a proper exposure. The data will be lost when the next exposure is carried out on the same data acquisition channel. To save the data, use the KEEP command.

11.5.15 KEEP

Copies a previously completed glance exposure to disk on the system computer, collecting headers and assigning a run number in the process.

Format: `KEEP <channel> ["<title>"]`
Channel: The name of the CCD data acquisition channel to be used.
Title: A title for the observation (optional)
helpitemExamples : `KEEP RED`
Comments: The system will report the allocated run number.

11.5.16 KILLMULT

Stops a sequence of multiple exposures.

Format: `KILLMULT <channel>`
Channel: The name of the CCD data acquisition channel.
Example: `KILLMULT RED`
Comments: The current exposure in the series is left to complete normally, and all pending exposures are cancelled. The channel becomes ready for another command when the current exposure completes. `KILLMULT` can be followed by `FINISH` or `ABORT` for a complete stop.

11.5.17 MULTRUN

Takes a sequence of exposures, all of the same exposure time

Format: `MULTRUN <channel> <nruns> <time> ["<title>"]`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Example: `MULTRUN RED 25 60 "AX DRACO 25 exposures"`
Comments: There also commands `MULTARC`, `MULTFLAT`, `MULTBIAS`, `MULTDARK` which have similar formats, except that `MULTBIAS` does not require a time.

11.5.18 NEWTIME

Change the exposure time of an exposure in progress.

Format: `NEWTIME <channel> <time>`
Example: `NEWTIME RED 1200`
Channel: The name of the CCD data acquisition channel to be used.
Time: The exposure time in seconds
Comments: The system will not accept an exposure time less than the current exposed time.

11.5.19 PAUSE

Pauses a CCD exposure.

Format: `PAUSE <channel>`
Channel: The name of the CCD data acquisition channel to be used.
Examples : `PAUSE RED`
Comments: This command suspends the current CCD exposure, closing the CCD shutter. The command will be aborted if no exposure is in progress.

11.5.20 PROMOTE

Promotes a scratch datafile to the main data area on the system computer, assigning it a run number in the process.

Format: `PROMOTE <filenum>`

Filenum: The number of the scratch file

Examples : `PROMOTE 5`

Comments: The system will report the allocated run number. However, since the headers for the observation are collected when the data is originally taken, the run number will not appear in the headers.

11.5.21 RAT_WAIT

RAT_WAITs for an exposure to complete before returning control to ICL.

Format: `RAT_WAIT <channel> <timeout>`

Channel: The name of the CCD data acquisition channel to be used.

Timeout: The maximum time to wait (seconds)

Examples : `RAT_WAIT RED 90`

Comments: The commands for carrying out CCD exposures normally return control to ICL before they complete. Whilst this is desirable in normal operation, it makes it impossible to write ICL procedures to carry out a number of exposures sequentially (as in a focus run for example). Such ICL procedures can be produced using the WAIT command (see section ? for examples). The timeout parameter of the WAIT command forces it to return an error to ICL if the exposure does not complete; it is recommended that timeouts be made generous.

11.5.22 RUN

Takes an exposure of an astronomical target, and transfers the data plus headers to an HDS file on the system computer.

Format: `RUN <channel> <time> ["<string>"]`

Channel: The name of the CCD data acquisition channel to be used.

Time: The exposure time in seconds

Title: A title for the observation (optional)

Examples : `RUN RED 1.5 "NGC1068 nucleus"`

Synonym: `TARGET`

Comments: This command takes a single exposure of an astronomical target, collects header information pertaining to that exposure, and transfers both data and headers into an HDS file on the system computer. During the observation the system will report the run number allocated, and will announce the start and end of the exposure. The user will be informed once the data has been written to disk; until this notification has been received, no further exposure can be carried out on this detector channel. Exposures cannot be carried out until the detector has been set up using the SETUP command.

11.5.23 SCRATCH

Takes an exposure, and transfers the data plus headers to a numbered HDS file in the scratch area on the system computer.

Format:	`SCRATCH <channel> <filenum> <obstype> <time> ["<string>"]`
Channel:	The name of the CCD data acquisition channel to be used.
Filenum:	The number of the scratch file
Obstype:	The observation type. Valid observation types are ARC, BIAS, DARK, FLAT, and TARGET.
Time:	The exposure time in seconds
Title:	A title for the observation (optional)
Examples :	`SCRATCH RED 5 ARC 60`
Comments:	As for the RUN command, except that the data is finally transferred not to the main data area on the system computer but to a scratch area. This command is intended primarily for use with setup procedures.

11.5.24 SETUP

Sets up the default detector format, and prepares a channel for taking data.

Format:	`SETUP <channel>`
Channel:	The name of the CCD data acquisition channel to be used.
Examples :	`SETUP RED`
Comments:	The system will read the default detector format from the configuration database and set the detector up accordingly. The user will be informed when the set-up is complete. No exposures can be made until the channel has been set up by this command.

11.5.25 SKY

This is equivalent to the RUN command, but intended for sky exposures rather than observations of astronomical targets.

Format:	`SKY <channel> <time> ["<string>"]`
Channel:	The name of the CCD data acquisition channel to be used.
Time:	The exposure time in seconds
Title:	A title for the observation (optional)
Examples :	`SKY TAURUS 1.5 TITLE="Twilight flatfield; B filter"`
Comments:	As for the RUN command, except that the observation type is set in the headers as being a sky flat field.

11.5.26 SLOUCH

Sets the CCD readout speed to STANDARD SPEED.

Format:	`SLOUCH <channel>`
Channel:	The name of the CCD data acquisition channel.
Example:	`SLOUCH RED`
Synonym:	`READOUT_SPEED SLOUCH`
Comments:	This sets the CCD to its standard readout mode, used for normal observing.

11.5.27 SPEEDY

Sets the CCD readout speed to QUICK SPEED.

Format: `SPEEDY <channel>`
Channel: The name of the CCD data acquisition channel.
Example: `SPEEDY RED`
Synonym: `READOUT_SPEED SPEEDY`
Comments: This sets the CCD to its fast readout mode, usually only used for setting up. The penalty of the fast readout is a slightly higher readout noise. The bias and gain of the CCD will also change.

11.5.28 WINDOW

Windows a CCD detector

Format: `WINDOW <channel>`
Channel: The name of the CCD data acquisition channel to be windowed.
Examples : `WINDOW BLUE`
Comments: The system will prompt the user for the number of windows to be set-up, and the origin and size of each window. Windowing and binning of the CCD will be enabled. **At present use of more than one window on a CCD is not recommended.**

11.5.29 WINK

Takes a scratch exposure as for the SCRATCH command, except that no headers are collected.

Format: `WINK <channel> <filenum> <obstype> <time> [TITLE="string"]`
Channel: The name of the CCD data acquisition channel to be used.
Filenum: The number of the scratch file
Obstype: The observation type. Valid observation types are ARC, BIAS, DARK, FLAT, and TARGET.
Time: The exposure time in seconds
Title: A title for the observation (optional)
Examples : `WINK RED 5 ARC 60`
Comments: As for the SCRATCH command, except that no headers are collected.

11.6 Data Taking Commands - IPCS detector

11.6.1 EXPOSE

Starts an exposure on a specified detector.

Format: `EXPOSE <detectorname> <exposuretime>`
Example: `EXPOSE IPCS 1000`
Synonym: `EI` (≡ `EXPOSE IPCS`)
Units: Seconds.
Comments: If the previous exposure has not been kept EXPOSE will prompt the user to do this, but EXPOSE will store the data only in the DMS, not in a disc file. EXPOSE IPCS does not open the shutter at the start of the exposure, nor close it at the end; this must be done explicitly.

11.6.2 EXPOSENP

Starts an exposure on a specified detector without collecting the archive packets.

Format: `EXPOSENP <detectorname> <exposuretime>`

Example: `EXPOSENP IPCS 1000`

Synonym: `ENPI` (≡ `EXPOSE IPCS`)

Units: Seconds.

Comments: This command works as expose, but does not collect archive packets. This saves time if you do no expect to KEEP the data. However if you run KEEP after EXPOSENP then KEEP will collect the archive packets.

11.6.3 IPCONT

Continues a paused IPCS exposure.

Format: `IPCONT`

Comments: To continue an exposure paused by `IPPAUSE`

11.6.4 IPCSCLOSE

Closes the IPCS shutter.

Format: `IPCSCLOSE`

Synonym: `IPC`

11.6.5 IPCSFORMAT

Sets up the data window and resolution parameters for taking IPCS data.

Format: `IPCSFORMAT`

Comments: This is an interactive procedure which prompts for the parameters required to set up the IPCS and the DMS for a given data format. Briefly these are:-

- Number of CCD rows (the spatial direction) read out (NROWS). This must be in the range 64 to 256.
- Start row on CCD. This must be chosen so that the entire region read out is on the chip.
- Number of CCD rows read into buffer. This should not exceed (NROWS – 7), and may not exceed 255.
- Spatial resolution factor along the slit. This can be 1 (coarsest resolution), 2, 4, or 8.
- Number of CCD pixels read into the buffer in the spectral direction. This may not exceed 320.
- Resolution factor in the spectral direction. This can be 1, 2, 4 or 8; and is normally 8.

