E U R O P E A N S O U T H E R N
O B S E R V A T O R Y

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral

Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

New Testbench

Software User's Manual

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1 Abreviation and acronyms

LG	Low Gain
HG	High Gain
LN	Liquid Nitrogen
GUI	Graphic User Interface
CCS	Central Control Software
FIERA	Fast Imager Electronic Readout Assembly
WS	Workstation
VLT	Very Large Telescope
RTAP	Real Time Application Platform (Hewlett-Packard)
GPIB	General Purpose Interface Bus
SW	Software

2 How does it work?

2.1 Hardware implementation

First of all, have a look to the physical set up (Figure 1 & Figure 2):

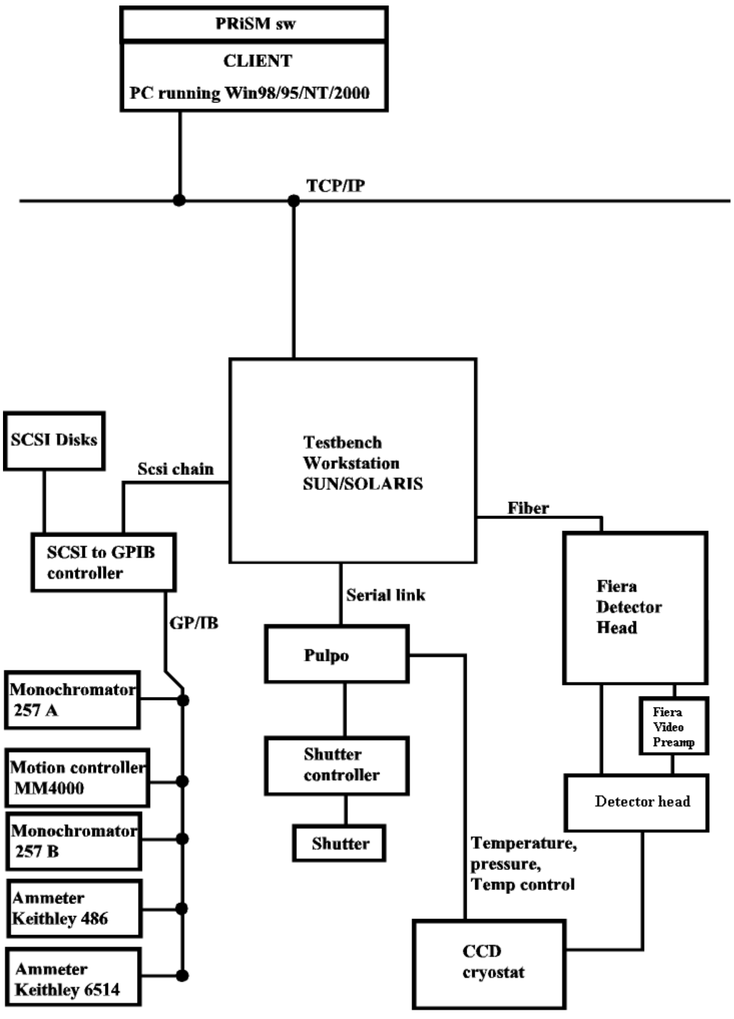


Figure 1 Hardware set up of the Testbench

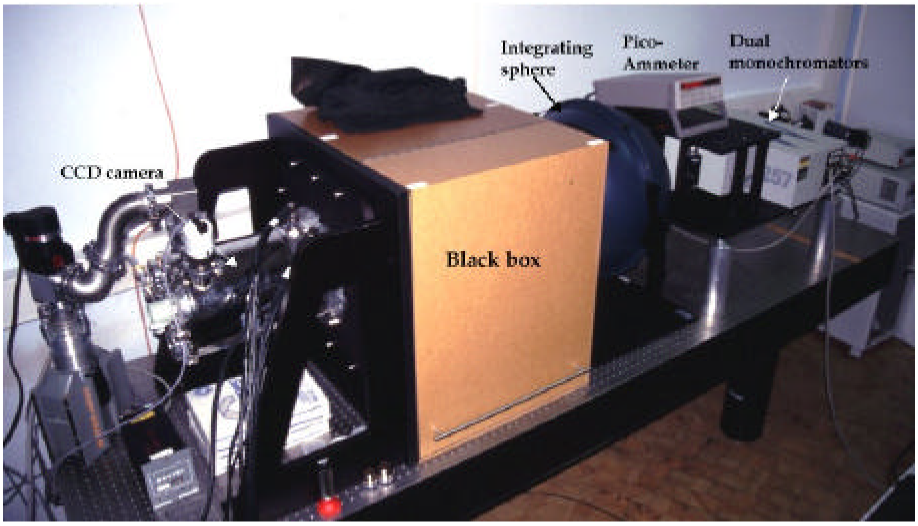


Figure 2 Testbench hardware implementation

The system is mounted on a Newport 300 cm x 90 cm optical table top, which provide static rigidity and flatness, in addition to the standard configuration of sealed mounting holes. All hardware components are GPIB driven and controlled through a GPIB controller, by National Instruments, which holds up to 14 GPIB devices and is attached to a SPARC board with embedded FIERA controller through SCSI connection. A PULPO monitoring unit [7] for environmental variable control (temperature, humidity, etc.) will also be part of the system.

2.1.1 Lamp housing and lamp:

Two light sources are disposable on the testbench:

- An halogen lamp with horizontally elongated filament (power up to 250W, typically OSRAM Xenophot HLX64640 or Philips 7148,150W or equivalent), hold in a standard convention cooled housing (ORIEL), equipped with a F/1 condenser, which produce a ~3 cm diameter collimated beam. This beam is then focused on the monochromator input slit by means of a secondary f/4 plano-convex lens, which matches the acceptance pyramid of the monochromator. The light system maximizes the total power into the monochromator and provides a smooth continuum within the desired wavelength range. This system is driven by a Power Supply and a Light Intensity Controller also produced by Oriel. The light intensity controller is directly connected to the lamp housing through a light sensing head, which monitors light variations, and interfaced to the power supply. It allows maintenance of constant light levels, for the duration of an exposure (exposure lengths vary from few seconds to about ten minutes) regardless of lamp aging, line voltage variations or changes in the ambient temperature.

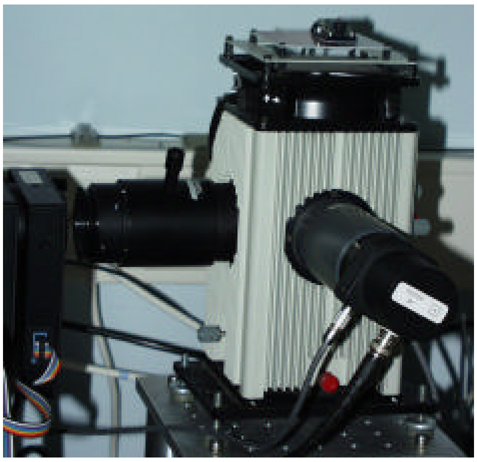


Figure 3 Halogen lamp housing

Figure 4 Halogen lamp power supply (down) and light intensity controller (up)

- A 150W Xenon arc lamp in a Universal Lamp Housing (ORIEL) with its power supply (ORIEL 68806)

Figure 5 Xenon lamp housing

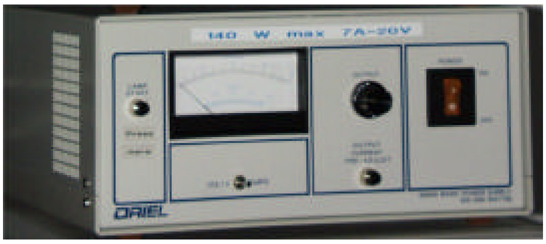


Figure 6 Xenon lamp power supply

2.1.2 Monochromator:

An Oriel Multispec 257 Double Monochromator in subtractive dispersion configuration. In the current setup, the output from the first unit is dispersed in the reverse direction by the second unit, thus homogenizing the light across the output slit. The net dispersion remains as that produced by the first monochromator, but the amount of stray light is greatly reduced, quoted by Oriel to be of the order of 10-7 of the unblocked signal. That is, almost three orders of magnitude smaller that the measured stray light for a single monochromator of the same kind. The two devices can be controlled via GPIB in either an independent way or together (using the first one as master). Both are equipped with microstepping motor driven slits and 600 l/mm ruled gratings, whose peak efficiency is at 400 nm (Figure 10). The usable wavelength region (that is, where the grating efficiency is more than 20%), goes from 250 to 1300nm (well beyond our requirements). With this configuration, a minimum bandpass of ~0.1 nm can be reached. Two motorized filter wheels, that hold up to five filters each, are attached at the input of the first monochromator. They control respectively the order sorting filters from Schott (2 filters, with cut-off wavelength respectively at 450 and 665 nm) and neutral density filters from Melles Griot (see Table 2).

Schott GG475		Schott RG665	
Wavelength (nm)	Transmittance	Wavelength (nm)	Transmittance
200 to 450	$< 10^{-5}$	200 to 620	$< 10^{-5}$
460	$9\ 10^{-5}$	630	$< 6\ 10^{-4}$
470	0.17	640	0.01
480	0.66	650	0.10
490	0.85	660	0.33
500	0.89	670	0.59
510	0.90	680	0.75
520	0.90	690	0.83
530 to 1200	0.91	700	0.88
		710	0.90
		720	0.90
		730 to 1200	0.91

Table 1 Separating order filters available on the monochromators

Reference	Diameter (mm)	Transmission	Material	Optical density (@ 550nm)
03FNQ045	25	50.12%	Fused Silica	0.3 ± 0.02
03FNQ047	25	25.12%	Fused Silica	0.6 ± 0.03
03FNQ057	25	10%	Fused Silica	1 0.± 05
03FNQ065	25	0.3162%	Fused Silica	2.5 ± 0.125

Table 2 Neutral density available on the monochromators

The first unit is also equipped with an integrated shutter, which can be controlled both via external TTL signals and through GPIB commands. The minimum exposure time setting is 20msec, the transition time ~2ms. Positioning the shutter before the light is inputted into the integrating sphere, instead that putting it at the exit port, has the advantage of eliminating the shutter pattern problem.

Figure 7 The two monochromators MS257

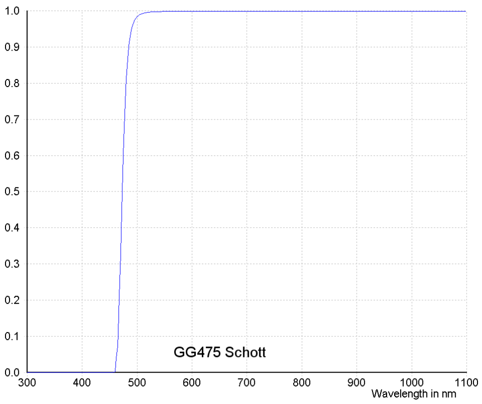


Figure 8 GG475 filter

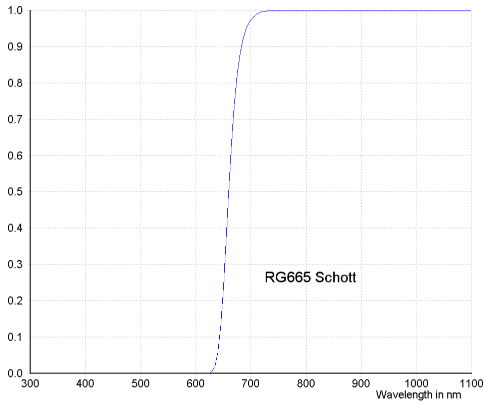


Figure 9 RG665 filter

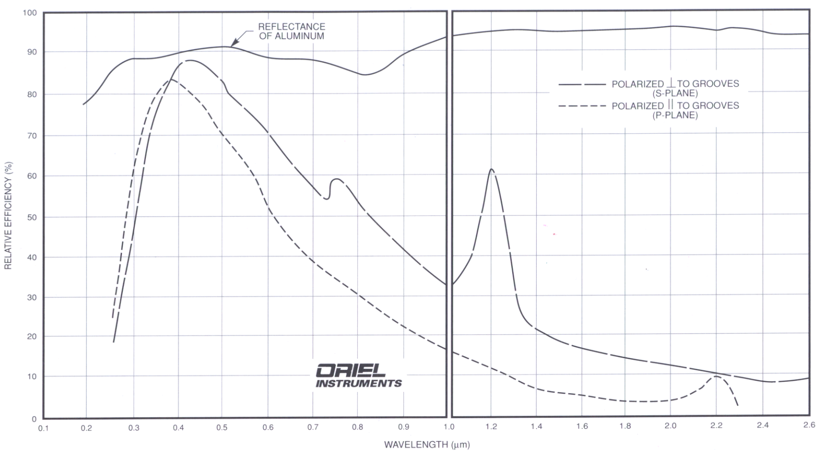


Figure 10 Grating mounted on the monochromators

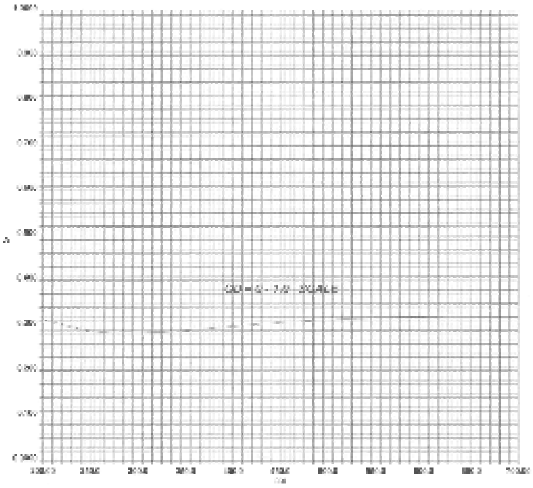


Figure 11 03FNQ045 neutral density

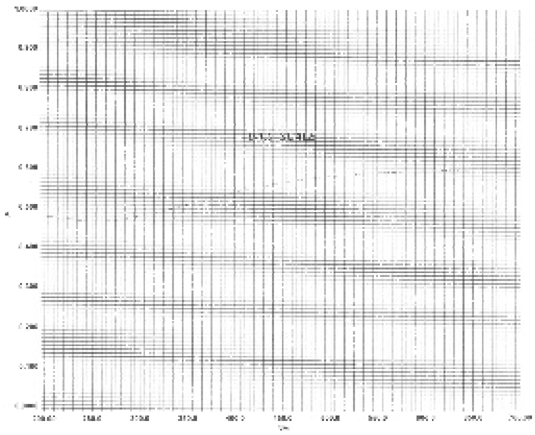


Figure 12 03FNQ047 neutral density

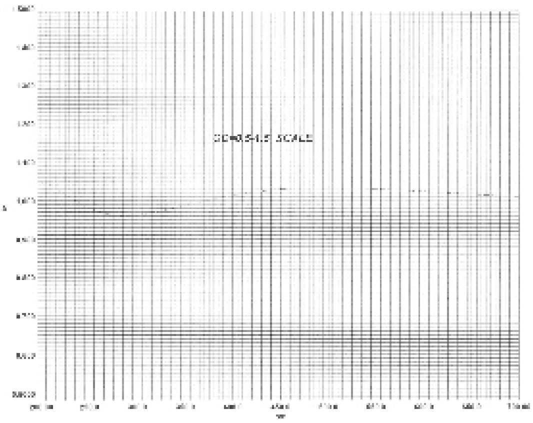


Figure 13 03FNQ057 neutral density

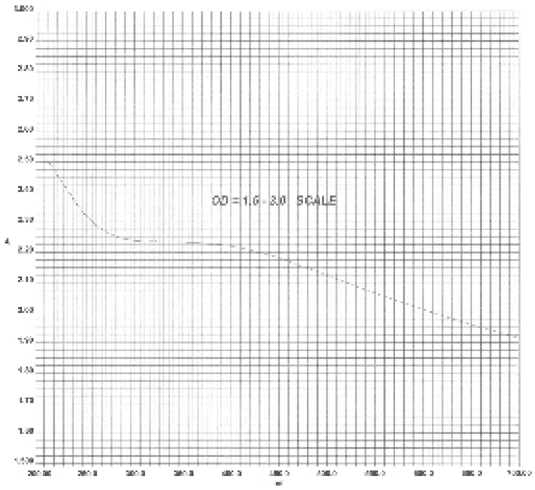


Figure 14 03FNQ067 neutral density

2.1.3 Integrating Sphere:

A 50 cm diameter "custom made" Labsphere (Figure 16). Its 8 inches exit port provides a uniform illumination, over an area bigger than the size of 8k × 8k CCD or Mosaic (a typical 8k × 8k with 15 um pixel has a diagonal of about 17 cm; we will refer to this example throughout the paper). The primary output port is at 180 degrees with respect to the input port. A secondary output port (about 1.3cm), which hosts a photodiode, is drilled close to the primary output port. A baffle situated inside the sphere prevents that the output port “sees” directly the light source. The internal coating of the sphere is made in Spectraflect, a material that ensures a reflectance better than 98% in the range 400 – 1100 nm and better than 96% in the UV range (320-400 nm) (Figure 15). The best degree of uniformity across the illuminated field is achieved when mounting the CCD in close contact with the exit port. Otherwise, the degree of uniformity, defined as the ratio of the illuminance at the edge of the field to the illuminance on the axis through the center, is a function of the distance of the target form the source [8]. The second option has been chosen in order to have enough space between the sphere exit port and the detector to perform experiments (for instance, to put a lens and a target image to be projected onto the CCDs). The detector will be put at a distance of 50 to 75 cm from the sphere output port, so that, for a 8 inches light beam and a 8k X 8k 15 μm pixel CCD, the degree of uniformity of illumination is always in the range 95% - 98%. A better than 1% uniformity is of course obtained for smaller detectors.