The procedure sets the start of the CCD window in the spectral direction to pixel 30, to avoid the unthinned region of the CCD. For details of how to adjust this, and for details of how to set up more complicated windows, refer to Chapter 4 of the *IPCS-II Users' Manual.*

11.6.6 IPCSOPEN

Opens the IPCS shutter.

Format: `IPCSOPEN`
Synonym: `IPO`
Comments: Please watch the raw video display when the shutter is opened.

11.6.7 IPCSSDC

To set the IPCS format up in a way suitable for calculating the S-distortion correction.

Format: `IPCSSDC`
Comments: Sets up an IPCS window at full resolution in both directions, centred in Y on the part on the chip on which the image of the narrow dekker will fall.

11.6.8 IPNEWT

Changes the exposure time for an IPCS exposure.

Format: `IPNEWT <newexposuretime>`
Example: `IPNEWT 2400`
Units: Seconds.
Comments: The new time should be greater than the exposed time so far.

11.6.9 IPPAUSE

Pauses an IPCS exposure.

Format: `IPPAUSE`
Comments: Pauses data collection during an IPCS exposure, but does not close the shutter.

11.6.10 IPSTOP

Stops an IPCS exposure.

Format: `IPSTOP`
Comments: The data in the DMS buffer may then be transferred to the Vax disc with `KEEP`, otherwise the disc file must be closed with `CLOSE`. Does not close the IPCS shutter.

11.6.11 IPUPDATE

Updates the IPCS exposed time on the MIMIC display.

Format: `IPUPDATE`
Comments: Causes the IPCS exposes time to update on the MIMIC display, if for some reason it is not doing so.

11.6.12 KEEP

Transfers a data frame from the DMS buffer to the Vax 4000 Data disc.

Format: `KEEP <detectorname>`
Example: `KEEP IPCS`
Synonym: `KI` (≡ `KEEP IPCS`)

Comments: Transfers the data to a disc file in the directory DCT_OBSDIR: on the Vax 4000. The disc file will be given a name which consists of a file number, which is sequential, and the name of the DMS buffer that the data came from.

11.6.13 CLEAR_OVERILLUM

Clears the Overillumination status.

Format: `CLEAR_OVERILLUM`

Comments: An overillumination trip closes the shutter and will not allow the user to open it until the overillumination status has been cleared. It is important for the user to establish why the overillumination condition occurred, and to ensure that it will not happen again, before issuing this command.

11.6.14 OVERSCAN

Sets the area of the CCD read out to be the whole area of the chip.

Format: `OVERSCAN`

Comments: This ensures the whole of the CCD is read out, but unlike the overscan switch on the INT IPCS it does not scan the whole of the output of the EMI image tube, there is no way of doing this. Beware of possible bright light sources off the edge of the chip. After using this command it will be necessary to set up the observing window again with `IPCSFORMAT`.

11.6.15 STANDBY

Runs the IPCS EHT down slowly.

Format: `STANDBY`

Comments: This is equivalent to setting the rotary switch on the IPCS cubicle on the telescope to "STANDBY" and pressing the "LOAD" button. In either case it is important to verify that the IPCS EHT has in fact run down, by checking the EHT supply on the telescope or the raw video display, before switching any lights on in the dome.

11.7 Other DMS Commands

11.7.1 DMS_ABORT_READ

Aborts a readout from a detector to the DMS.

Format: `DMS_ABORT_READ <buffername>`

Example: `DMS_ABORT_READ ISISCCD1`

Comments: The buffername must be specified, not the detector name; valid values are ISISCCD1 and FOS. Only to be used in exceptional circumstances.

11.7.2 DMS_ABORT_TRANS

Aborts a data transfer from the DMS to the system computer.

Format: `DMS_ABORT_TRANS SYS`

11.7.3 DMS_CLEAR_BUFF

Clears the DMS buffer for a particular detector.
Format: `DMS_CLEAR_BUFF <buffername>`
Example: `DMS_CLEAR_BUFF IPCS`
Comments: Valid parameters are: ISISCCD1; FOS and IPCS.

11.7.4 DMS_CLOSE_BUFF

Closes all DMS buffers.
Format: `DMS_CLOSE_BUFF`

11.7.5 DMS_MONITOR

Switches DMS monitor mode on or off.
Format: DMS_MONITOR <onoroff>
Example: DMS_MONITOR ON
Comments: Can be used to start the IPCS exposure time updating if it is not doing so.

11.7.6 DMS_RESET

Software reset of the DMS.
Format: `DMS_RESET`

11.7.7 DMS_START

Reads the status of the DMS into the system computer.
Format: `DMS_START`

11.8 MIMIC Commands

11.8.1 MIMIC PAGES

Lists the names of the available MIMIC pages.
Format: `MIMIC PAGES`
Comments: Pages can then be selected using `SCREEN`.

11.8.2 MIMIC UPDATE

Refreshes the screen if it appears to have become out of date.
Format: `MIMIC UPDATE`

11.8.3 MIMIC_START

Starts up the MIMIC.
Format: `MIMIC_START`
Comments: An interactive procedure to start up the MIMIC. Will prompt for the node name of the Vaxstation to run it on.

11.8.4 MIMIC_STOP

Closed down the MIMIC.
Format: `MIMIC_STOP`

11.8.5 SCREEN

Selects a MIMIC screen.
Format: `SCREEN <screenname>`
Example: `SCREEN ISIS`
Comments: Selects a screen from the list given by `MIMIC PAGES`. This is usually only used if there is a fault with the mouse on the Vaxstation.

12 DCL Level Commands for the Vax 4000

These commands can be issued on the Vax 4000 when logged in as OBSERVER, and with default directory U1:[OBSERVER]. They can either be issued in a separate session, from the $ prompt, or from the ICL interface by typing:-
`DCL <COMMAND> [<parameters>]`

12.1 Tape Writing Commands

Tapes can be written in two formats, FITS format or as a VMS backup of the data files. Two tapes are normally written: the D-tape or archive tape, which must be in FITS format; and the C-tape or copy tape, which can either be a direct copy of the D-tape, or a tape written by the observer in the format of his choice. The VMS Backup utility is described in detail in the DEC manual set, this section will describe the commands required to produce FITS tapes.

12.1.1 FITSINIT

To initialise a new FITS tape.
Format: `FITSINIT`
Comments: The program requires the tape to be mounted on a tape drive on the one of the Vaxes , normally tape drive MUC1:. It prompts for the name of the tape user and owner. It should only be used for new tapes.

12.1.2 WRITE_FITS

To write data files to a fits tape.
Format: `WRITE_FITS`
Comments: The program requires the tape to be mounted on a tape drive on one of the Vaxes, normally tape drive MUC1:. If it is a new tape then `FITSINIT` must be run first. The program prompts for the numbers of the first and last files to be written to tape. The program will search for files with these numbers on the WHT data disc (DISK$WHTDATA:), and write them as FITS files to the specified tape. There is no problem if a file in the sequence is missing. If WRITE_FITS is run to a tape

which already has Fits files on it, the program will search for the end of the tape before starting to write, i.e. it will not overwrite existing files *unless* a FITSINIT is issued.

13 Local Subsystem Commands

13.1 Autoguider Commands

13.1.1 ?NET

Checks what devices are accessible across the network from the autoguider.

Format: `?NET`

Comments: Sends a message to each device in turn across the network and waits for an acknowledgement. Logs which devices acknowledge and which do not. Useful for diagnosing network problems.

13.1.2 ACQINT

Changes the integration time when in acquisition mode.

Format: `ACQINT <integrationtime>`

Example: `ACQINT 8000`

Units: Milliseconds.

13.1.3 ACQWIND

Specifies the acquisition window for the Autoguider.

Format: `<x1> <y1> <x2> <y2> ACQWIND`

Example: `50 50 300 200 ACQWIND`

Defaults: x1=30, y1=30, x2=360, y2=250

Comments: Sets the acquisition field on the Autoguider CCD in pixels.

13.1.4 CASS

Selects the Cassegrain Autoguider.

Format: `CASS`

Comments: There are also commands to select other autoguiders, including `UES`, `PRIME`, and `AUTOFIB`.

13.1.5 FIELD

Scans the field searching for guide stars.

Format: `<nstar> FIELD`

Example: `1 FIELD`

Comments: Causes the CCD autoguider to read out and search for guide stars, marking the `nstar`th brightest star in the field to use as a guide star. nstar defaults to 1, `FIELD` is equivalent to `1 FIELD`.

13.1.6 GUIDE

Starts the Autoguider tracking a star or stops it.

Format: `GUIDE ON <n> or GUIDE OFF`
Example: `GUIDE ON 1`
Comments: Starts or stops the Autoguider following a guide star. n specifies the rank of the guide star in order of brightness, and defaults to 1.

13.1.7 GUIINT

Changes the integration time when in guiding mode.

Format: `GUIINT <integrationtime>`
Example: `GUIINT 4000`
Units: Milliseconds.

13.1.8 GUILOOPS

Changes the number of integrations over which the autoguider averages before sending an error signal to the Vax.

Format: `GUILOOPS <nloop>`
Example: `GUILOOPS 5`
Default: nloops=1

13.1.9 GUISIZE

Changes the size of the guiding box.

Format: `GUISIZE <npixels>`
Example: `GUISIZE 30`
Default: npixels=15
Comments: This can be used to increase the size of the guiding box in bad seeing conditions.

13.1.10 GUIWIND

Sets the position of the guiding box in CCD pixels

Format: `GUIWIND <x> <y>`
Example: `GUIWIND 150 224`
Defaults: X and Y default to the position of the currently selected star.
Comments: This can be used to reacquire the guide star when the telescope is moved by an accurately known amount, or to start guiding at a predetermined position.

13.1.11 SHUT–DOWN

Shuts down the Autoguider and warms the chip up.

Format: `SHUT-DOWN`
Comments: Starts a shut down sequence for the Autoguider by warming the CCD chip up above 0°C. This process takes about 5 minutes and the observer should check that it works.

13.1.12 START–UP

Starts up the Autoguider.

Format: `START-UP`

Comments: Starts up the Autoguider by turning on the nitrogen flushing and cooling the chip to around -30°C. If in any doubt the observer should verify by checking the flowmeter attached to the outlet that the nitrogen flow has indeed been turned on.

13.1.13 STATS

Causes a statistics summary for the current guiding run to be displayed on the autoguider display screen. This display includes mean and standard deviation of the seeing and transparency values, which are useful for assessment of the weather conditions.

Format: `STATS`

Comments: This command appears not to work at present!

13.1.14 STEMP

Sets the target temperature for the autoguider chip.

Format: STEMP <temperature>

Example: `STEMP -25`

Units: Degrees C.

13.1.15 TEMP

Causes the temperature on the autoguider display to be updated.

Format: `TEMP`

13.2 DMS commands

The DMS has many functions, in addition to those provided by the user interface (the mouse). Those described here are useful for setting up the detectors; for diagnostic information when something goes wrong; or for taking and temporary storage of data if the Vax 4000, or the parallel link between the Vax 4000 and the DMS, is not available.

13.2.1 ?IMAGES

Lists the image files available on the DMS disc.

Format: `?IMAGES`

Commets: Lists the named images on the DMS disc available for temporary storage of data. Images of three formats exist, full format for large and small CCDs and 2560 by 200 for IPCS data. Only images of these formats can be stored in these files.

13.2.2 ?NET

Checks what devices are accessible across the network from the DMS

Format: `?NET`

Example: `?NET`

Comments: Sends a message to each device in turn across the network and waits for an acknowledgement. Logs which devices acknowledge and which do not. Useful for diagnosing network problems.

13.2.3 ?REGS

Displays the contents of several DMS registers.

Format: `?REGS`

Comments: Displays the contents of several DMS registers. Of particular interest are registers 2 and 5, which contain the number of pixels the DMS is expecting from FOS/GEC5 and EEV2 respectively. Useful for diagnostic purposes if it is suspected that a CCD readout might have hung, or some pixels might have been lost

13.2.4 .IS

Lists the items on the image stack and their dimensions.

Format: `.IS`

13.2.5 CALC–SDC

Calculates an IPCS S-distortion correction.

Format: `CALC-SDC`

Comments: Calculates the IPCS S-distortion correction from a suitable frame in the IPCS buffer of the DMS. The frame should be a well exposed image of a continuum source such as a tungsten lamp, through a narrow dekker, and obtained with X and Y resolution factors of 8.

13.2.6 CLO

Closes all image buffers.

Format: `CLO`

13.2.7 CRECALL

Transfers data from a named file on the DMS disc and displays it in the EEV2 image buffer.

Format: `CRECALL <filename>`

Example: `CRECALL EEV01`

Comments: The file must have dimensions 800 by 1180 pixels. Once a file has been placed in the buffer it can be transferred to the Vax 4000 disc with `KEEP RED`. If the icon for this buffer is not displayed when this is done it will be necessary to run `RECOVER-DATA`.

13.2.8 DEV?

Lists the image buffers which are open.

Format: `DEV?`

Comments: Used to check whether the image buffers have the correct format.

13.2.9 DEV>STK

Makes the top item of the DMS stack equivalent to a particular data buffer.

Format: `<buffernumber> DEV>STK`

Example: `2 DEV>STK`

Comments: Valid values of *buffernumber* are 1 (for the FOS/GEC5 buffer); 2 (for the EEV2 buffer) and 4 (for the IPCS buffer). This command is useful when data transfer to the Vax 4000 is not possible, as data from the top of the stack can be stored on the DMS disc with `PUT-FILE`. The command assigns pointers, and it is not necessary to repeat each time a new frame is read into the buffer, this frame will automatically become the top item on the stack.

13.2.10 E–STK

Erases the image stack if it has become full.

Format: `E-STK`

13.2.11 ERUN

Opens an image buffer for EEV2 CCD data

Format: `ERUN`

Comments: The buffer is 800 by 1180 pixels, and can be used to store data from a full frame readout.

13.2.12 ESD

Enables or disables the IPCS S-distortion correction.

Format: `<n> ESD`

Example: `1 ESD`

Comments: Enables or disables the S-distortion correction: 1 to enable and 0 to disable.

13.2.13 FOCUS

Select spectral lines for Hartmann focus test.

Format: `FOCUS`

Comments: Allows the user to select three spectral lines from a two dimensional image (either IPCS or CCD) for use when focussing with the Hartmann shutters and the DMS analysis routines. Plots a cut through each line after selection, allows the user to accept or reject that line.

13.2.14 FOCUS–LEFT

Analyses an exposure taken with the left Hartmann shutter open and the right closed.

Format: `FOCUS-LEFT`

Comments: For each line selected by `FOCUS` or `FOCUS-SET` it calculates the centroid and FWHM of the line at three points along it.

13.2.15 FOCUS–RIGHT

Analyses an exposure taken with the right Hartmann shutter open and the left closed.

Format: `FOCUS-RIGHT`

Comments: For each line selected by `FOCUS` or `FOCUS-SET` it calculates the centroid and FWHM of the line at three points along it, and the shift relative to the last time `FOCUS-LEFT` was run.

13.2.16 FOCUS–SET

Allows the user to type in the position of lines for use by FOCUS-LEFT and FOCUS-RIGHT.

Format: `FOCUS-SET`

Comments: Prompts the user for the positions of three lines for use by `FOCUS-LEFT` and `FOCUS-RIGHT`, as an alternative to interactive selection with `FOCUS`.

13.2.17 FRECALL

Transfers data from a named file on the DMS disc and displays it in the FOS/GEC5 image buffer.

Format: `FRECALL <filename>`

Example: `FRECALL GEC01`

Comments: The file must have dimensions 400 by 590 pixels. Once a file has been placed in the buffer it can be transferred to the Vax 4000 disc with `KEEP FOS`. If the icon for this buffer is not displayed when this is done it will be necessary to run `RECOVER-DATA`.

13.2.18 GET–FILE

Transfers data from a named file on the DMS disc to the top of the DMS stack.

Format: `GET-FILE <filename>`

Example: `GET-FILE GEC01`

Comments: Files and their dimensions can be listed on the terminal with `?IMAGES`.

13.2.19 GET–SDC–ARRAY

Recalls an S-distortion correction from the DMS disc.

Format: GET-SDC-ARRAY

Comments: Recalls an S-distortion correction from disc, and also outputs details of the correction to the terminal.

13.2.20 GRUN

Opens an image buffer for GEC5/FOS CCD data.

Format: `GRUN`

Comments: The buffer is 400 by 590 pixels, and can be used to store data from a full frame readout.

13.2.21 IRECALL

Transfers data from a named file on the DMS disc and displays it in the IPCS image buffer.

Format: `IRECALL <filename>`

Example: `IRECALL IPCS01`

Comments: The file must have dimensions 2560 by 200 pixels. Once a file has been placed in the buffer it can be transferred to the Vax 4000 disc with `KEEP IPCS`.

13.2.22 IRUN

Opens an image buffer for IPCS data.

Format: `IRUN`

Comments: The buffer is 2560 by 200 pixels.

13.2.23 LOAD–SDC

Transfers an S-distortion correction from the DMS to the IPCS Image Processing Chassis.

Format: `LOAD-SDC`

13.2.24 PUT–FILE

Transfers data from the top item of the DMS stack to a named file on the DMS disc.

Format: `PUT-FILE <filename>`

Example: `PUT-FILE GEC01`

Comments: Transfers data to a named file which already exists. Files and their dimensions can be listed on the terminal with `?IMAGES`. The stack area must have the same dimensions as the named file, the stack area dimensions can be listed with `.IS`.

13.2.25 PUT–SDC–ARRAY

Stores an S-distortion correction on the DMS disc.

Format: PUT-SDC-ARRAY

Comments: Stores an S-distortion correction on disc, and also outputs details of the correction to the terminal.