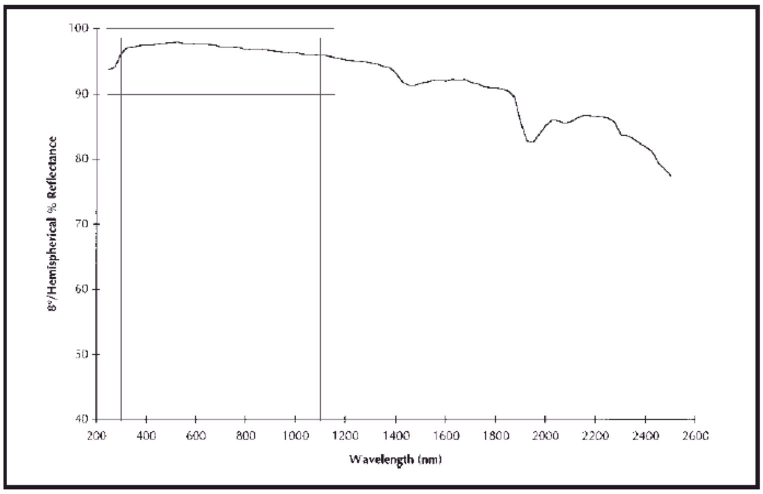


Figure 15 Integrating sphere coating (Spectraflect) reflectance as a function of wavelength

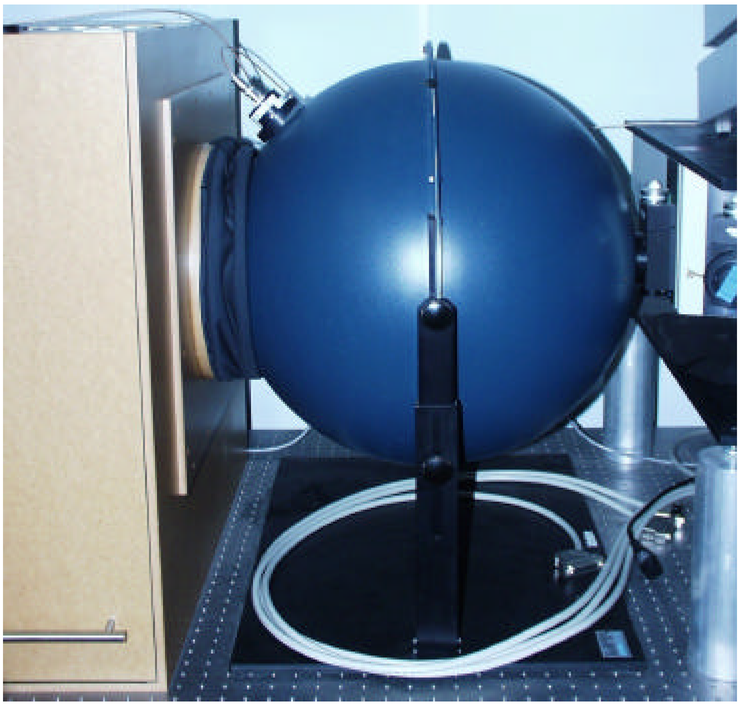


Figure 16 The integrating sphere

2.1.4 Picommeters and diodes:

The testbench will be equipped with two photodiodes, one permanently mounted at the secondary output port of the integrating sphere and the other, needed for absolute flux calibration of the system, put at the detector's position. A permanent solution, with the latter diode fixed as close as possible to the detector and sharing with it the same focal plane, is also planned for the future. Separate ammeters are attached to diodes through low-noise triax cables. A Keithley 486 is connected to the sphere's diode: a 5½-digit autoranging picoammeter designed for low current applications where fast-reading rates must be performed. The measurement range is between 2nA and 2mA, with a resolution of 10fA (@2nA range). The diode is a Hamamatsu 1cm^2 Silicon Photodiode for precision photometry (NEP ~10-15) with good UV QE. The second diode is also a 1 cm^2 silicon Hamamatsu photodiode, which has been absolute calibrated by reference to PTL (National Physical Laboratory, England) and to PTB (Physikalisch-Technische Bundesantalt) standards. At present it is interfaced to a Keithley 6514 Electrometer/Multimeter, the same measuring range is between 20pA and 20mA. Both ammeters are controlled via GPIB by means of the GPIB controller.

Figure 17 The two ammeters: ke486 (down) and ke6514 (up)

2.1.5 Flanges system and light tight zone:

The integrating sphere is attached to a flange, fixed onto the table top, through a flexible light shield, which allows a length span of ~25cm. A second flange, which will hold a custom made plate for each detector head (at least three different systems are foreseen for the VLT detectors systems), is positioned at a distance of 50 cm from the first flange. The dewar itself will be hanging from the outer wall of the flange. A wooden light-tight box, with lateral access door, will close the space in between the two flanges. The flanges, the box, and some other minor elements are being designed by ESO's mechanical design office (Figure 2).

2.1.6 Motion controller

Figure 18 Motion controller MM4000

Figure 19 Motors assembly hosting a laser

A motion controller from Newport is also available that can drive up to 4 motors. An assembly (Figure 19), containing 3 motors and allowing movements in the 3 axis respectively to the CCD surface (Figure 73). The main use of this assembly is to drive a laser beam on to the CCD surface.

2.2 Software implementation

The software underlying this set up is described Figure 20:

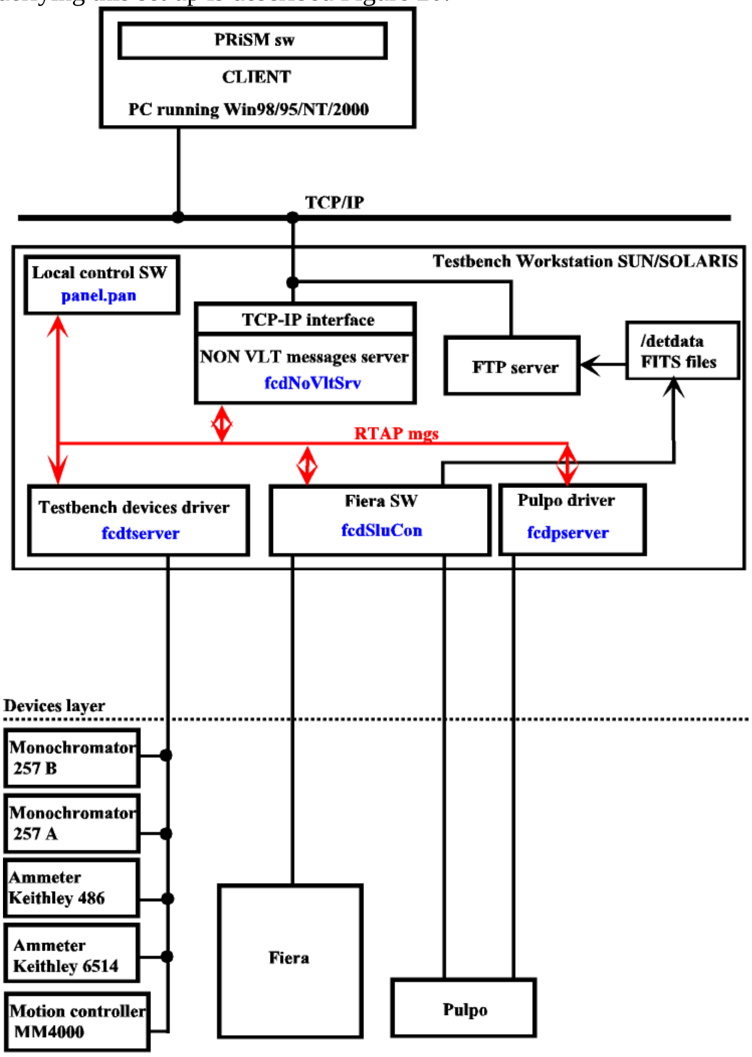


Figure 20 Software setup of the Testbench

The blue names inside the boxes are the servers names to be launched before any access to the hardware.
FIERA in a standalone way can be used, provided that the fcdNoVltSrv server is running.

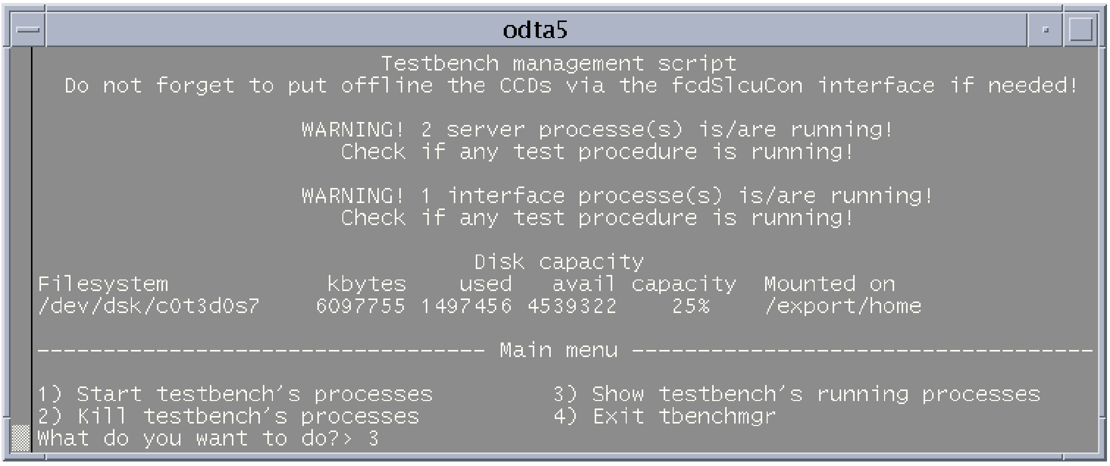
3 From the workstation side

3.1 Prerequisite:

The "fcdrun" account has to be used to control locally the testbench. The {root} directory is "/export/home/fcdrun".
On the UNIX workstation called odta5 near the testbench, after a reboot, you need to start all hardware devices.
First, you have:

- To launch the RTAP message manager (command: vccStartEnv -e $RTAPENV), here, if one echoes $RTAPENV you should get wodta5a.
- To Check that the variable CCDNAME is properly defined, echo $CCDNAME, the setenv command could be added into the odta5.cshrc.local file located in the {root} /config/.

Next, you have to launch all the servers written in blue in the previous figure. To manage with that, a UNIX shell script "tbenchmgr.sh" will help you. By typing "tbenchmgr" at a shell prompt on odta5, you enter the main menu as shown by Figure 21:



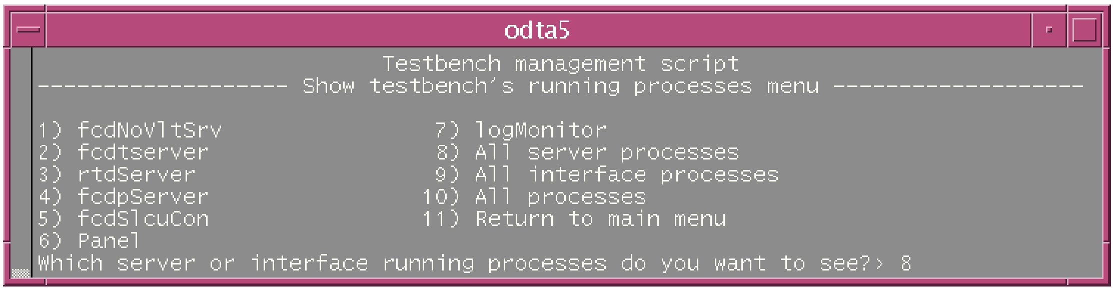
```
odta5
                          Testbench management script
   Do not forget to put offline the CCDs via the fcdSlcuCon interface if needed!

                    WARNING! 2 server processe(s) is/are running!
                       Check if any test procedure is running!

                    WARNING! 1 interface processe(s) is/are running!
                       Check if any test procedure is running!

                                  Disk capacity
Filesystem               kbytes    used    avail capacity  Mounted on
/dev/dsk/c0t3d0s7       6097755 1497456 4539322    25%     /export/home

---------------------------------- Main menu ----------------------------------

1) Start testbench's processes          3) Show testbench's running processes
2) Kill testbench's processes           4) Exit tbenchmgr
What do you want to do?> 3
```

Figure 21 Testbench management script main menu

It is highly recommended to use this script to start up the testbench software and not to use shortcuts.

This script gives you information on the testbench environment and access to a simple menu that allows you to start, to stop and to trace one or a group of processes. A version of this script can be found here, 16/06/2002 version. This script is located in “{root}/tbenchSoft/script/tbenchmgr.sh”. A symbolic link “tbenchmgr” has been created in the {root} directory the following line has been added at the end of the “.bashrc” file:
alias tbenchmgr ~/tbenchmgr

Before accessing the main menu, the script warns the user if server or interface processes are running. This is to prevent several sessions of the same server to run at the same time and to avoid that several users access the testbench at the same time. In case of a warning, you can get information on the nature of the running servers and/or interfaces by entering the "Show running testbench's processes" (item nr. 3). You should obtain the following sub menu (Figure 22):



```
odta5
                          Testbench management script
------------------ Show testbench's running processes menu ------------------

1) fcdNoVltSrv                  7) logMonitor
2) fcdtserver                   8) All server processes
3) rtdServer                    9) All interface processes
4) fcdpServer                  10) All processes
5) fcdSlcuCon                  11) Return to main menu
6) Panel
Which server or interface running processes do you want to see?> 8
```

Figure 22 Testbench management script: running Testbench processes menu

By choosing the item nr. 8 (All server processes), a typical output should be (Figure 23):

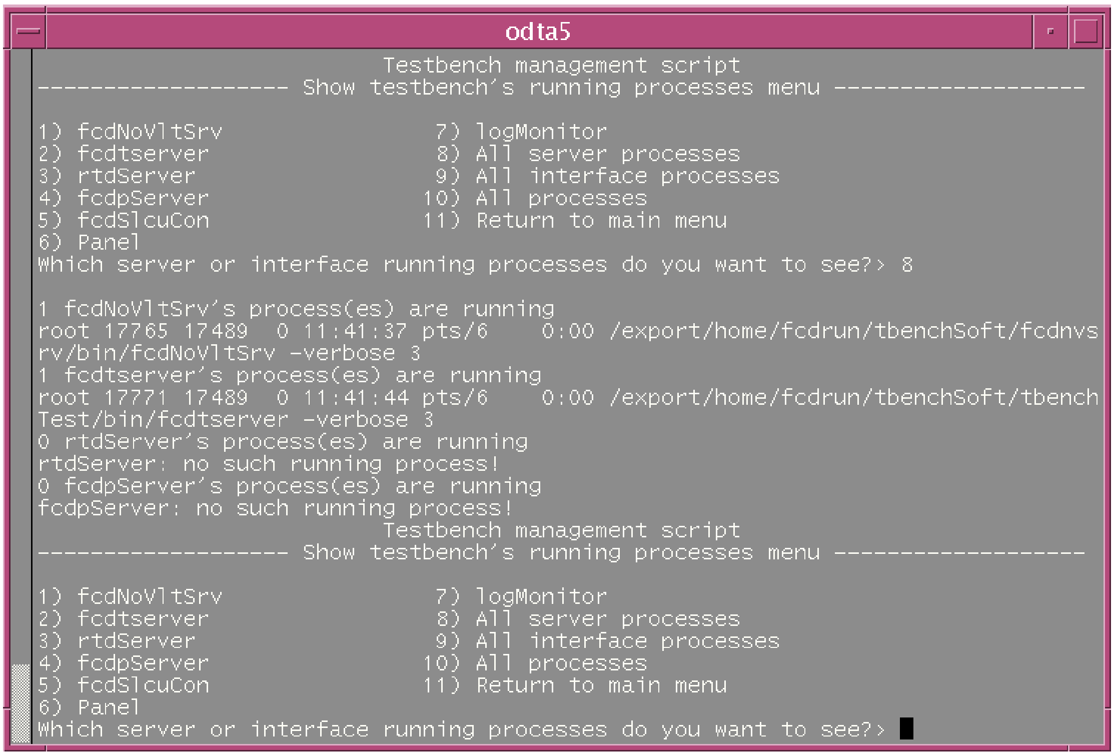


Figure 23 Testbench management script: see all servers processes

You know which processes are running. Now you should get informed on the purpose of the presence of these processes: a true session of measurements is running, these are remaining processes from a previous session ... If these processes can be removed, you should go back to the main menu and enter the "Kill testbench's processes" menu (item nr. 2).