13.2.26 RECOVER

Initialises the DMS display.

Format: `RECOVER`

Synonym: `START-DISPLAY`

Comments: This can be used if the display hangs up or if the lookup table or cursor position appear to be corrupted. It can sometimes, but not usually, recover from the Opal board crash, when the display screen goes blue. It does not affect the data.

13.2.27 RECOVER–DATA

To ensure that data stored in the DMS is ok after a hardware reset.

Format: `RECOVER-DATA`

Comments: After a hardware reset of the DMS this procedure will ask the user if valid data is present in the three DMS image buffers (FOS, EEV, and IPCS), and if it is will display that data on the DMS screen.

13.2.28 SEX

Sets the IPCS integration time.

Format: `<exposuretime> SEX`

Example: `1000000 SEX`

Units: Milliseconds.

Comments: This sets the IPCS exposure time but does not begin the integration, which must be done with 0 TIM.

13.2.29 TIM

To begin an IPCS integration.

Format: `0 TIM`

Comments: Begins an IPCS exposure for the time set by `SEX`.

13.2.30 TIMES

Displays IPCS integration timing information.

Format: `TIMES`

13.2.31 X–FIND

Calculates position and FWHM in the X direction.

Format: `X-FIND`

Comments: Allows the user to select a pixel with the cursor, then takes a cross section in X centred on that pixel, and calculates the location and FWHM of a peak assumed to be situated there.

13.2.32 Y–FIND

Calculates position and FWHM in the Y direction.

Format: `Y-FIND`

Comments: Allows the user to select a pixel with the cursor, then takes a cross section in Y centred on that pixel, and calculates the location and FWHM of a peak assumed to be situated there.

13.2.33 ZM

Allows the zoomed area on the buffer 3 (EEV3) image display to be moved.

Format: `ZM`

Comments: Allows the user to move the zoomed area around in the buffer 3 image. The rectangle can be moved with the mouse, pressing [SELECT1] on the mouse changes the zoomed area to the current area of the rectangle. Pressing the return key exits from ZM.

13.3 CCD controller commands

13.3.1 ?OPEN .

Interrogates a CCD shutter to see whether it is open.

Format: `?OPEN .`

Comments: If the response is -1 then the shutter is open; if it is 0 then the shutter is closed. Other responses indicate a problem with the shutter.

13.3.2 1P

Commands after this refer to Physical Head 1.

Format: `1P`

Comments: After issuing this command further CCD commands will affect Physical Head 1, until this is changed by issuing `2P`. Commands that require the correct Physical Head to be set include: `OPEN`; `CLOSE`; `UNJAM`; `RED`; `PIC` and `CLR`. Consult RGO technical staff to find out which Physical head number refers to the CCD you are using.

13.3.3 2P

Commands after this refer to Physical Head 2

Format: `2P`

Comments: After issuing this command further CCD commands will affect Physical Head 2, until this is changed by issuing `1P`. Commands that require the correct Physical Head to be set include: `OPEN`; `CLOSE`; `UNJAM`; `RED`; `PIC` and `CLR`.

13.3.4 1V

Commands after this refer to Virtual Head 1.

Format: `1V`

Comments: After issuing this command further CCD commands will affect Virtual Head 1, until this is changed by issuing `2V`. Commands that require the correct Virtual Head to be set include: `QUICK SPEED`; `STANDARD SPEED`; `CONFIG`; `RED`; `PIC`; `CLR` and local binning and windowing commands. Consult RGO technical staff to find out which Virtual head number refers to the CCD you are using.

13.3.5 2V

Commands after this refer to Virtual Head 2

Format: `2V`

Comments: After issuing this command further CCD commands will affect Virtual Head 2, until this is changed by issuing `1V`. Commands that require the correct Virtual Head to be set include: `QUICK SPEED`; `STANDARD SPEED`; `CONFIG`; `RED`; `PIC`; `CLR` and local binning and windowing commands. Consult RGO technical staff to find out which Virtual head number refers to the CCD you are using.

13.3.6 CLOSE

Closes a CCD shutter.

Format: `CLOSE`

13.3.7 CLR

Clears a CCD.

Format: `CLR`

Comments: **This command currently only works from the Network vocabulary, invoked by typing** `NETWORK`.

13.3.8 NETWORK

Invokes the Network vocabulary.

Format: `NETWORK`

13.3.9 OPEN

Opens a CCD shutter.

Format: `OPEN`

13.3.10 PIC

Takes an exposure and reads it out.

Format: `<headnumber> 0 PIC`

Comments: Local command to clear the chip, take an exposure of an exposure time previously set up with the `SEX` command, and read the chip out. A buffer must have been set up in the DMS to receive the data. The first parameter is the head number and is 1 or 2. The second parameter can be used to delay the start time. **This command currently only works from the Network vocabulary, invoked by typing** `NETWORK`.

13.3.11 QUICK SPEED

Changes the readout rate to the faster (and higher noise) of the two allowed values.

Format: `QUICK SPEED`

Comments: This provides a quicker readout of the CCD, and hence less dead time between exposures, together with a slightly higher dynamic range, at the expense of somewhat higher readout noise. If you wish to run the CCD in this mode you must issue this command after every hard or soft reset of the CCD controller. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type `>CCDn`, where n is 1, 2, 3 or 4 and denotes the network address of the CCD in question; then type `SPEEDY`.

13.3.12 REBOOT

Software reset of the CCD controller.

Format: `REBOOT`

13.3.13 RED

Reads out a CCD.

Format: `RED`

Comments: Reads out a CCD into an existing DMS buffer. Useful in diagnosing CCD problems. **This command currently only works from the Network vocabulary, invoked by typing `NETWORK`.**

13.3.14 SET-TIME

Sets the internal clock of the CCD controller.

Format: `<HH:MM:SS> SET-TIME`

Example: `14:28:00 SET-TIME`

Comments: This affects the time stamp which will appear in the headers of CCD exposures. If accurate times are required this should be reset every night. **Currently the seconds must be zero.**

13.3.15 SET-DATE

Sets the date for the internal clock of the CCD controller.

Format: `<dd:mm:yy> SET-DATE`

Example: `01:10:93 SET-DATE`

Comments: This affects the date recorded in the headers of CCD exposures.

13.3.16 SEX

Sets exposure time.

Format: `<headnumber> <exposuretime> SEX`

Example: `1 10000 SEX`

Units: Milliseconds.

Comments: Local command to set exposure time. The first parameter is the CCD head number, and is 1 or 2. **This command currently only works from the Network vocabulary, invoked by typing `NETWORK`.**

13.3.17 STANDARD SPEED

Changes the readout rate to the slower (and lower noise) of the two allowed values.

Format: `STANDARD SPEED`

Comments: This resets the readout speed of the CCD back to the default (slower) speed, with reduced readout noise. This command is only available from the VHT vocabulary, if it appears not to work type `VHT` then try again. This instruction can also be issued over the network from the DMS terminal, to do this type >`CCDn`, where n is 1, 2, 3 or 4 and denotes the network address of the CCD in question; then type `SLOUCH`.

13.3.18 T–STAT

Displays the temperature of the CCD chip in the current physical head.

Format: `T-STAT`

13.3.19 T–SHOW

Displays temperature information for both Physical heads.

Format: `T--SHOW`

13.3.20 TELE

Displays telemetry from a CCD controller.

Format: `<headnumber> TELE`

Example: `2 TELE`

Comments: Displays voltages and currents from the CCD controller, with their nominal values. This is useful for diagnosing faults with CCDs and controllers.

13.3.21 UNJAM

Unjams a CCD shutter which is stuck.

Format: `UNJAM`

Comments: This is the first thing to try if a CCD shutter appears to stick. Issuing the `UNJAM` command may free the shutter, this can be checked with the `OPEN` and `CLOSE` `commands`

13.3.22 VHT CONFIG

Displays the virtual head table configuration of a CCD controller.

Format: `VHT CONFIG`

Comments: This is actually two commands: VHT selects the Virtual Head Table and CONFIG displays the configuration. This command is useful because along with the windowing and binning information it also displays the readout speed (Quick or Standard) selected. This information is not available on the Vax Mimic. The correct Virtual head must be selected (with 0V or 1V) before this command is issued.

13.4 The Engineering MIMIC

The Engineering MIMIC can be used to display the status of ISIS and the A&G box in rather more detail than is provided by the Vax MIMIC. Command can also be issued to move mechanisms in and device which is on the network, most commonly ISIS and the A&G box. These commands consist of a Mnemonic which identifies the device to be operated on, a number which identifies what operation is to be carried out on the mechanism (move, initialise, status request or reprogram), and if appropriate (i.e. in the case of moving a mechanism) a demanded position in parentheses. Details of these commands, and how to issue them from the Engineering MIMIC terminal, are given in "The Engineering Mimic", a loosely bound document with a pale green cover, which is usually to be found near the engineering MIMIC terminal.

14 The DMS User Interface

The Detector Memory System has a mouse driven user interface which provides the user with some data assessment facilities. The mouse has three buttons and is moved around on a reflecting pad. The mouse drives a cursor on the screen which is in the form of a cross. The cursor can be moved anywhere on the screen. The screen consists of an image display area and a menu area; the menu area appears in the top right hand corner of the screen. When CCD data is displayed there are also one or more "icons", small CCD images, these enable the user to switch between CCD buffers displayed in the main display area.

14.1 Use of the Mouse

Moving the mouse on the reflective pad moves the cursor anywhere on the screen including the menu area, the icons, and the image area. The mouse has three buttons, which are designated SELECT1 (the left hand key); SELECT2 (the centre key); and ESCAPE (the right hand key). SELECT1 is used to select a function or to perform an operation; SELECT2 is only used in those instances where two functions can be performed from a single menu option (such as increasing or decreasing the contrast); and ESCAPE is used to return to the menu from an option, or to return to the main menu from another menu.

14.2 The Menu Structure

14.2.1 The Main Menu

The Main Menu enables the user to select any of the other available menus, and the ZOOM function. Any item can be selected by placing the cursor on the menu name, and pressing SELECT1. The options are:-

- **PREFERENCES** - this menu has not been implemented and trying to select it will have no effect.
- **DISPLAY** - Selecting this menu gives various options for changing the contrast and lookup table of the image displayed in the image display area.
- **ZOOM** - This does not select a menu, but is an option. After selecting the ZOOM option with SELECT1, pressing SELECT1 again zooms in, while SELECT2 zooms out. Moving

the mouse on the keypad while the display is zoomed moves the cursor in the image in the same sense as the mouse is being moved on the pad, while attempting to keep the cursor in the centre of the screen. This results in the image moving on the screen in the opposite sense to that in which the mouse is being moved, with some timelag. ESCAPE returns the display to normal (i.e. not zoomed), and returns the user to the Main menu.

- **STATISTICS** - Selecting this menu gives various options for defining windows in the data area, and for statistical operations on the data within these windows.
- **WINDOWS** - This menu gives options for defining windows on the DMS screen, but is not currently used.
- **3D MODES** - This menu gives options for examining three dimensional data arrays. These are not useful for any of the ISIS data acquisition modes implemented to date.
- **SCREENS** - This menu allows the user to select between types of data (i.e. CCD or IPCS), and will in future be used to select between display formats.

14.2.2 The Display Menu

The display menu allows the user to choose between lookup tables and to change the contrast of the display. There are two lookup tables, a colour table and a greyscale. When driven from the Mouse interface, the chosen table always covers a range between 0 and 2^n, where n is in the range 1 to 16. However the display wraps around, so the full range of allowed data values (0 to 65535) is covered by $2^{(16-n)}$ wraps of the lookup table.

The following options can be selected by placing the cursor on the option name on the display menu and pressing SELECT1 :–

- **GREY** - Selects the Greyscale lookup table and leaves the user in the Display menu.
- **COLOUR** - Selects the Colour lookup table and leaves the user in the Display menu.
- **REVERSE** - Reverses the lookup table and leaves the user in the Display menu.
- **SHIFT** - After selecting this option with SELECT1, pressing SELECT1 again increases the contrast of the display, i.e. reduces the range that one wrap of the lookup table covers, by a factor of two. SELECT2 decreases the contrast of the display, i.e. increases the range that one wrap of the lookup table covers, by a factor two. ESCAPE returns the user to the Display menu, leaving the lookup table as it was last set.
- **NORMAL** -

14.2.3 The Statistics Menu

The Statistics menu allows the user to define windows and perform statistical operations on data within these windows. These include cross sections in X and Y, made by collapsing a window onto the X or Y axis. These functions perform differently depending upon whether they are operating on IPCS data or CCD data, for IPCS data they sum the data in the perpendicular direction, whereas for CCD data they average them. This difference must be borne in mind when, for instance, estimating count rates per pixel for IPCS data, and estimating atmospheric transparency from a CCD spectrum of a spectrophotometric standard. At present only two windows are available for all data screens and all buffers, these remain in place until adjusted with the SET WINDOW options, even when the user switches between IPCS and CCD data. A future enhancement will provide separately defined windows for each data buffer.

With the X-CUT and Y-CUT functions it is possible to perform a preliminary sky subtraction. To do this Window 1 is placed on the object spectrum, and Window 2 on a suitable sky area. It is not necessary to make Window 2 exactly the same width as Window 1, as appropriate scaling is applied. It is not necessary to place Window 2 precisely in the spectral direction, as the limits in this direction of the sky region are changed to those of Window 1.

Options available from the Statistics menu are:-

- **SET WINDOW1** - After selecting this option with SELECT1 the user can adjust the size of Window 1 by moving the mouse on the reflective pad. After then pressing SELECT2 the user can adjust the position of the window by moving the mouse. The user can return to adjusting the size with SELECT1 and the position with SELECT2 as many times as necessary. ESCAPE returns to the Statistics menu.
- **SET WINDOW2** - This allows the user to adjust the size and position of Window 2, and the function of the keys is exactly the same as for SET WINDOW1.
- **CALCULATE** - This calculates, and displays near the bottom right hand corner of the display: the location and size in X and Y of the window selected with one of the SET WINDOW options or the WINDOW USE option; and the mean, maximum, minimum and standard deviation of all the pixel values within that window. It leaves the user in the Statistics menu.
- **PIXEL** - After selecting this function with SELECT1 the user can move the cursor around in the image display area, and read out individual pixel values with SELECT1. SELECT2 toggles between a zoomed and unzoomed display. ESCAPE returns to the unzoomed display and returns the user to the Statistics menu.
- **X-CUT** - This option collapses the selected window onto the X-axis, and plots the result. For IPCS data it sums the pixels in Y, and for CCD data it averages them. If the WINDOW1–WINDOW2 option is selected with WINDOW USE then the left and right boundaries of WINDOW2 will be changed to match those of WINDOW1, and the data from WINDOW2 will be scaled by the ratio of the window widths before subtraction. The plot will remain displayed until ESCAPE is pressed, when the user will be returned to the Statistics menu.
- **Y-CUT** - This option collapses the selected window onto the Y-axis, and plots the result. For IPCS data it sums the pixels in X, and for CCD data it averages them. If the WINDOW1–WINDOW2 option is selected with WINDOW USE then the upper and lower boundaries of WINDOW2 will be changed to match those of WINDOW1, and the data from WINDOW2 will be scaled by the ratio of the window widths before subtraction. The plot will remain displayed until ESCAPE is pressed, when the user will be returned to the Statistics menu.

- **Z-CUT** - This option is not applicable to any of the current ISIS data taking modes.
- **WINDOW USE** - This option selects the window to which X-CUT, Y-CUT or CALCULATE will be applied. After selecting this option with SELECT1 further presses of SELECT1 will cycle between: WINDOW1; WINDOW2; and WINDOW1–WINDOW2. The current selection is displayed just below the menu. ESCAPE returns the user to the Statistics menu.

14.2.4 The Screens Menu

The Screens menu allows the user to determine which data buffer is displayed in the image area, and how the data is displayed. In each case the mapping between the data buffer and the image display is such that the whole data buffer is displayed. For windowed CCD data the window is displayed in its correct position on the chip. For all CCD data the aspect ratio of the detector is preserved. Options, which can be selected with SELECT1, are:–

- **CCDS** - Data from one of the CCDs is displayed. Individual CCDs can be selected using the icons alongside the main display area.
- **IPCS 8:1** - This option has not been implemented.
- **IPCS 1:1** - The IPCS data buffer is selected. The whole display is not necessarily used in the vertical direction, and for the IPCS the pixels do not necessarily have the correct aspect ratio on the screen.

The remaining screens are not used for displaying ISIS data.

Part VII
APPENDICES

A Properties of the ISIS Gratings

In this appendix the properties of the ISIS gratings are presented in graphical form; the grating setting, slit to detector reduction factor, vignetting factor, and reciprocal dispersion (Å/mm) are presented as a function of wavelength for all red and blue gratings. For completeness graphs for both blaze-to-collimator and blaze-to-camera are presented, although only use of the former is recommended, and graphs for grating H2400B in the red arm are also presented, although this is not a particularly efficient combination. The explanation and the program used to generate the plots are due to C.R. Jenkins.

The grating equation is

$$\sin i - \sin r = \lambda/d$$

for a first-order spectrum. The camera-collimator angle in ISIS, θ, is nominally 40°, although the exact value will be slightly different for each channel.

$$i + r = \theta$$

(with appropriate sign conventions for i and r). Solving these two equations gives:

$$\sin i = \frac{\lambda}{d} \pm \frac{\sin\theta}{2(1+\cos\theta)}\sqrt{2(1+\cos\theta) - \frac{\lambda^2}{d^2}}$$

where the positive sign corresponds to the normal condition for ISIS, namely blaze to collimator. The grating *setting* for each channel is then given by multiplying i (in degrees) by 100 and adding an offset (which is the autocollimation angle for each grating mount). These offsets are 30800 for the blue channel and 35500 for the red. In solving for the grating setting, one has to check for the cases where the angle of incidence exceeds 90°, or where the discriminant becomes imaginary (corresponding to the wavelength where constructive interference cannot be achieved).