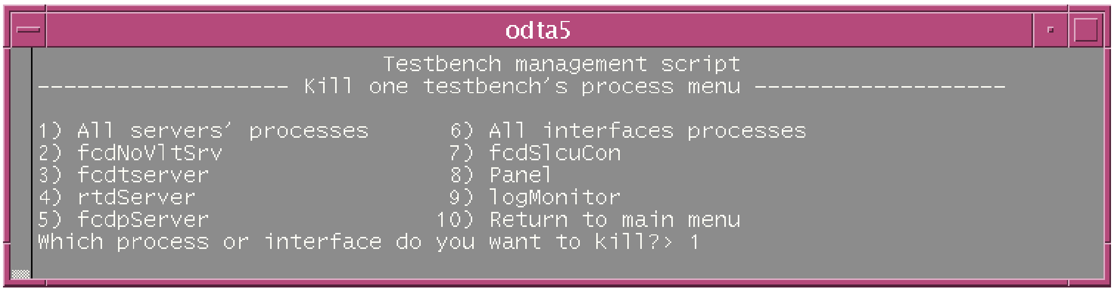


Figure 24 Testbench management script: kill testbench processes menu

You can use the appropriate item to kill a specific process or a group of processes. For example, we can choose the item nr. 1 (Figure 24). All previous server processes will be removed (Figure 25).

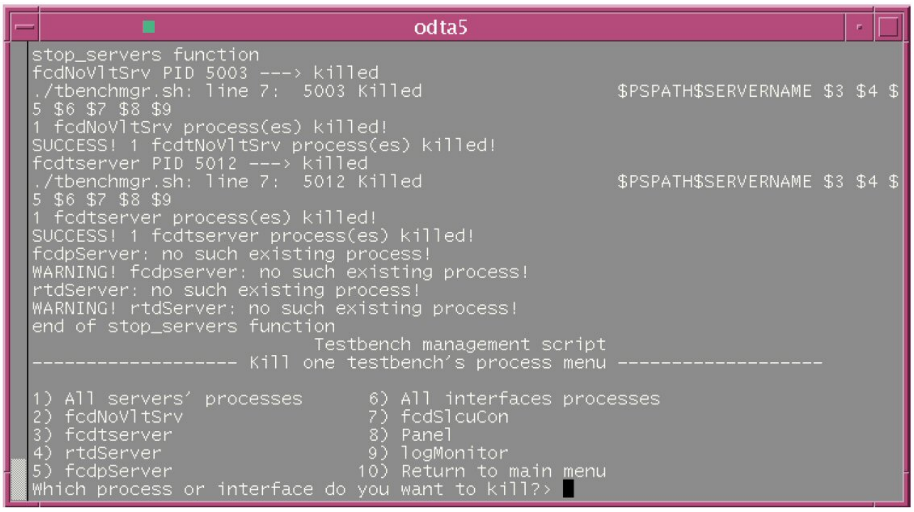


Figure 25 Testbench management script: kill all servers processes

The script also gives information about the free space available on the disk that hosts the log file (Figure 21). If the disk usage is above 90% of its capacity (it should not happened!), contact the system manager.

3.2 How to set up the GPIB:

On August 2001, a new GPIB PCI board was installed on the new SPARC. To set up GPIB device, the following software should be used: ibconf (Figure 26).

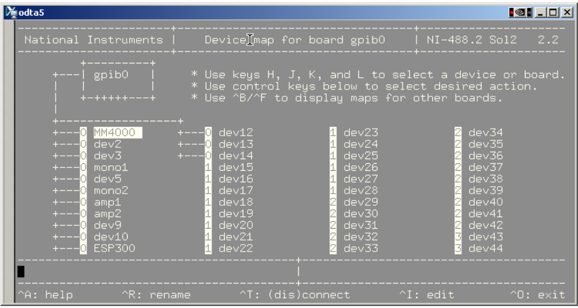


Figure 26 The ibconf utility

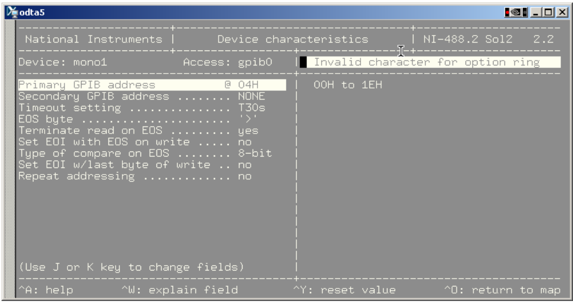


Figure 27 The ibconf utility: configuration for the 1st monochromator

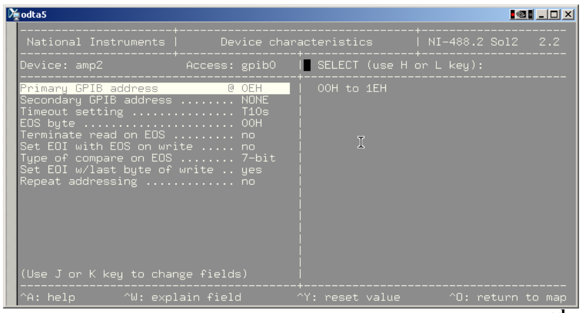


Figure 28 The ibconf utility: configuration for 2nd ammeter

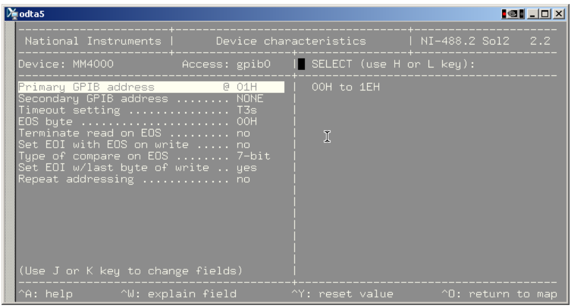


Figure 29 The ibconf utility: configuration for MM4000

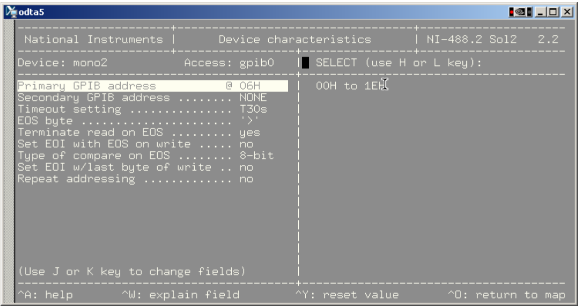


Figure 30 The ibconf utility: configuration for the 2nd monochromator

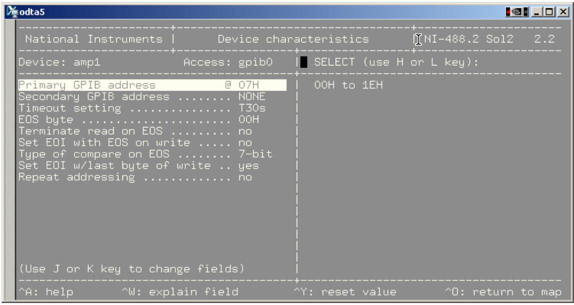


Figure 31 The ibconf utility: configuration for the 1st ammeter

Move to a given device by using the "k" character on the keyboard.
Hereafter, the panels showing the configuration data for each device:

3.3 Start the Testbench software

First, from main menu, we enter the "Start testbench processes " menu (item nr. 1). You should obtain the following menu (Figure 32):

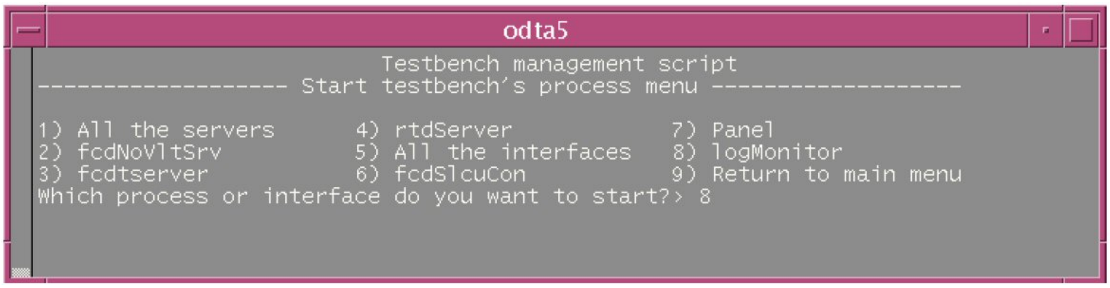


Figure 32 Testbench management script: start logMonitor

3.3.1 The logMonitor

As all servers provide output messages in the log file, it is recommended, before any initialisation of the testbench servers, to launch the log monitor interface (item n. 8). You will be able to check each step of the initialisation of each server. You should obtain this interface (Figure 33):

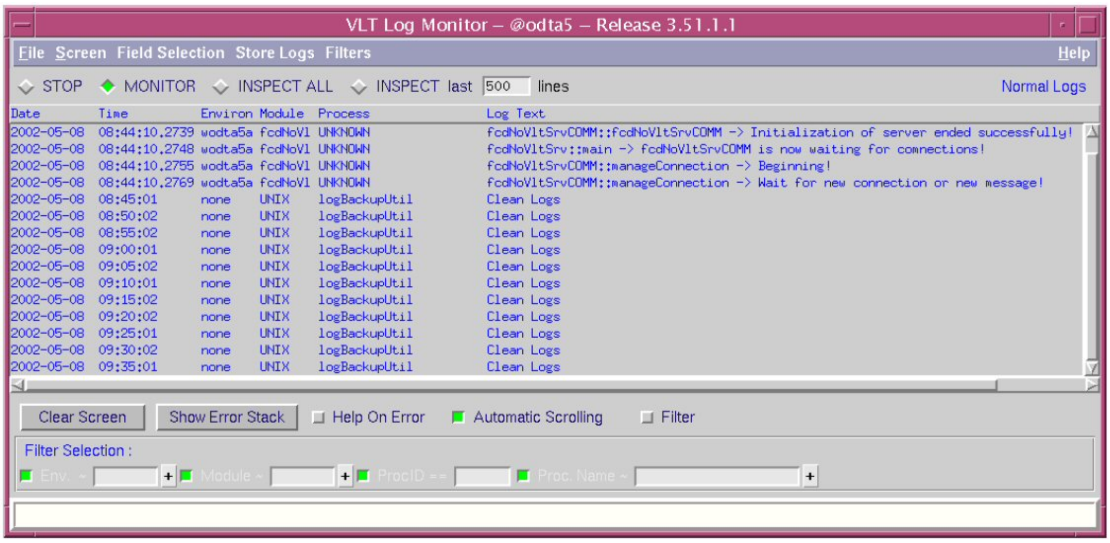


Figure 33 logMonitor interface

See the Central Control Software (CCS) User Manual of the VLT Software to have more details about the possibilities of the logMonitor.

3.3.2 The fcdNoVltSrv server

Next, you have to launch the tcp-ip interface manager (command: fcdNoVltSrv; item n. 2 in the " Start testbench's process" menu). You can find a version of the binary there (build June 6th) and the source code here (build June 6th version). On the WS, the binary could be found there: "{root}/tbenchSoft/fcdnvsrv/bin/fcdNoVltSrv" build June 6th, 2002 and the source code here: "{root}/tbenchSoft/fcdnvsrv/src/" (June 6th, 2002 version) and can be compiled by using make clean all. The purpose of this server is to allow any NON-VLT software client to communicate with VLT-SW drivers. This service uses the 2331 port. To enable fcdNoVltSrv to communicate, edit the /etc/services and add in this file: wodt 2331/tcp, put this command between vccMAKE::begin and vccMAKE::end. There is no need to restart anything but fcdNoVltSrv. The code source is located here. To launch this server, just select the item nr. 2 as shown in the following menu (Figure 34):

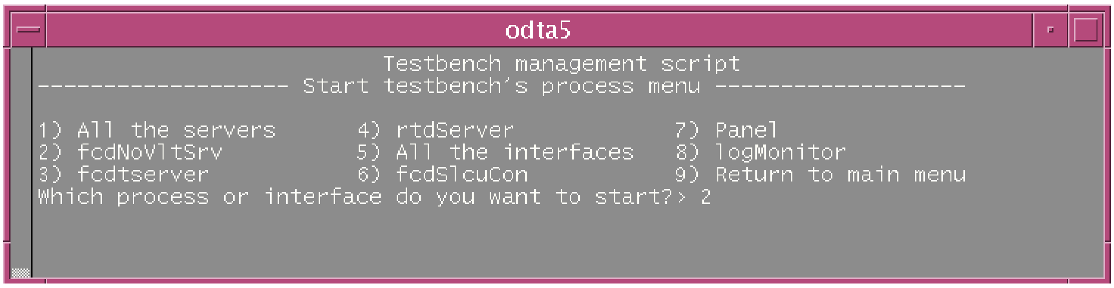


Figure 34 Testbench management script: starts fcdNoVltSrv server

Then, you are invited to choose a verbosity level in the range [0,4], 0 provides the lowest amount of messages and 4 the maximum (Figure 35).

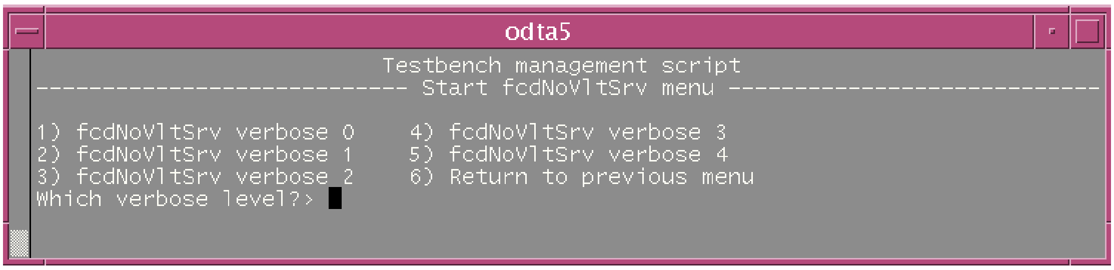


Figure 35 Testbench management server: chooses the verbosity level for fcdNoVltSrv

Meaning of the verbosity levels:

- 0: this the default; only message coming from the main program are provided
- 1: previous messages + error messages from the "client communication object"
- 2: previous messages + information messages from the "client communication object"
- 3: previous messages + error messages from the "driver object"
- 4: previous messages + information messages from the "driver object"

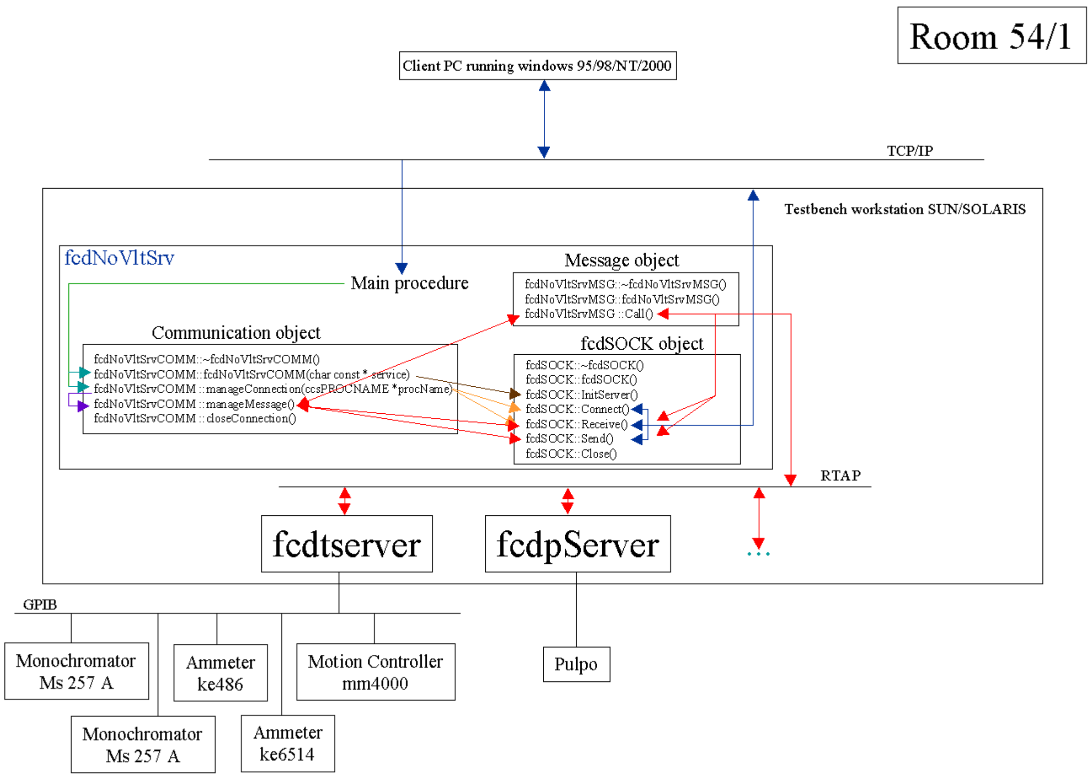


Figure 36 Software architecture of fcdNoVltSrv

Finally, a typical output provided by this server at start up, with verbosity level = 4, in the logMonitor (Figure 37):

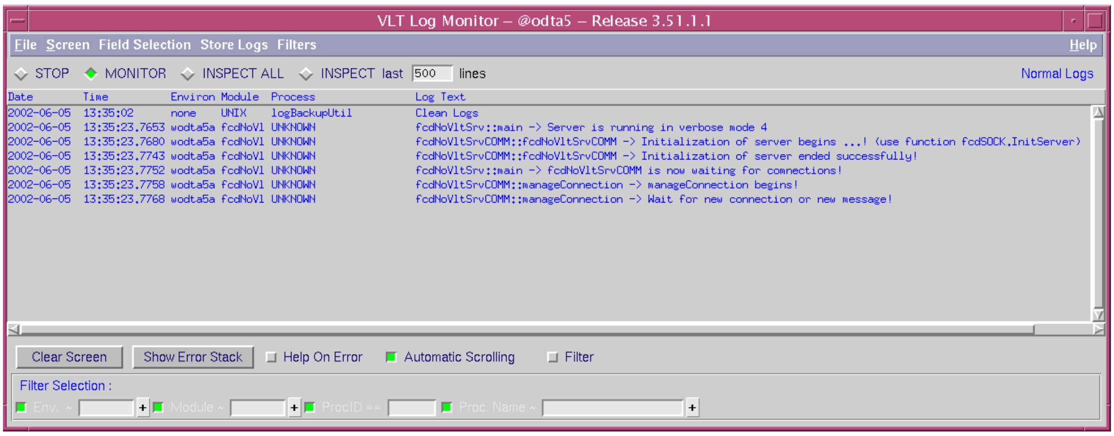


Figure 37 Messages in logMonitor at fcdNoVltSrv startup

3.3.3 The Fiera software

The Fiera software (command: fcdSlcuCon+STARTUP+ONLINE; item n. 6 in the " Start testbench processes" menu; Figure 38), this one should be ONLINE, by usual means or user own request. The pulpo server (fcdpserver) is launched automatically by Fiera SW.

Before invoking the STARTUP command and setting the CCDs on line, you must verify that the $CCDNAME environment variable is properly defined and that the definition of the voltages applied to the CCD in the configuration file "volttable.def" in the directory $INS_ROOT/SYSTEM/COMMON/CONFIGFILES/$CCDNAME are correct.

Wrong voltages can cause irreversible damage to the CCD.

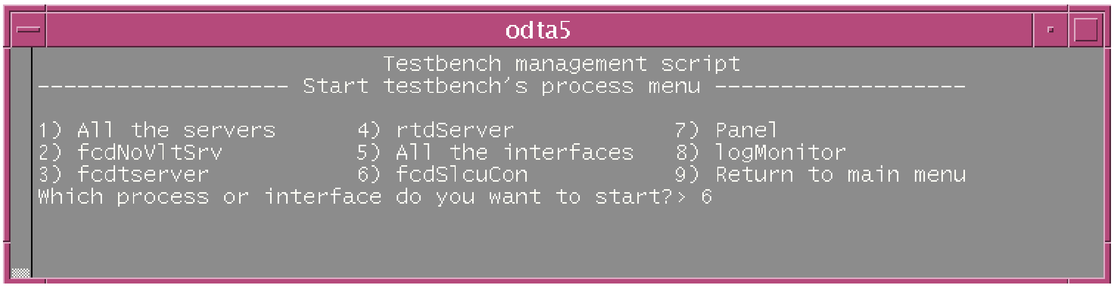


Figure 38 Testbench management script: starts fcdSlcuCon

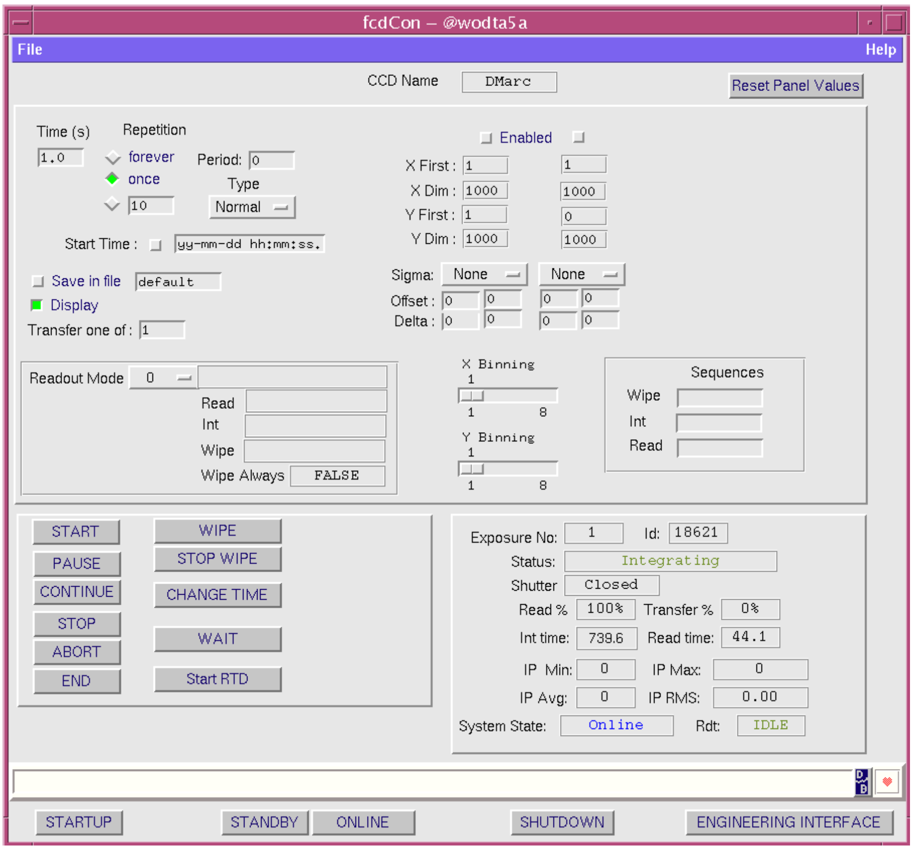


Figure 39 fcdSlcuCon interface

By invoking STARTUP (Figure 39), several processes, that send messages both to a terminal window and to the log file, are launched. Typical outputs are (Figure 40):

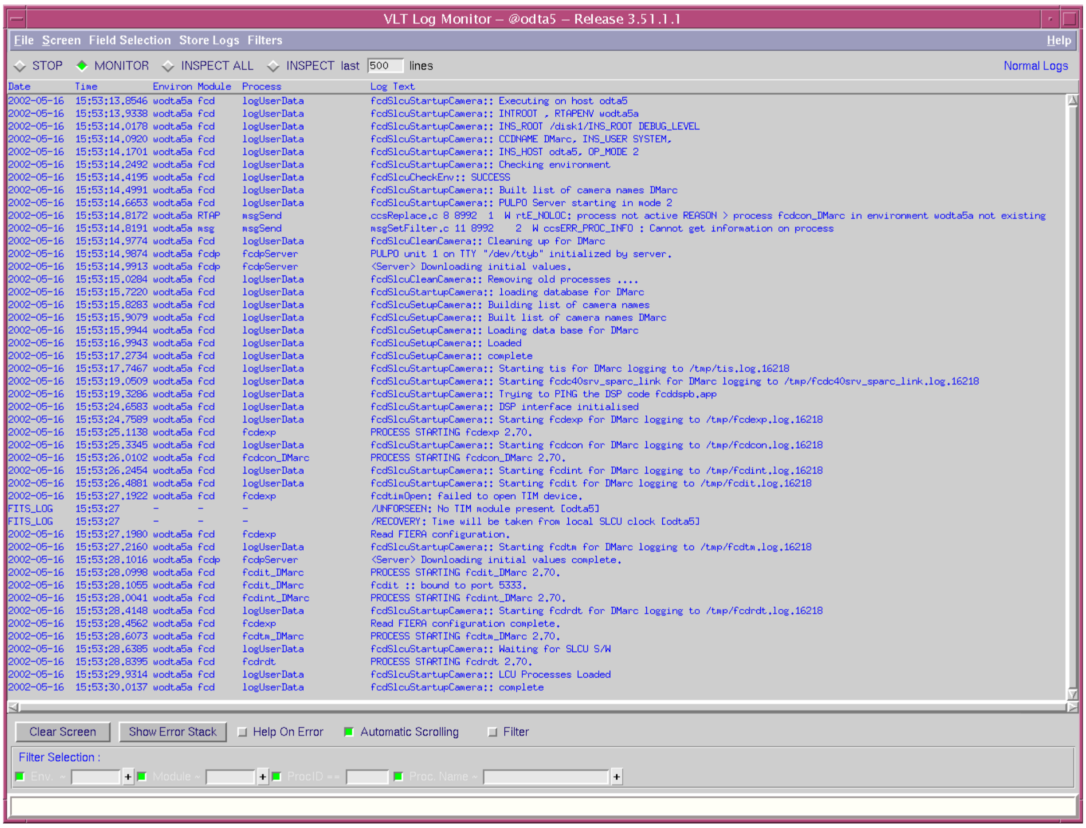


Figure 40 Messages in the logMonitor when STARTUP is invoked

Next, the ONLINE command (Figure 39) applies the voltages previously defined. Typical output is (Figure 41):

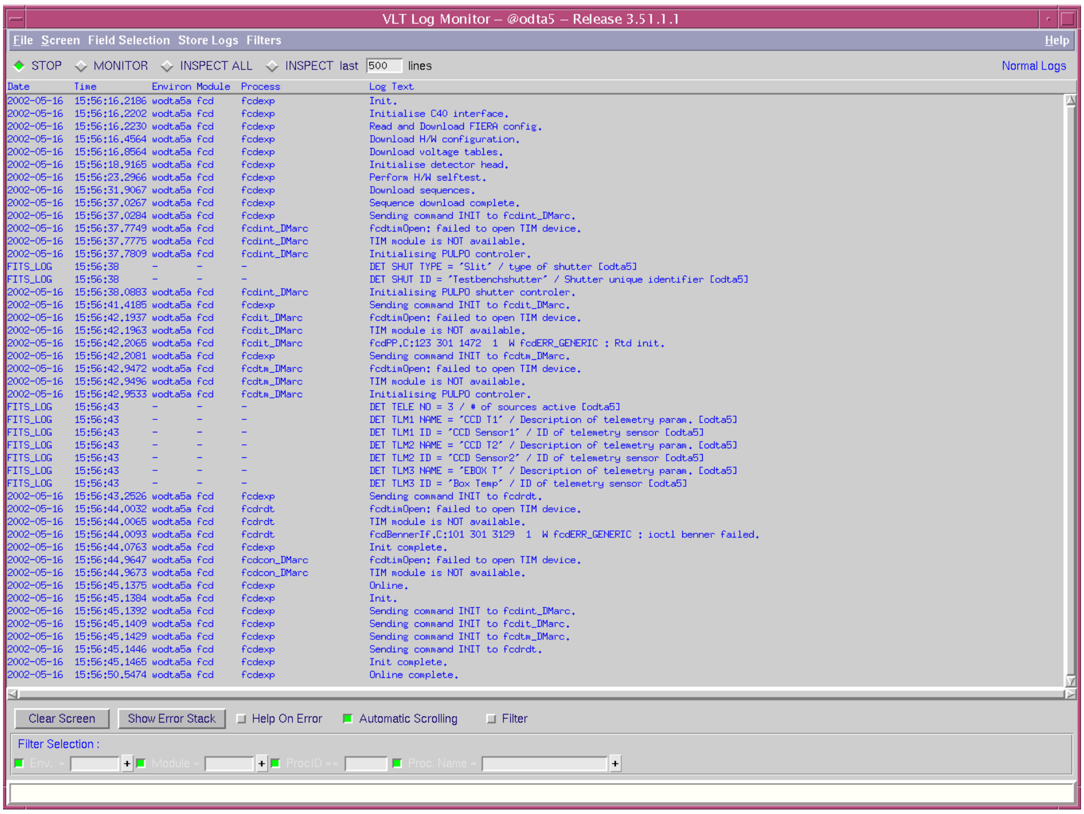


Figure 41 Messages in the logMonitor when ONLINE is invoked

3.3.4 The fcdtserver server

The testbench server (command: fcdtserver; item n. 3 in the "Start testbench processes" menu, then choose a verbosity level; Figure 42). You can find a version of the binary here (build June 12th, 2002) and the source code here, June 12th, 2002 version. On the WS, the binary could be found there “{root}/tbenchSoft/tbenchTest/bin/fcdtserver” build June 12th, 2002 and the source code here: “{root}/tbenchSoft/tbenchTest/src/” (June 12th, 2002 version) and can be compiled by using make clean all.
Before starting this server, the following devices must be switched on: GPIB to SCSI box, the two monochromators MS257, the ke486 ammeter, the ke6514 ammeter and the MM4000 motion controller optionally. If one of the devices fails, you will be informed in the logMonitor; the program will proceed with the rest of the initialisation. The fcdtserver can run with all or only some of these devices online.

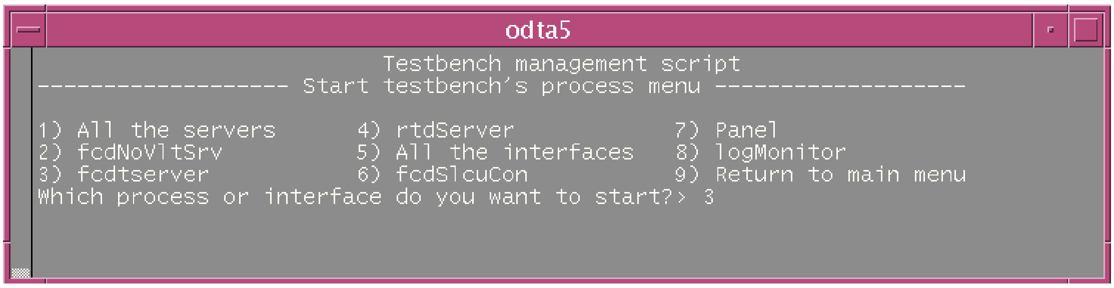


Figure 42 Testbench management script: starts fcdtserver

Then, you are invited to choose a verbosity level in the range [0,5], 0 provide the lowest amount of messages and 5 the maximum (Figure 43).