The reduction factor follows simply; it is:

$$\frac{\cos r}{\cos i}\frac{f_{coll}}{f_{cam}}$$

where f_{coll} is 1650 mm and f_{cam} is 500 mm.

The gratings in ISIS are 200 × 150 mm^2, and the cameras have sufficient aperture to accommodate the fully dilated 200 mm beam. Most of the vignetting (excluding refinements of matching central obstructions between camera and telescope pupil) occurs simply because light misses the grating at high angles of incidence. The fractional loss is:

$$v = \frac{2\psi - \sin 2\psi}{\pi}$$

where ψ is given by:

$$\cos\psi = 200/150\cos i$$

This internal vignetting only exceeds 1% for the 1200 and 2400 gratings.

The dispersion is given by:

$$\frac{\Delta\lambda}{\Delta s} = \frac{d\cos r}{f_{cam}}$$

B Grating and Detector Efficiencies

This appendix presents **laboratory** measurements of the efficiencies of the ISIS gratings and of the CCD and IPCS detectors in use on ISIS.

C Efficiency of Dichroics and Polarisation optics

This appendix presents laboratory measurements of the transmission properties of the five main ISIS dichroics, and measurements made using the comparison lamps on the spectrograph, of the efficiency of two reddest dichroics in both transmission and reflection. The final panel of this appendix shows the throughput of the polarization optics (half- and quarter-wave plates and the Savart plate) measured with the comparison lamps.