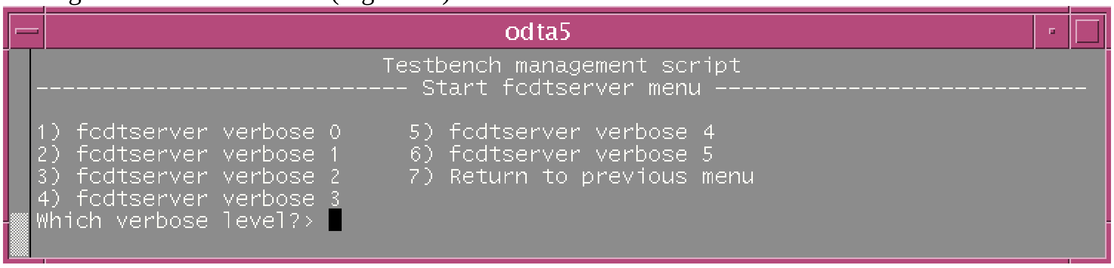


Figure 43 Testbench management script: chooses fcdtserver verbosity level

First, fcdtserver tries to initialise the two monochromators (Figure 45 & Figure 46). It does the following actions in this order:

- Open the logical UNIX devices /dev/mono1 and /dev/mono2.
- Clear these devices.
- Configure the End Of String character on the GPIB (on both devices) to '>' which is the character used by the MS257 to end the messages it sends.
- Query the ID of /dev/mono1 (version number of internal software).
- Query the wavelength unit and changing it to 'NM' (nanometer) if needed (on both devices).
- Set the output port of /dev/mono2 to B.
- Set the filter number 1 on the density filter wheel on /dev/mono1 (1: attenuation of 100%, 2: 10%, 3: 1%, 4: 50%, 5: 25%); the density filter wheel is attached to /dev/mono1.
- Set the order sorting filter wheel so that below 500 nm the filter 1 is used, between 500 and 700 nm the filter 2 and over 700 nm the filter 3.
- Set the bandpass at 10 nm on both devices.
- Query the maximum wavelength reachable with the grating.
- Set the current wavelength at 632nm.

Special characteristics of the MS257:

- The MS257 does not have service request (SRQ) capabilities. So that, we have to wait between the moment we send a command and the moment we can read the result. A standard time out of 2 seconds is needed; for the commands that invoke movements (gratings rotation, slit width, ...), the time-out must be of 5s. These values have been determined experimentally.

- Sometimes, after a long time online, it is impossible for fcdtserver to get connected with the MS257 and initialise it. The only solution is to turn the power off of the two monochromators and then to turn them on in the right order (first MS257_1, next MS257_2).

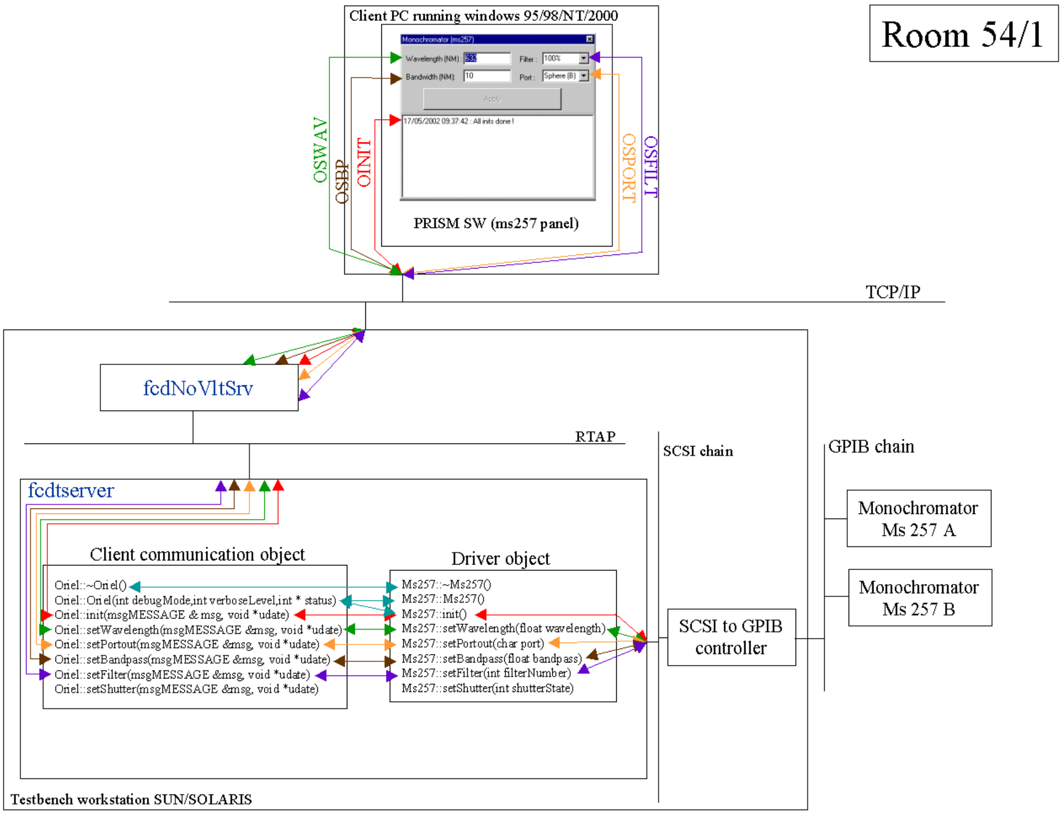


Figure 44 Software architecture from the client PC to the monochromator MS257

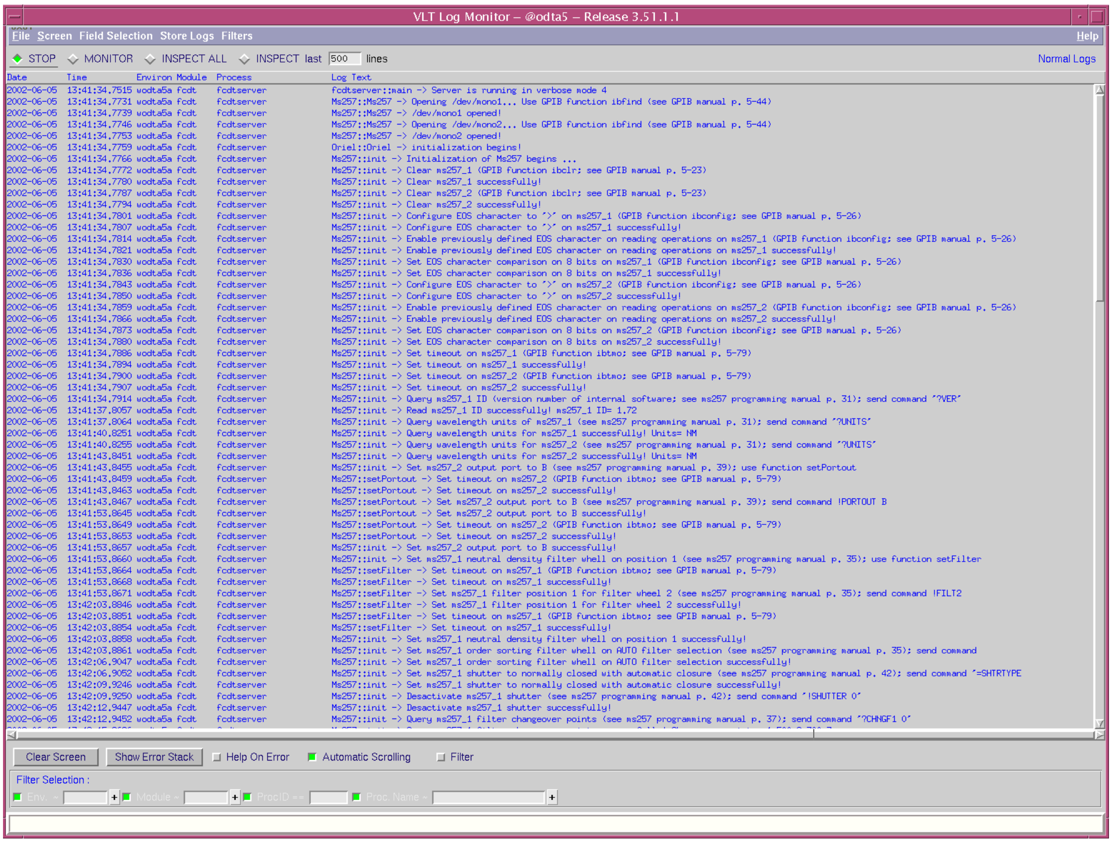


Figure 45 Messages in the logMonitor during the initialisation of the monochromator (verbosity level 4)

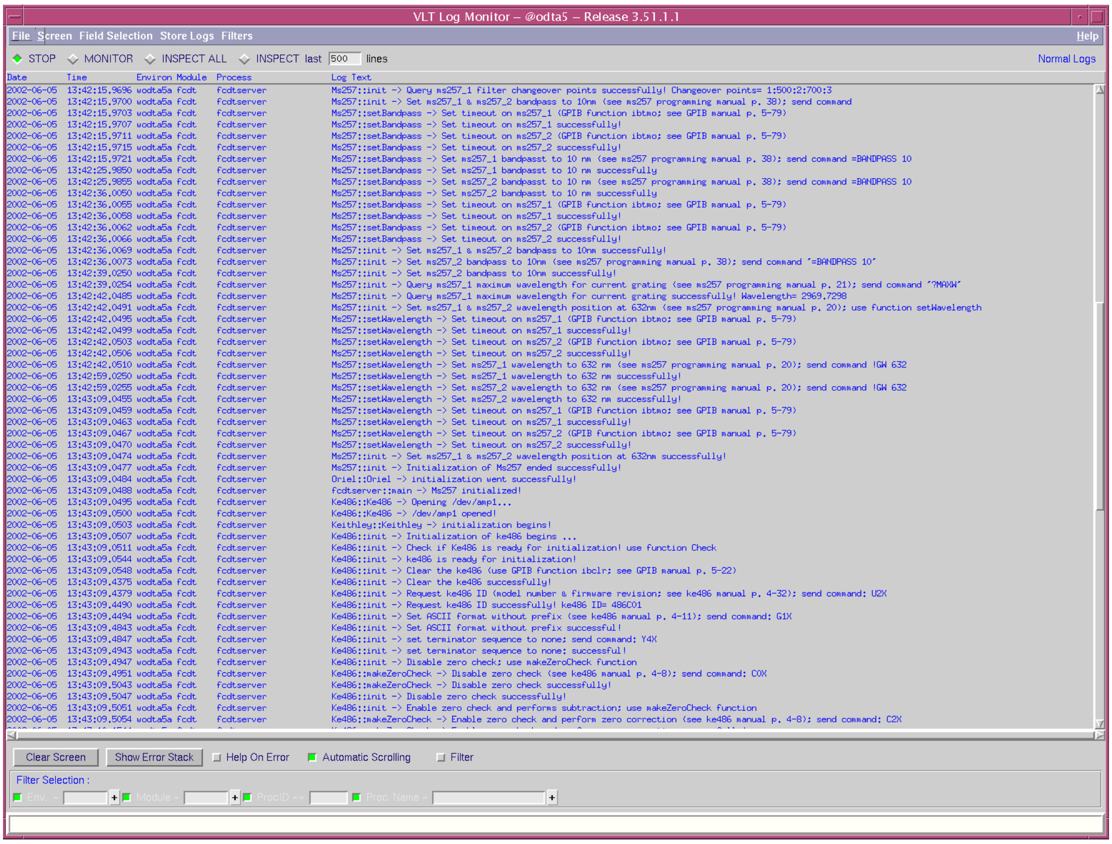


Figure 46 Messages in the logMonitor during the initialisation of the monochromator and the ke486 (verbosity level 4)

Then, the ammeter Ke486 (Figure 46 & Figure 48):

- Open the logical UNIX device /dev/amp1.
- Clear this device.
- Query the ID of /dev/amp1 (model number and firmware revision).
- Set ASCII format without prefix and without terminator sequence for the data transfer.
- Enable zero check and performing zero correction.
- Enable digital + analog filters.
- Query the complete status word.

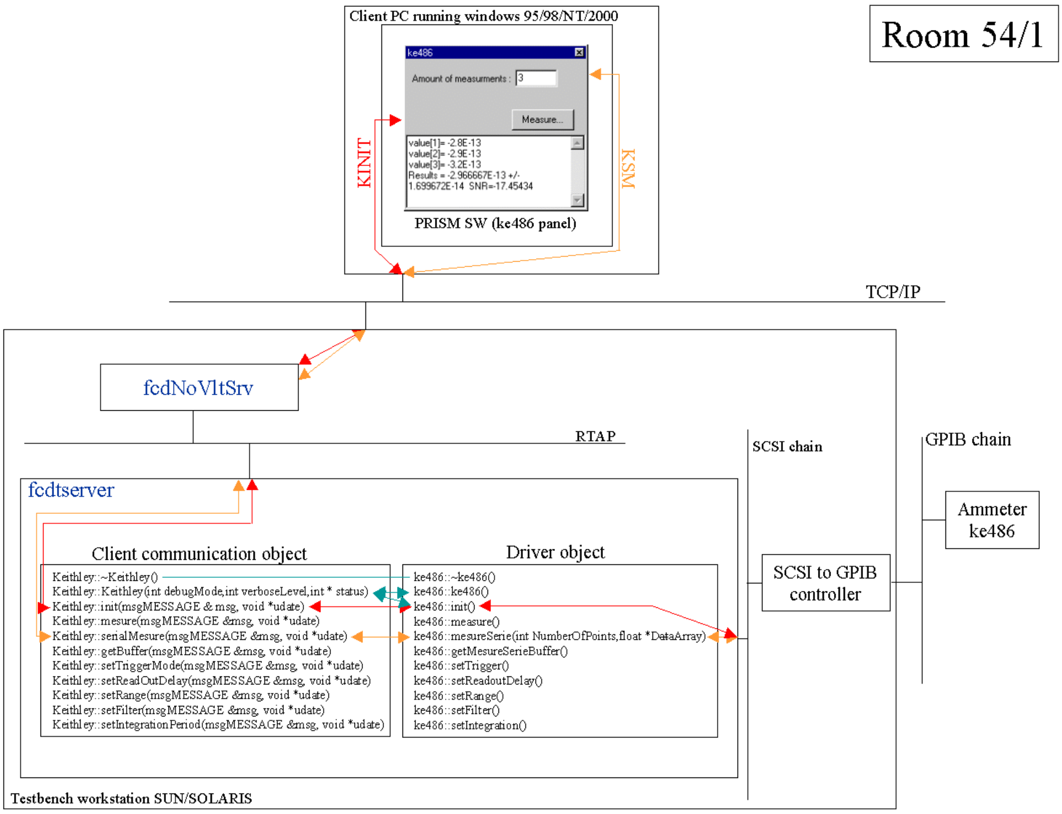


Figure 47 Software architecture from client PC to the ammeter ke486

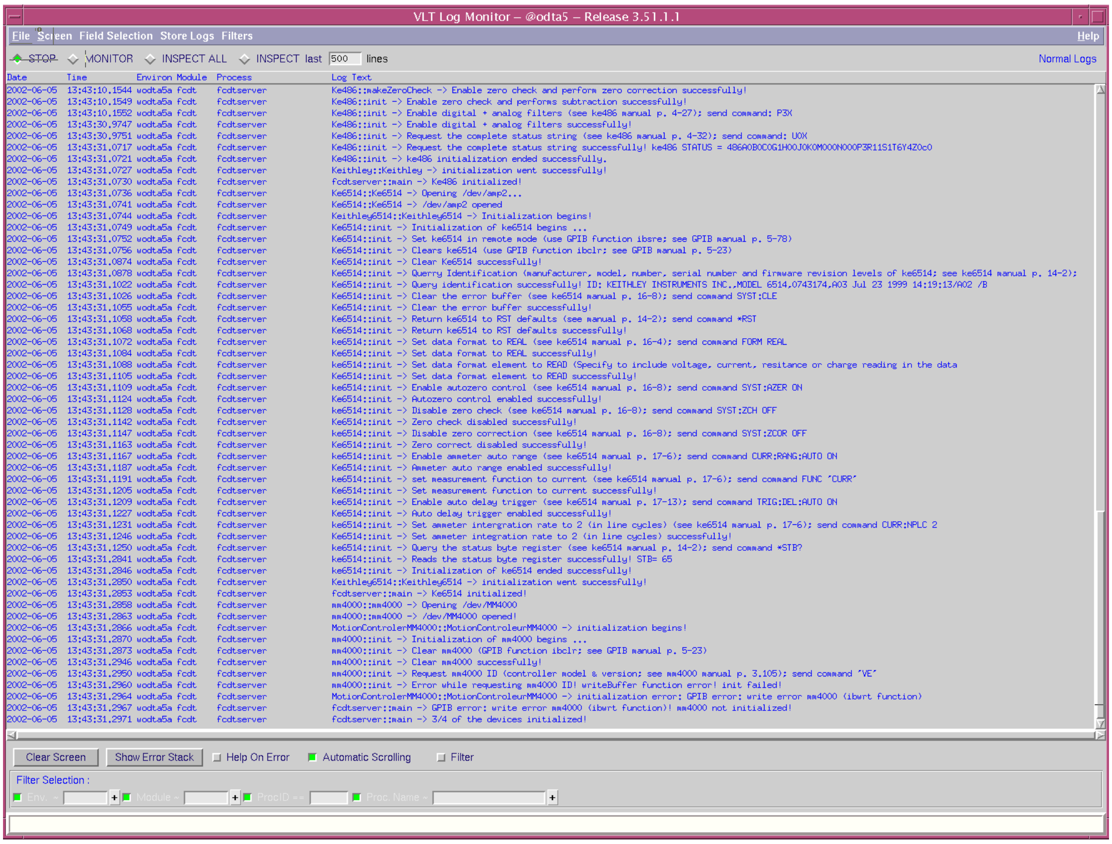


Figure 48 Messages in the logMonitor during the initialisation of the 486, the ke6514 and the MM4000 (verbosity level 4)

Next, the ammeter Ke6514 (Figure 48):

- Open the logical UNIX device /dev/amp2.
- Clear this device.
- Query the ID of /dev/amp1 (manufacturer, model, number, serial number and firmware revision).
- Clear the error buffer.
- Reset to the default conditions and cancel all pending commands.
- Set data format to real.
- Enable autozero control and disable zero check.
- Enable auto range selection.
- Select current measurements.
- Enable auto delay trigger
- Set integration rate to 2 cycles/mn.
- Query the status byte register.

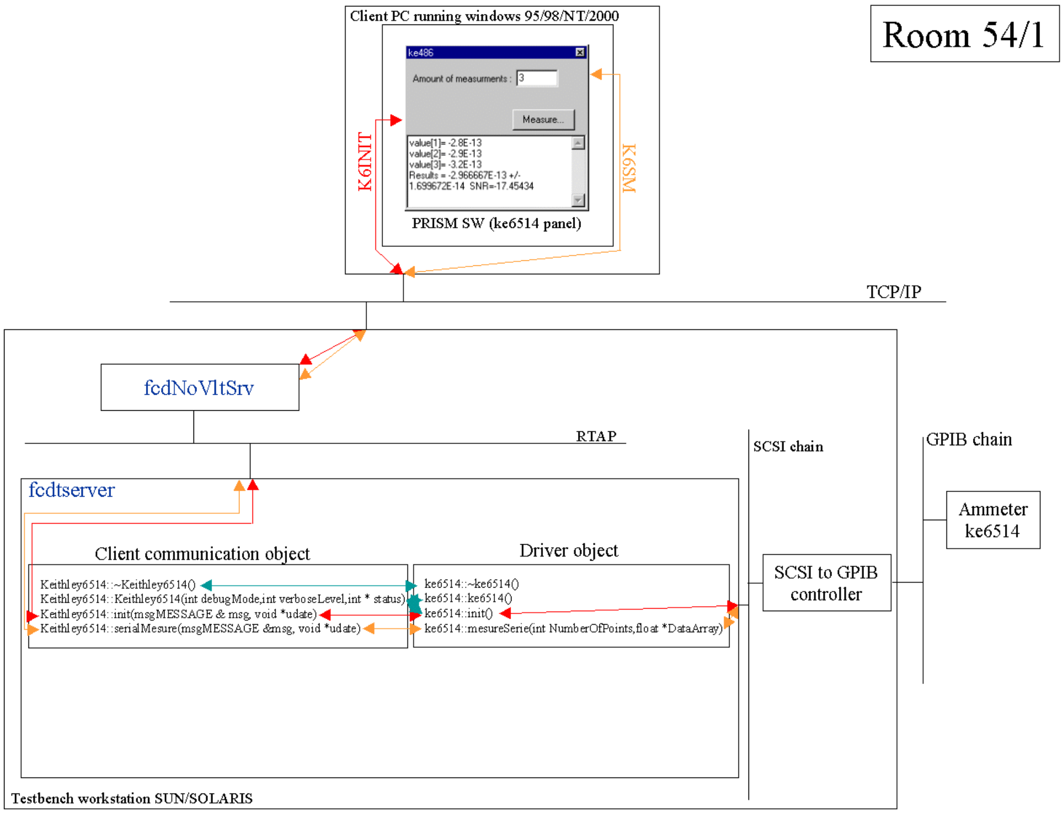


Figure 49 Software architecture from the client PC to the ammeter ke6514

Finally, the motion controller mm4000 (Figure 48):
Open the logical UNIX device /dev/MM4000.
Clear this device.
Query the ID of /dev/MM4000 (controller model and version).
Set motor power ON.

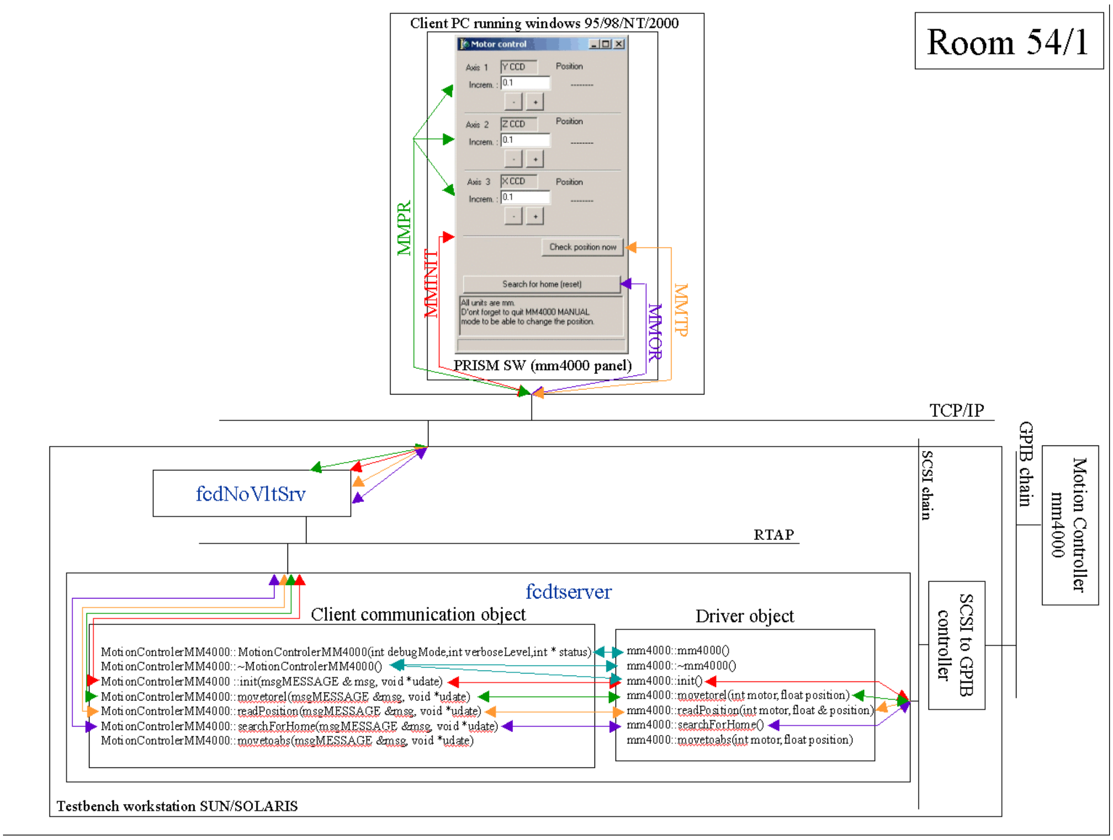


Figure 50 Software architecture from the client PC to the motion controller MM4000

Special characteristics of the MM4000:

- Like the MS257, the MM4000 does not have service request (SRQ) capabilities. Therefore, we have to wait between the moment we send a command and the moment we can read the result. A time-out of 2 seconds is needed. This value has been determined experimentally.

Meaning of the verbosity levels:

- 0: this is the default; only messages coming from the main program are provided.
- 1: previous messages + error messages from the "client communication object".
- 2: previous messages + information messages from the "client communication object".
- 3: previous messages + error messages from the "driver object".
- 4: previous messages + information messages from the "driver object".
- 5: previous messages + messages from GPIB based functions readBuffer() and writeBuffer().

This is a typical output provided by the daemon start up with verbosity level 4.

For other unexpected behaviours of the testbench, the user can refer to the TestbenchLog.doc file (a shortcut to this file is present on the desktop). This file contains the problems we have already experienced.

An FTP server must be running (port 21) at the workstation's side, so that PRiSM will be able to pick up image FITS files from the /DETDATA directory.

3.3.5 The rtdServer

Next, you have to launch the Real Time Display Server (command: rtdServer; item n. 4 in the " Start testbench's process" menu) that is needed by the RTD software to display images (RTD software can be launched threw the fcdSlcuCon interface). See “Real Time Display User Manual” for more information (Doc.No. VLT-MAN-ESO-17240-0866).

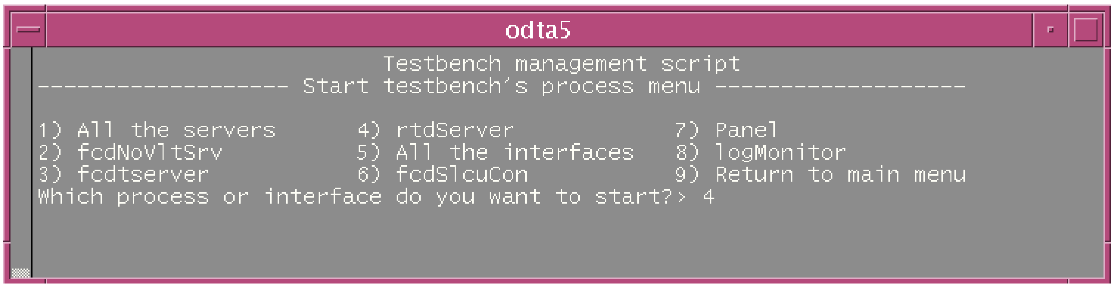


Figure 51 Testbench management script: starts rtdServer

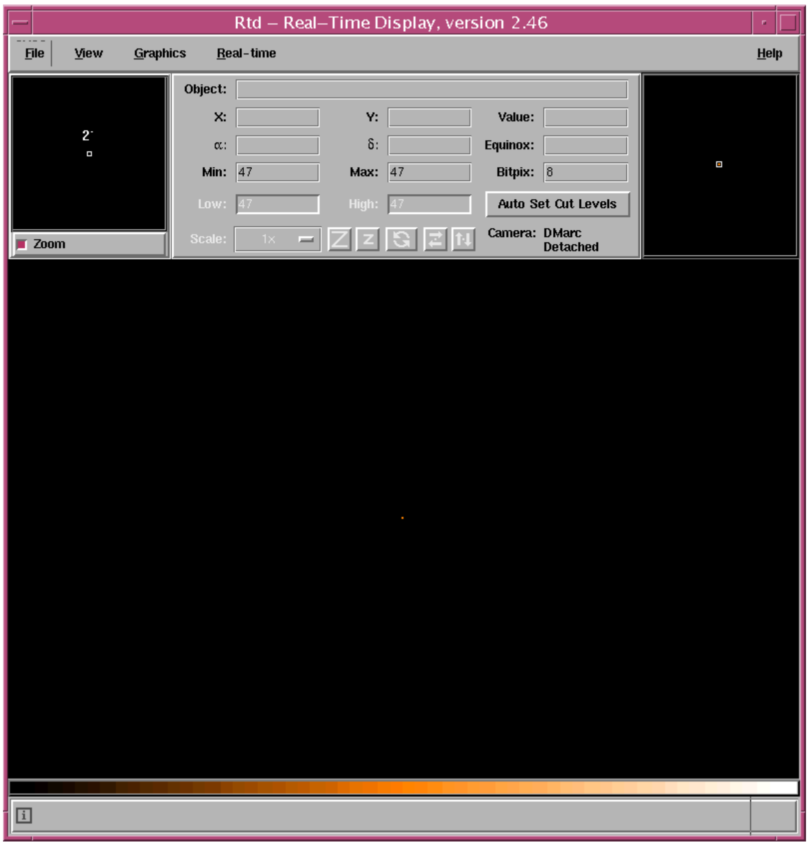


Figure 52 rtd interface

3.4 *Interface*

The only tool available is a local control panel (item n. 7 in the "Start testbench processes" menu) located at {root} /tbenchTest/interface/panel.pan (Figure 53).

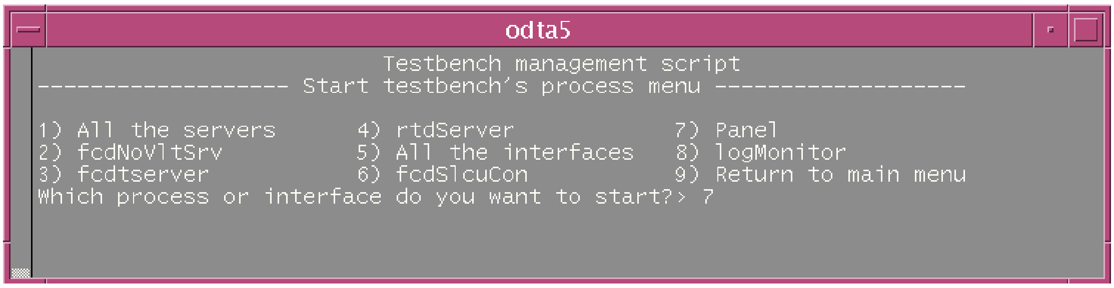


Figure 53 Testbench management script: starts panel.pan

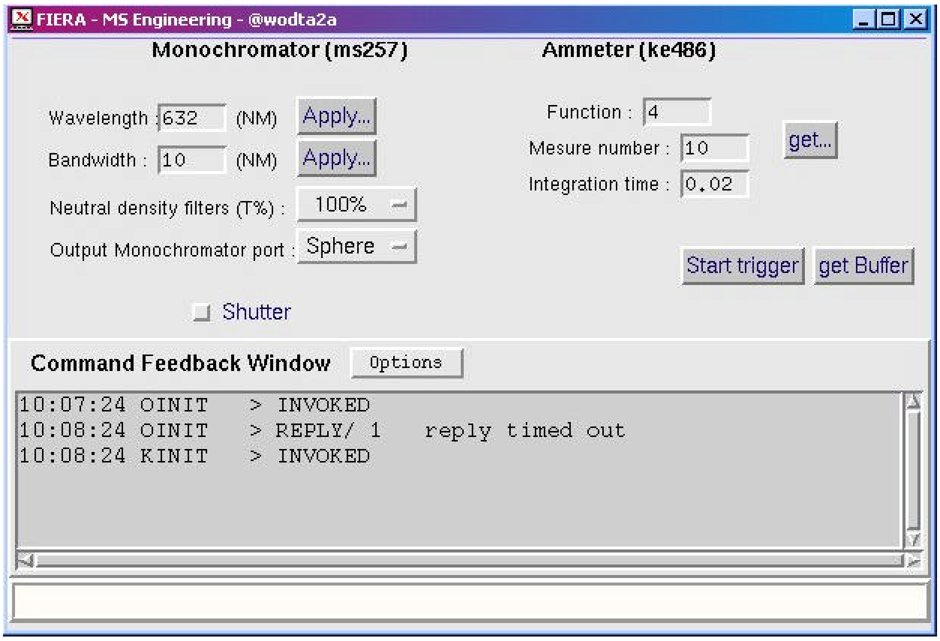


Figure 54 The panel.pan interface

This panel controls the monochromators and the ke486 ammeter locally and interactively. Press buttons and sometime it takes time to get the reply, but please be patient (Figure 54).
For instance:
11:57:57 OSWAV > INVOKED
11:58:12 OSWAV > REPLY/ L OK