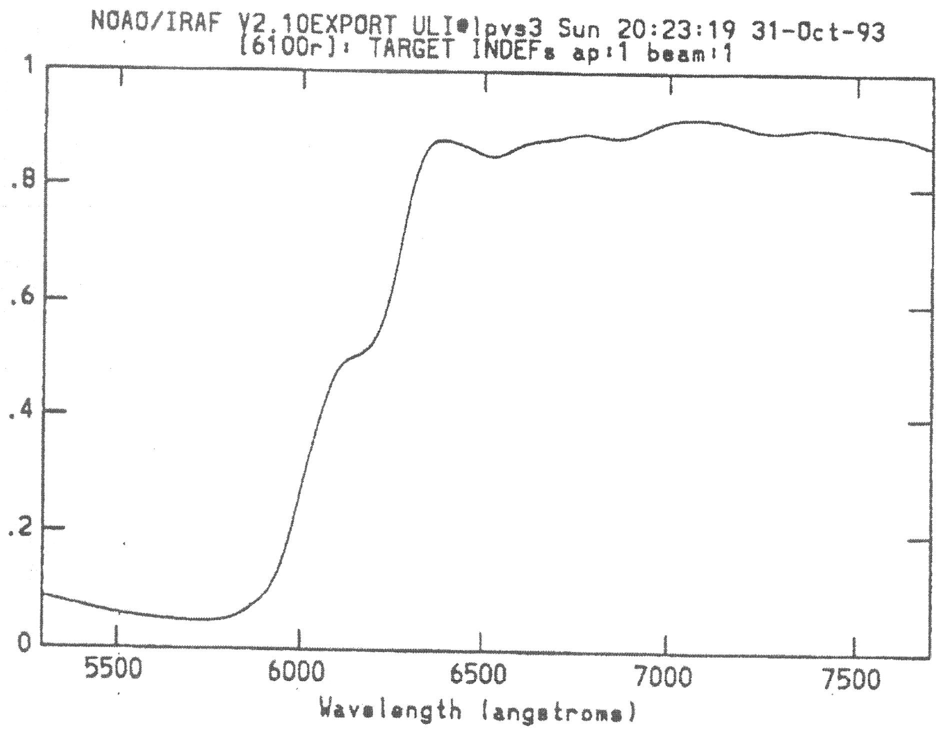

Figure 19: Transmission as a function of wavelength for the 6100Å dichroic

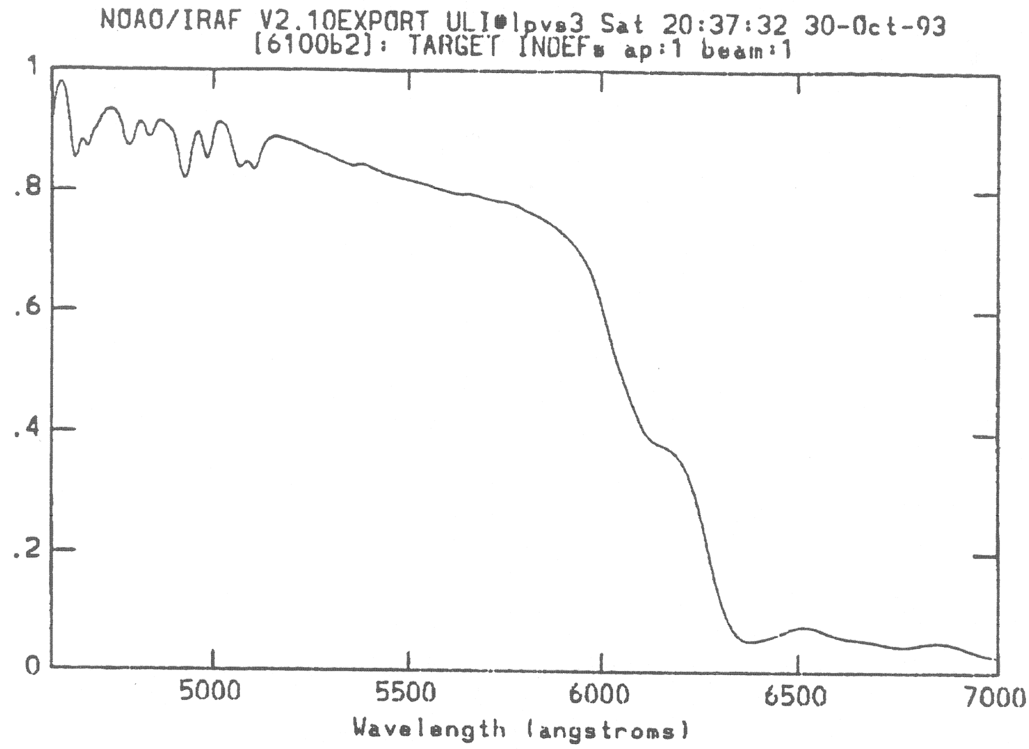

Figure 20: Reflectivity as a function of wavelength for the 6100Å dichroic

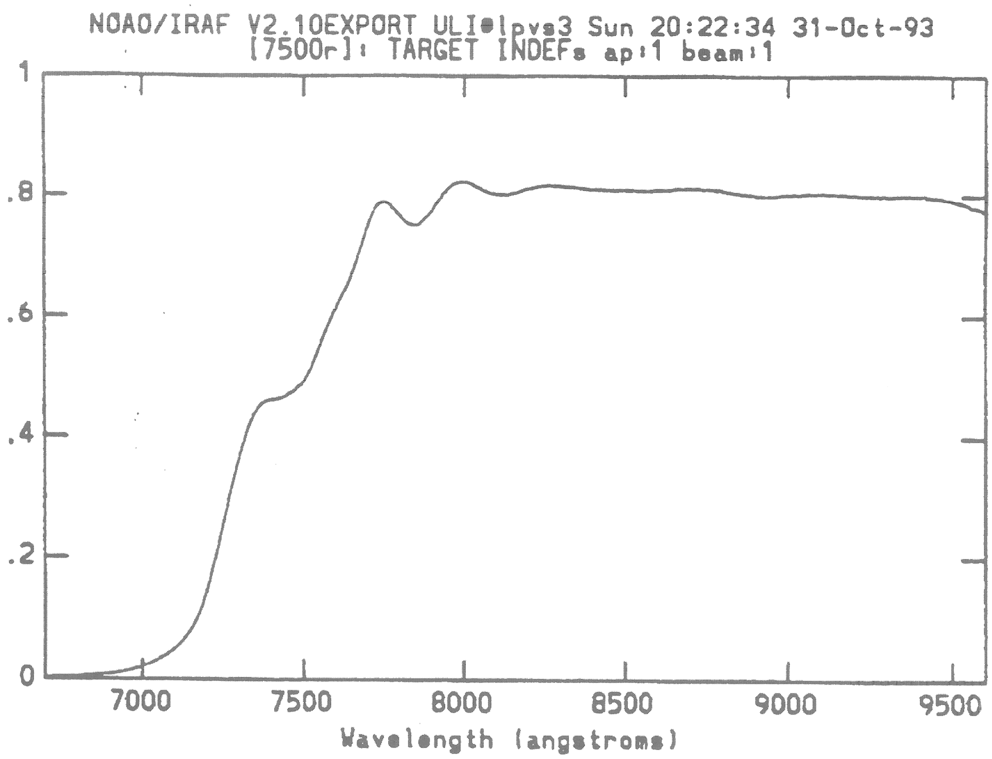

Figure 21: Transmission as a function of wavelength for the 7500Å dichroic

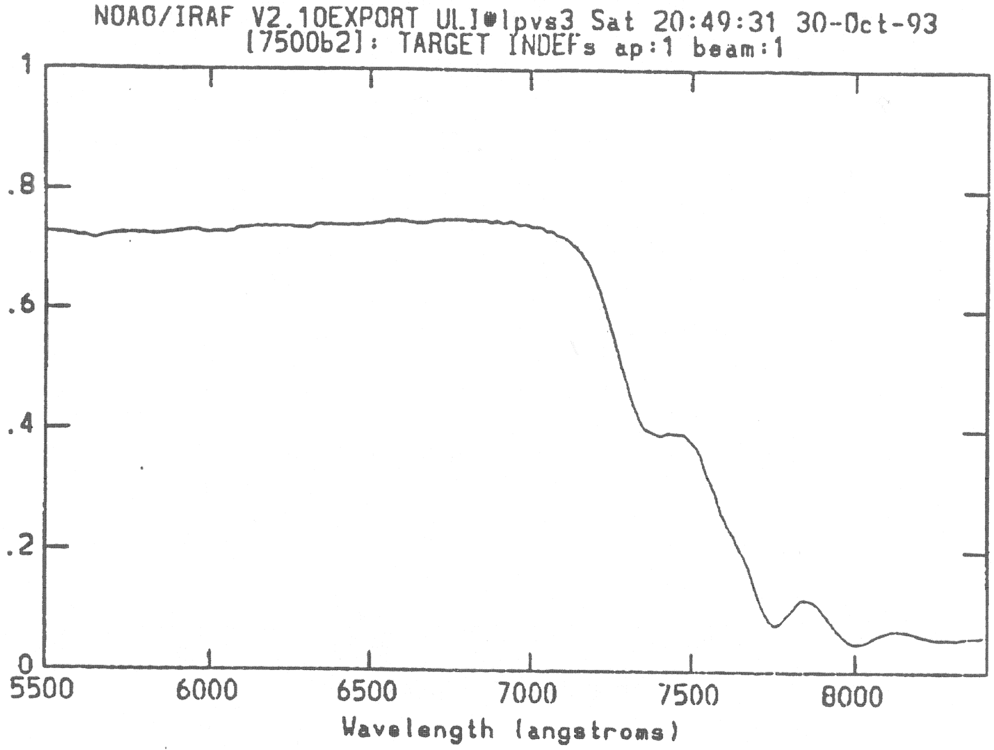

Figure 22: Reflectivity as a function of wavelength for the 7500Å dichroic

D Details of Neutral Density Filters

This appendix gives the actual values of the densities of ND filters in both the star–beam ('MAINFILTND') and in the calibration–lamp beam ('COMPFILTA/B').

Table 11: ND values of ISIS/FOS Main–Beam Filters (85mm diameter)

Nominal ND λ(Å)	0.3	0.6	0.9	1.0	1.2	1.5	1.8	2.0	3.0
3000	0.53	0.57	0.88	1.02	1.29	1.58	2.09	2.11	3.65
3250	0.48	0.58	0.90	1.03	1.30	1.56	2.07	2.08	3.66
3500	0.44	0.59	0.91	1.04	1.30	1.55	2.05	2.07	3.65
4000	0.40	0.62	0.93	1.05	1.29	1.54	2.00	2.06	3.63
4500	0.36	0.63	0.95	1.06	1.28	1.51	1.93	2.03	3.52
5000	0.34	0.64	0.95	1.05	1.26	1.48	1.86	1.99	3.37
5500	0.32	0.64	0.95	1.04	1.23	1.43	1.78	1.93	3.22
6000	0.31	0.64	0.95	1.02	1.21	1.40	1.71	1.88	3.08
6500	0.30	0.63	0.94	1.01	1.19	1.36	1.64	1.83	2.96
7000	0.29	0.62	0.93	1.00	1.17	1.33	1.59	1.79	2.85
7500	0.28	0.62	0.93	0.99	1.15	1.30	1.54	1.76	2.76
8000	0.27	0.61	0.92	0.98	1.13	1.28	1.50	1.74	2.66
8500	0.26	0.60	0.92	0.97	1.12	1.26	1.47	1.71	2.60
9000	0.26	0.60	0.91	0.97	1.11	1.25	1.45	1.70	2.59

Table 12: Neutral Densities of ISIS/FOS Calibration–Beam Filters (75mm diam)

Nominal ND λ(Å)	0.2	0.3	0.5	0.6	0.8	0.9	1.2	1.8	2.0	3.0
3000	0.38	0.52	0.44	0.56	0.87	0.89	1.30	2.11	2.26	3.63
3250	0.35	0.48	0.44	0.58	0.88	0.90	1.30	2.08	2.24	3.63
3500	0.32	0.45	0.46	0.59	0.89	0.91	1.30	2.06	2.20	3.63
4000	0.29	0.40	0.48	0.61	0.90	0.93	1.30	2.01	2.17	3.60
4500	0.26	0.36	0.50	0.63	0.91	0.95	1.28	1.95	2.09	3.48
5000	0.25	0.34	0.51	0.63	0.90	0.95	1.26	1.87	2.01	3.34
5500	0.24	0.33	0.52	0.63	0.89	0.95	1.23	1.79	1.94	3.19
6000	0.22	0.31	0.53	0.63	0.88	0.94	1.21	1.72	1.86	3.06
6500	0.21	0.30	0.53	0.62	0.87	0.94	1.19	1.65	1.79	2.94
7000	0.21	0.29	0.53	0.62	0.86	0.93	1.17	1.59	1.73	2.84
7500	0.21	0.28	0.53	0.61	0.85	0.92	1.15	1.54	1.69	2.74
8000	0.20	0.28	0.53	0.60	0.84	0.91	1.14	1.50	1.65	2.67
8500	0.19	0.27	0.53	0.60	0.82	0.91	1.12	1.46	1.62	2.60
9000	0.19	0.26	0.52	0.59	0.81	0.90	1.12	1.43	1.58	2.59

E Details of the La Palma Sky

E.1 Sky Brightness and Spectrum

Typical sky brightness at La Palma, in mags per square arcsec, are given below, in 'dark', 'grey' & 'bright' time. *These data refer to clear conditions* (no cloud or dust; low aerosols; extinction at V between 0.10–0.16 mag/airmass).

Table 13: La Palma Sky Brightness (Mag/Square Arcsec)

U	B	V	R	I	Moon	Data Source
21.4	22.3	21.4	20.4	19.3	Dark	JKT+Peoples Photometer, June 1984
21.0	21.8	20.8	20.4	19.4	Dark	JKT + CCD June-September 1989
19.9	20.3	20.1	19.6	19.0	Grey	" "
17.4	17.4	16.9	17.5	17.7	Bright	" "

In the Table, 'Dark' means Moon below the horizon; 'Grey' means above the horizon with phase 0.58-0.67, and 'bright' means above the horizon with phase 0.90-0.96. *The sky data are guidelines*; precise values depend *critically* on angular distance from the Moon, the elevation of the Moon, and the atmospheric aerosol & dust content.

The dark-sky variation between 1984–9 may be partly due to a correlation with phase of the 11-year Solar cycle; a variation of 0.5 mag has been reported by the UK Schmidt Telescope, but because of the lower geomagnetic latitude of La Palma a slightly smaller amplitude is expected here.

Flux–calibrated, low–resolution night sky (airglow) spectra have been presented by C.R. Benn (*Gemini*, **35**, p 20, 1992) and by C. Jenkins & S. Unger (*ING La Palma Technical Note No 82*). Note that in the red, emission lines from OH and H_2O molecules dominate the spectrum, and so the broad–band magnitudes given above do not give a good idea of the sky continuum flux at any particular wavelength.

E.2 Extinction at La Palma

The extinction as a function of wavelength has been tabulated by D.L. King (*ING Tech Note No 31*); a data file and interpolation program are stored in the [LPINFO] directories at Cambridge and La Palma. These data are valid only for a very clear night with low aerosol content, and correspond to an extinction of 0.10 mag/airmass in the 'V' band. (A value of 0.15 is more typical, and values above 0.18 will usually include a contribution from dust). The actual extinction for any (clear) night can be obtained from the Carlsberg Meridian Circle data (also stored in [LPINFO]), and for values at 'V' between 0.08 & 0.16, the extinction curve usually has the same shape as King's curve.

The King extinction curve is repeated here. m is the value in magnitudes per airmass. Note the low value at 5500Å.

Sahara dust can extinguish starlight and reflect light from the Moon and street-lamps. Although it is thought normally to be grey in extinction at optical wavelengths (D. Jones, *Tech Note No 10*; D. Stickland et al., *Observatory*, **107**, 74, 1987), very non-grey extinction has been reported once (Andrews & Williams, *ibid*, **109**, 15, 1989).