4 From the client's side

4.1 Network configuration

A wrong network configuration can cause connection problems (such as timeout error) not so obvious to understand.
Open the properties menu from Network and Dial-up Connection icon on the desktop. You should obtain this window (Figure 55):

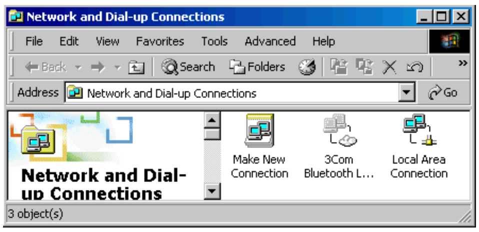


Figure 55 Network configuration: network and dial-up connection properties

Then, open the properties menu of Local Area Connection. You should obtain that (Figure 56):

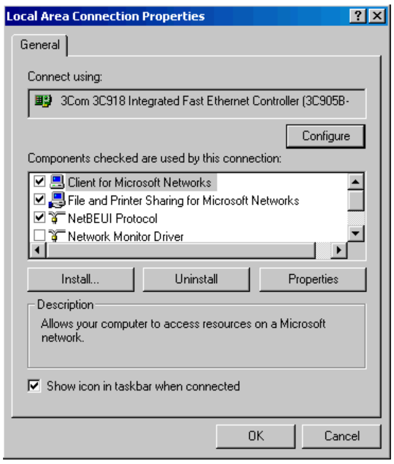


Figure 56 Network configuration: local area connection properties

Select the configure button and check the configuration in each tab (Figure 57 & Figure 58 & Figure 59):

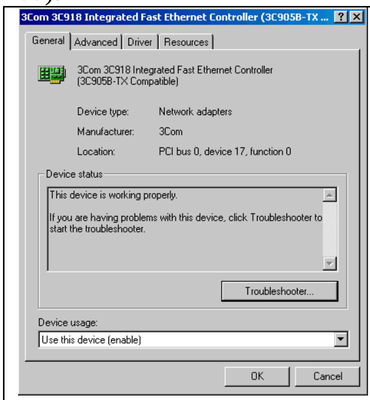


Figure 57 Network configuration: general tab

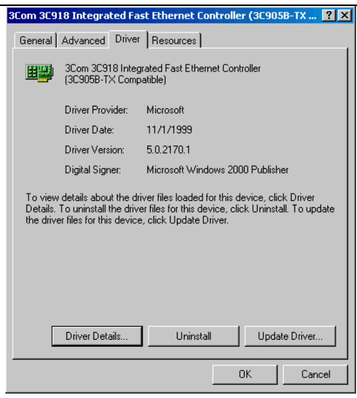


Figure 58 Network configuration: driver tab

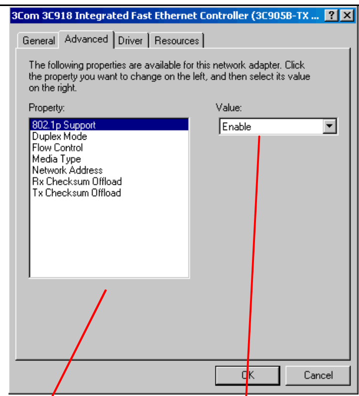


Figure 59 Network configuration: advanced tab

802.1p Support	Enable
Duplex Mode	Hardware Default
Flow Control	Disable
Media Type	Auto Select
Network Address	not present
Rx Checksum Offload	Enable
Tx Checksum Offload	Enable

4.2 Prism SW

It's needless to say that all the servers (Pulpo, FIERA and testbench devices) must be running on the workstation.

4.2.1 The monochromator

Selecting the following menu initiate the connection with the monochromator (Figure 60):

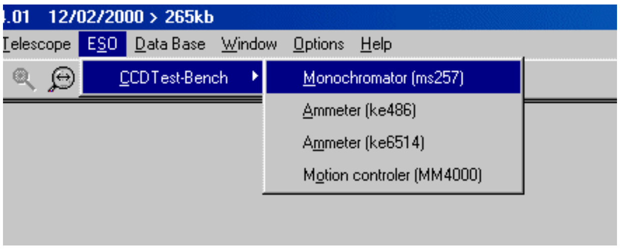


Figure 60 PRiSM software: monochromator menu

The following window should appear (Figure 61):

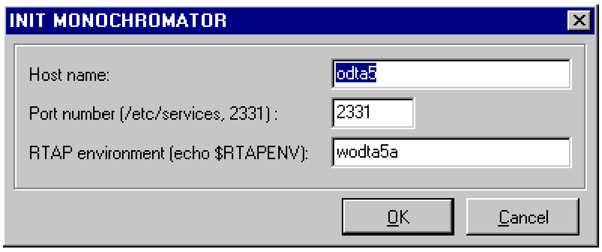


Figure 61 PRiSM software: monochromator init box

The parameters are:

- "Host name": The name of the UNIX workstation (for example: "odta5" or "134.171.5.155").
- "Port number": The tcp-ip socket port number (here 2331).
- "RTAP environment": The name of the RTAP environment. See the $RTAPENV value in the UNIX station environment.

After a while (~90s), a dialog box appears, the parameters that you want to apply to the testbench can be set here (Figure 62).

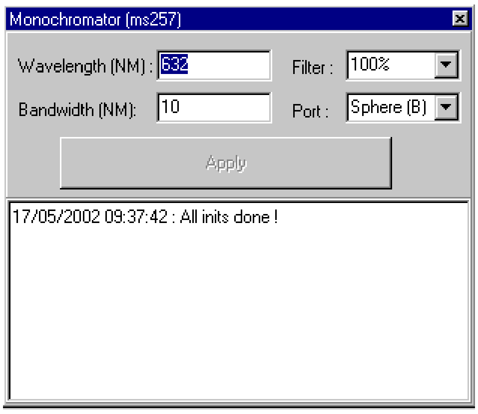


Figure 62 PRiSM software: monochromator dialogs box

The script commands available for the monochromator are:

- "**SetMonochromatorWav**"
  This function sets a wavelength value in nanometer (between 0 and 2500).
  Example:
  # Set the monochromator value to 620nanometer
  SetMonochromatorWav 620

- "**SetMonochromatorFilter**"
  This function selects the neutral density filter.
  Each value corresponds to a specific filter:
  for 100%, value = 1
  for 50%, value = 2
  for 25%, value = 3
  for 10%, value = 4
  for 1%, value = 5

Example:
Set the monochromator filter position to 50%
SeMonochromatorFilter 2

- "**SetMonochromatorBandwidth**"
  This function sets the monochromator bandwidth (in nanometer).
  Example:
  # Set the monochromator bandwidth to 10 nanometers
  SetMonochromatorBandwidth 10

- "**SetMonochromatorPort**"
  This function sets the monochromator output port (B or C).
  For port B, value =1 (
  For port C, value =2 (
  Example:
  # Set the output port monochromator B
  SetMonochromatorPort 1

- "**MonochromatorShutter**"
  Set the monochromator shutter stats.
  For open position, value=0.
  For closed position, value=1.
  Example:
  # Close the shutter
  MonochromatorShutter 1

Here an example of the monochromator interface in use (Figure 63):

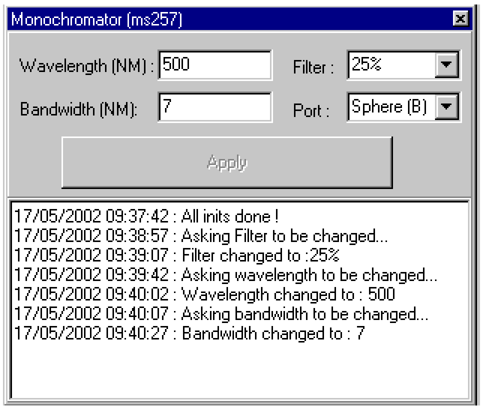


Figure 63 PRiSM software: monochromator dialogs box in use

And here a typical output in the logMonitor when we ask for a new wavelength (Figure 64):

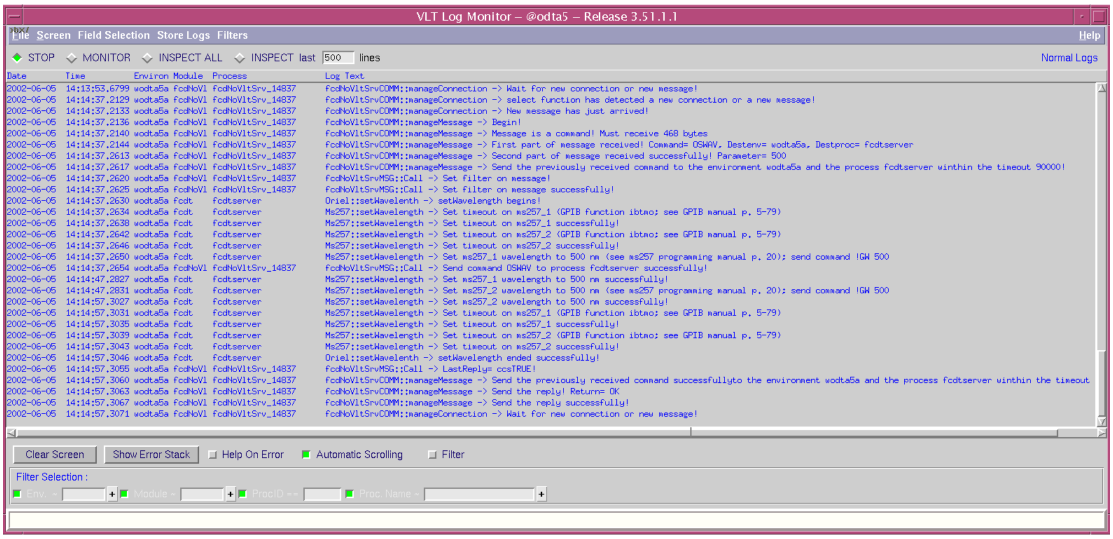


Figure 64 Messages in the logMonitor while a command is executed by the monochromator

4.2.2 The ammeters (ke486 and ke6514):

You have to initialise the ammeter by selecting the following menu (Figure 65):

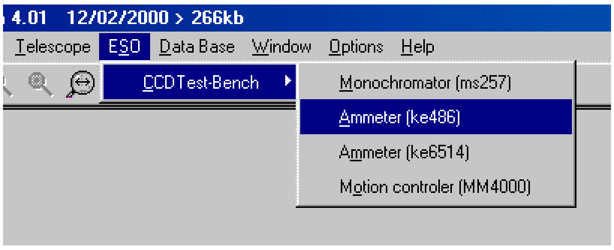


Figure 65 PRiSM software: Ammeter menu

The following window should appear (Figure 66):

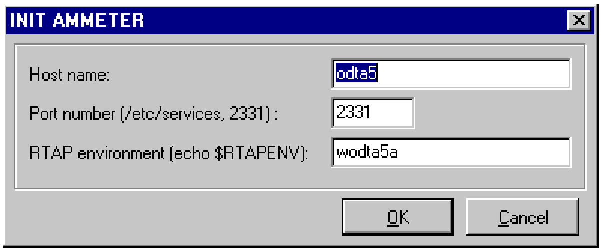


Figure 66 PRiSM software: ammeter init box

The parameters are the same for the monochromator:

- "Host name": The name of the UNIX station (for example: "odta5" or "134.171.5.155").
- "Port number": The tcp-ip socket port number talking to the fcdNoVLTSrv: 2331.
- "RTAP environment": The name of the RTAP environment. See the $RTAPENV value in the UNIX station environment.

After a small time (~20s for the ke486 and almost instantaneously for the ke6514, a dialog box appear in which you can choose the parameters that you want to apply on the ammeter. For example, you can get the current ammeter value by pushing the "Measure" button (Figure 67).

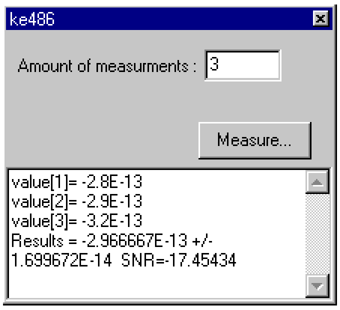


Figure 67 PRiSM software: ammeter dialogs box in use

The script function available for the ammeter is:

- "**GetAmmeterMeasure**"
  This function gets the ammeter value.
  The parameters are:
  The kind of measurement: in general, the value is 4 (see the ammeter documentation information)
  The sample number: from 1 to 50 measurements
  The integration time: from 0.01 s to 999.999 s
  The “MeasureValue” as output
  Example:
  #Get the ammeter value for the variable "MeasureValue" with a kind of measurement 4, a sample
  #number of 50 and an integration time of 0.02 s
  GetAmmeterMeasure 4 50 0.02 MeasureValue

Here a typical output in the logMonitor when we ask for a measurement with the ke486 (Figure 68):

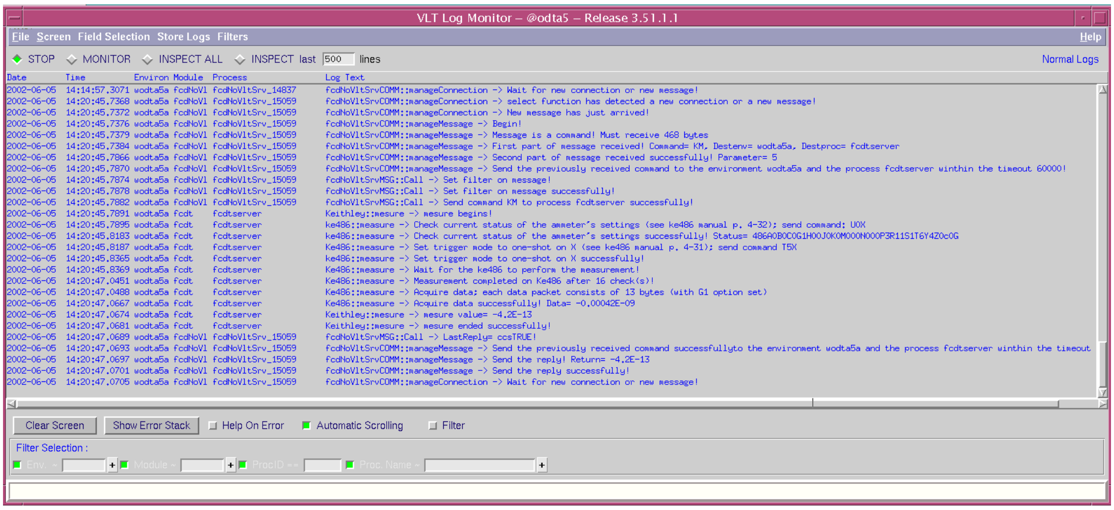


Figure 68 Messages in the logMonitor while the ke486 performs measurements

And here with the ke6514 (Figure 69):