Table 14: La Palma Standard Extinction Curve

λ	m	λ	m	λ	m
3000	3.7150	5700	0.1001	8400	0.0143
3100	1.5961	5800	0.0950	8500	0.0136
3200	0.9908	5900	0.0887	8600	0.0130
3300	0.6967	6000	0.0891	8700	0.0124
3400	0.5934	6100	0.0844	8800	0.0118
3500	0.5146	6200	0.0770	8900	0.0113
3600	0.4554	6300	0.0702	9000	0.0108
3700	0.4061	6400	0.0638	9100	0.0103
3800	0.3633	6500	0.0575	9200	0.0099
3900	0.3260	6600	0.0524	9300	0.0095
4000	0.2935	6700	0.0473	9400	0.0091
4100	0.2649	6800	0.0428	9500	0.0087
4200	0.2397	6900	0.0389	9600	0.0083
4300	0.2175	7000	0.0356	9700	0.0080
4400	0.1986	7100	0.0330	9800	0.0077
4500	0.1811	7200	0.0307	9900	0.0074
4600	0.1664	7300	0.0282	10000	0.0071
4700	0.1529	7400	0.0268	10100	0.0068
4800	0.1424	7500	0.0254	10200	0.0065
4900	0.1320	7600	0.0213	10300	0.0063
5000	0.1244	7700	0.0202	10400	0.0060
5100	0.1179	7800	0.0192	10500	0.0058
5200	0.1120	7900	0.0183	10600	0.0056
5300	0.1087	8000	0.0174	10700	0.0054
5400	0.1046	8100	0.0165	10800	0.0052
5500	0.1020	8200	0.0157	10900	0.0050
5600	0.0991	8300	0.0150	11000	0.0048

F The LAPLATE program.

The programme LAPLATE is a modification of the programme APLATE *Starlink User Note SUN 89)* developed at the Anglo-Australian Observatory (AAO).

This programme converts a list of equatorial coordinates (right_ascension and declination into focal plane positions (X and Y), for the fibre masks for the WHT.

LAPLATE runs starting from a user input file. This includes several parameters used by the programme and the equatorial coordinates of the observed objects.

The programme takes into account effects of precession and nutation of the rotational orientation of the field; for this, the equinox and observing date must be included in the input file. The effects of thermal contraction and expansion of the brass aperture plate are also considered; then, the input file must include information about the drilling temperature and the observing temperature. Though differential refraction effects cannot be calculated in advance, LAPLATE makes a first order correction using the zenith distance at which the field crosses the meridian. Regarding this last point, APLATE differs from LAPLATE because the latter uses the latitude of the La Palma Observatory.

LAPLATE Input file.

The following is an example for an input file (.DAT) for the LAPLATE programme:

```
M3 WHT-Aux
40ARCMIN
D 1992.27
E 1950.0
S 4.507320565
O 90.0
X 0.0,400.0
T 10.0,25.0
C 13 40 06.089 +28 32 12.41
F 13 40 38.120 +28 33 12.93 GS1
F 13 40 09.742 +28 27 15.30 GS2
F 13 39 55.393 +28 27 36.92 GS3
F 13 39 33.147 +28 32 51.73 GS4
P 13 40 25.376 +28 31 01.53 X1
P 13 40 23.213 +28 34 13.26 26
P 13 40 18.393 +28 34 45.30 50
P 13 40 18.568 +28 33 49.75 49
P 13 40 19.410 +28 32 50.81 43
P 13 40 19.231 +28 31 42.95 46 .
```

As can be seen, in this file each line starts with a keyword. Each keyword defines the data type given to the program. A brief description is provided below:

L is the plate label. Normally, the plate label will be the observed field. This label can contain up to 40 characters. It must identify clearly the field to avoid confusion in those cases where other fibre observing programmes use similar sky regions.

40ARCMIN defines the telescope field diameter. With the aid of this information, the programme checks if all the objects are on the telescope field; however, this command concerns the Anglo-Australian telescope and, actually, is has not been modified to be used for the La Palma telescopes. Then, the information obtained from this command is useless in this case.

D is the observing date in decimal years. This is required in order to correct for the rotational effects of precession and nutation. But, as this correction is a rotational correction, the plates can be used again at a later date (if the objects have no large proper motions). The rotational correction in this case is made adjusting the rotator and plate orientations (section 9.6.2).

E is the reference equinox for the objects equatorial coordinates. Also, this will be used to correct rotational effects.

S is the focal plane scale in units of "/mm.. This value depends on the telescope and the telescope focal plane used.

T are two temperature value: the drilling temperature and an estimation of the observing temperature. These are used to correct effects of expansion or contraction of the brass aperture plate. Default values for these temperatures will be 20 and 5 degrees.

C is for the equatorial coordinates of the centre of the observed field. The telescope will be pointed to this position on the sky.

X is to insert two extra fiducial positions at the specified distances (in arcsec) from the nominal plate centre. In the example, these positions are the plate centre and a point 400 arcsec North. These holes are employed to connect the semi-coherent guiding bundles to be used for the rotator adjusting. In general, the plates must have two extra fiducial holes, one 400 arcsec North from the plate centre and another one 400 arcsec South.

F corresponds to the fiducial objects positions. These are the equatorial coordinates of the guide stars. A fiducial object position must be specified in the following format:

F right_ascension declination equinox comments

Each equinox and comment are optional arguments. The equinox must be specified if the object position is referred to a different equinox from the one defined in the E command.

P are the positions for the targets, with a similar format to that used for the fiducial objects:

P right_ascension declination equinox comments

A point "." will be added on the line next to the last line containing positional data. This point indicates the end of file for the LAPLATE programme. After this ending point, other useful information not relevant for the programme, can be added.

LAPLATE Output file.

What follows is an example for an output file (.LOG) for the LAPLATE programme. It contains the corresponding output for each input parameter in the input file (as for the example shown before), and in the same order.

Comments on the Output file:

- The first line is a warning message because the focal plane scale used is not the default one provided by the programme. This message is not important as LAPLATE uses the focal plane scale specified by the user.
- The date refers to the time at which the data are processed.

```
*** WARNING - Unusual plate scale !  ***

Date:  16/11/1992 14:21
```

** Label: M3 WHT-AUX **

Plate Field: 40 arcminute Observers:.........................

Plate Scale = 4.507 arcsec/mm Observing date:.....................

Temperatures: Fibre Bundle:......................

Observe at 5 C, Comments:..........................

Drilling at 25 C ....

Julian Epoch Observn:1992.9 ....

Rotator Position Angle: 90.00

Equinox of Position 1950.0

Plate Centre: R.A. DEC.

13 40 02.89 + 28 31 11.7

5 Fiducial Objects

Fibre Hole R.A. DEC. X Y

____ 51 13 40 25.37 +28 31 01.5 HC(X1) -65.789 -2.097

____ 52 13 39 39.75 +28 30 59.1 HSC(525) 67.664 -2.890

____ 53 13 39 58.03 +28 33 28.4 HSC(X8) 14.275 30.314

____ 54 13 40 02.89 +28 31 11.7 * 0" N 0.000 0.000

____ 55 13 40 02.89 +28 37 51.7 * 400" N 0.182 88.770

10 Programme Objects

Fibre Hole R.A. DEC. X Y

____ 56 13 40 09.74 +28 27 15.3 GS2 -20.173 -52.414

____ 57 13 40 16.89 +28 26 38.8 X2 -41.120 -60.457

____ 58 13 40 00.04 +28 30 00.3 X3 8.314 -15.864

____ 59 13 39 52.17 +28 28 39.2 X5 31.311 -33.904

____ 60 13 39 46.73 +28 27 06.4 X6 47.175 -54.508

____ 61 13 39 46.80 +28 26 29.0 X7 46.949 -62.803

____ 62 13 39 51.01 +28 31 00.4 X9 34.730 -2.561

____ 63 13 40 23.21 +28 34 13.3 26 -59.350 40.438

____ 64 13 40 19.41 +28 32 50.8 43 -48.276 22.110

____ 65 13 40 19.23 +28 31 42.9 46 -47.785 7.049

* * * HOLE / FIBRE CROSS CHECK * * *

Plate Label: M3 WHT-AUX

APLATE Date: 16/11/1992

Observers:..

Observing Date:...

```
Comments:............................................................
.....................................................................
.....................................................................
Fibre Bundle:.........
           10.......  20.......  30.......  40.......  50.......
01.......  11.......  21.......  31.......  41.......
02.......  12.......  22.......  32.......  42.......
03.......  13.......  23.......  33.......  43.......
04.......  14.......  24.......  34.......  44.......
05.......  15.......  25.......  35.......  45.......
06.......  16.......  26.......  36.......  46.......
07.......  17.......  27.......  37.......  47.......
08.......  18.......  28.......  38.......  48.......
09.......  19.......  29.......  39.......  49.......
```

- Gives the value of the input file commands.
- Gives the coordinates of the field centre for telescope pointing.
- Gives information about fiducial objects: equatorial coordinates (R.A, DEC), fiducial object label and calculated plate position (X, Y) in millimetres from the plate centre.
- Gives information about the targets: equatorial coordinates (R.A, DEC), object label and calculated plate position (X, Y) in millimetres from the plate centre.
- The number shown at the end of the output file will be used to assign each fibre to the corresponding hole, by means of the object labels.