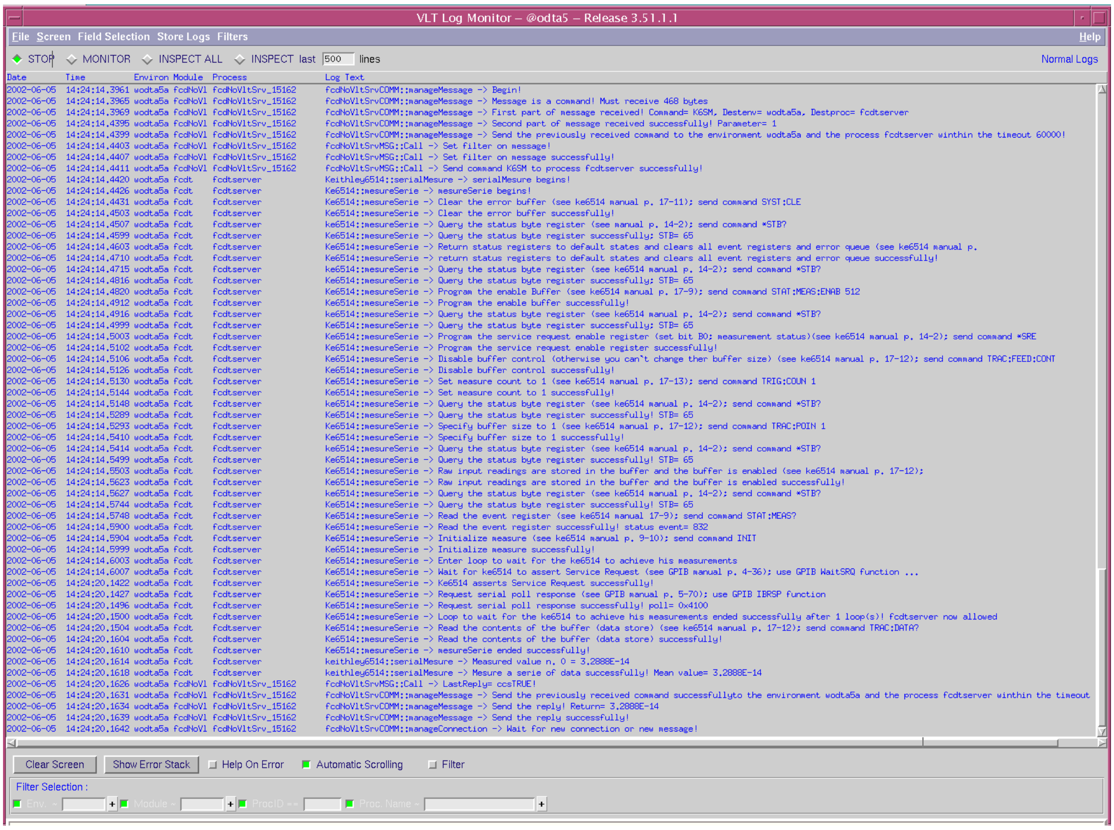


Figure 69 Messages in the logMonitor while the ke6514 performs measurements

4.2.3 The MM4000:

You have to initialise the ammeter by selecting the following menu (Figure 70):

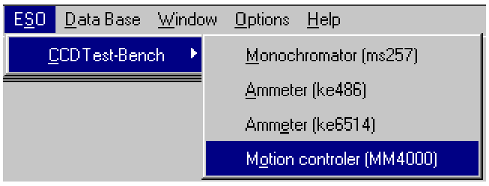


Figure 70 PRiSM software: MM4000 menu

The following window should appear (Figure 71):

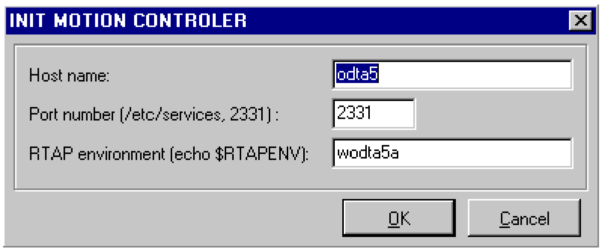


Figure 71 PRiSM software: MM4000 init box

The parameters are the same for the monochromator:

- "Host name": The name of the UNIX station (for example: "odta5" or "134.171.5.155")
- "Port number": The tcp-ip socket port number talking to the fcdNoVLTSrv: 2331.
- "RTAP environment": The name of the RTAP environment. See the $RTAPENV value in the UNIX station environment.

After a small time, a dialog box appear in which you can choose the parameters that you want to apply on the MM4000 (Figure 72).

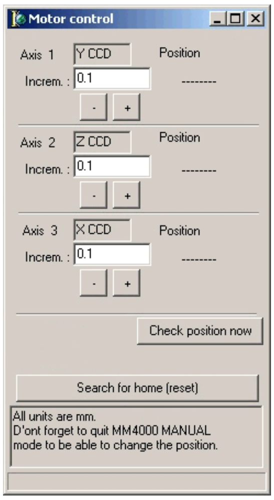


Figure 72 PRiSM software: MM4000 dialogs box

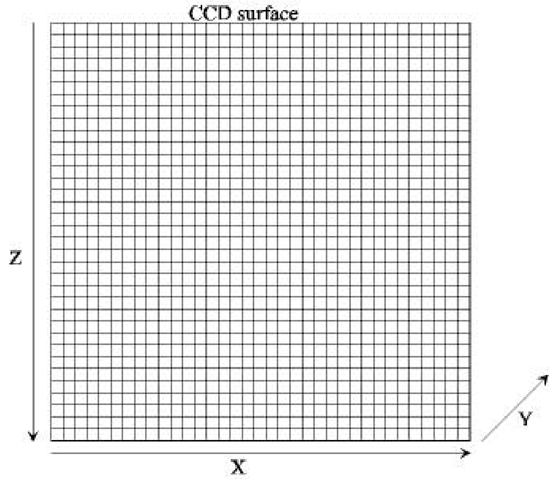


Figure 73 MM4000: defintion of the axis

The script commands available for the MM4000 are:

- "**MotionControlerMove**"
  This function asks mm4000 to move one motor.
  The input parameters are:
  The ID of the motor you want to move (1 -> Y CCD, 2 -> Z CCD, 3 -> X CCD) (Figure 71).
  The position to reach (in mm).
  No output parameters.
  Example:
  #Move the motor number 1 of 5 mm
  MotionControlerMove 1 5

- "**MotionControlerSearchForHome**"
  This function asks the mm4000 to search for home position.
  No parameter needed.

- "**MotionControlerGetPosition**"
  This function reads the actual position of one motor.
  The input parameter is the ID of the motor (1 -> Y CCD, 2 -> Z CCD, 3 -> X CCD).
  The output parameter is the actual position of the motor.
  Example:
  #Get the position in mm of motor number 1 in the variable "ActualPosition"
  MotionControlerGetPosition 1 "ActualPosition"

4.2.4 The fiera controller:

To have a complete description of the standard camera acquisition functions in Prism, see the following address: http://www.astrosurf.org/saturne/pap/PAP_help/recherche.html.
At first, you must choose FIERA as the standard controller in Prism For that, you can call the following menu (Figure 74):

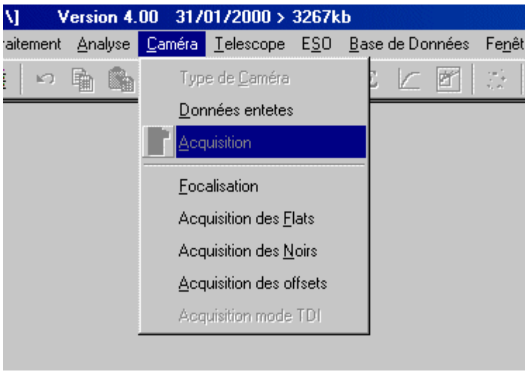


Figure 74 PRiSM software: camera controller menu

Now, you can call the CCD acquisition module and fill up this panel (Figure 75):

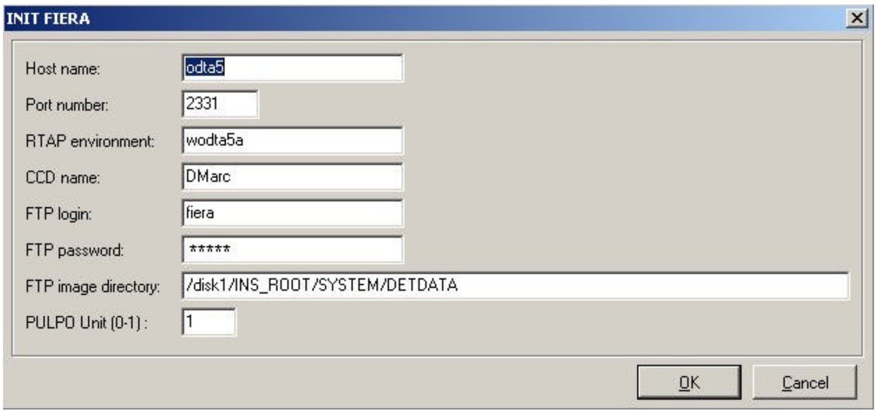


Figure 75 PRiSM software: camera controller init box

"Host name"	The name of the UNIX workstation hosting the FIERA-SW (for instance: "odta5" or "134.171.5.155").
"Port number"	The tcp-ip socket port number to talk to the fcdNoVltSrv. This one must be defined as 2331.
"RTAP environment"	The name of the RTAP environment. See the echo $RTAPENV value in the UNIX workstation environment.
"CCD name"	The name of the current CCD. It should be the value of the environment variable by echo-ing $CCDNAME on the Solaris workstation.
"FTP login"	The login of the FTP server, this FTP account should have read access to the "Image directory", otherwise it will fail.
"FTP password"	The password of the workstation's FTP server.
"Image directory"	Where FIERA drops by default the image, {$INS_ROOT}/DETDATA usually.

4.2.5 FIERA parameters

The common FIERA parameters are available in the "Camera" panel:

4.2.6 CCD temperature, vacuum and heaters power

All monitoring values are available in the "CCD monitoring panel":

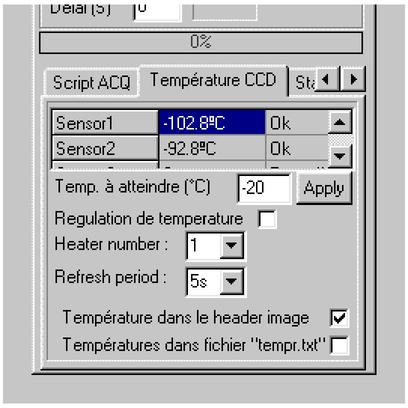


Figure 76 PRiSM software: monitoring values in the camera controller dialog box

All sensor values are available automatically through an array (Figure 76).
If you want to display a real time variation graph, you need only to click to the value.

4.2.7 Prism programming language

If you want to have complete and explicit help about the Prism programming language, see the following page:
To launch a Prism script, click the button in the "Script ACQ" panel:

To have some examples, see the "tbenchScriptPack".

5 Testbench cookbook

5.1 Testbench calibration

5.1.1 Principle

To be able to monitor the photon flux at the CCD surface during a serie of measurement, you have to know the ratio between the flux at the diode sphere position and the flux at the CCD surface position. For that purpose, a si-Photodiode (Hamamatsu S5287-1010R), that has been previously calibrated by the “Physikalisch-Technische Bundesanstalt” on April 2001 (see Table 3 that give the response of the photodiode in function of the wavelength), is placed at the position normally occupied by the CCD.

Wavelength (nm)	$S\phi(\lambda)$ (mA.W^{-1})	Relative Error (%)	Wavelength (nm)	$S\phi(\lambda)$ (mA.W^{-1})	Relative Error (%)
300.0	34.7	1	660.0	400.4	1
310.0	119.3	1	680.0	414.1	1
320.0	132.6	1	700.0	427.6	1
330.0	142.1	1	720.0	441.3	1
340.0	150.6	1	740.0	454.7	1
350.0	155.2	1	760.0	468.2	1
360.0	155.3	1	780.0	481.8	1
370.0	160.2	1	800.0	495.2	1
380.0	175.9	1	820.0	508.5	1
390.0	191.4	1	840.0	521.8	1
400.0	204.2	1	860.0	534.6	1
420.0	224.8	1	880.0	547.3	1
440.0	242.6	1	900.0	559.0	1
460.0	259.0	1	920.0	571.0	1
480.0	274.4	1	940.0	583.7	1
500.0	289.1	1	960.0	593.1	1
520.0	303.5	1	980.0	593.4	1
540.0	317.6	1	1000.0	573.6	1
560.0	331.5	1	1020.0	520.3	1

580.0	345.4	1	1040.0	419.2	1
600.0	359.2	1	1060.0	284.3	1
620.0	372.9	1	1080.0	193.4	1
640.0	386.8	1	1100.0	126.3	1

Table 3 Response of the Photodiode (Sf) in function of the wavelength

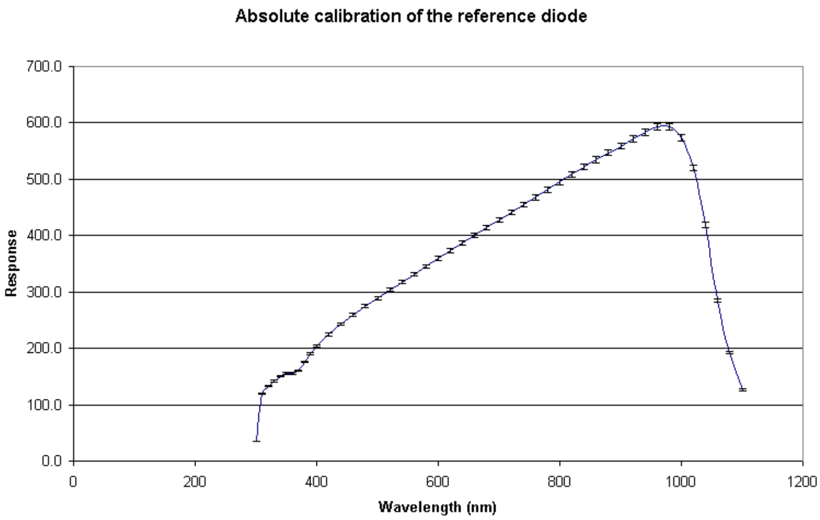


Figure 77

5.1.2 Realisation

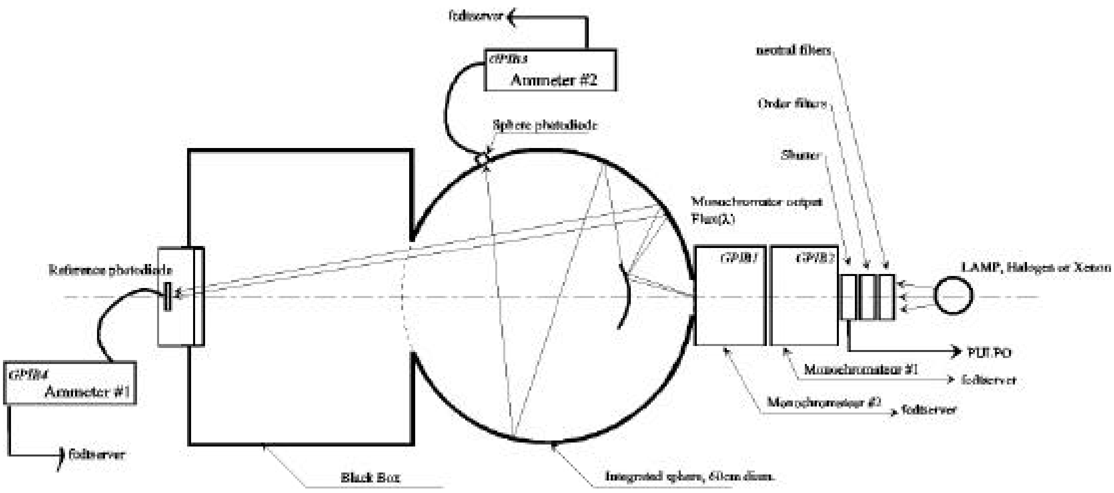


Figure 78 Testbench calibration principle

For this measurement, you need the monochromators, the two ammeters, the fcdNoVltSrv and fcdtserver running on the workstation, PRiSM running on the client PC. See section 3 for more information.

The PRiSM script "calibrate.pgm" performs measurements at the same wavelengths provided by Table 3. For each wavelength, it associates the photon flux at the calibrated Photodiode with the current value of the Sphere photodiode. Therefore, the Sphere photodiode is calibrated and can be used as a photon flux monitoring system that does not perturb the measurements.

As a result, the script gives you a file containing …

Wavelength (nm)	Flux (Photons/sec/cm2)	Current (Amps)	Error (Photons/sec/cm2)	Error (Amps)
300	1.146E+08	8.78E-11	2.4E+05	1.5E-13
310	1.606E+08	1.76E-10	5.2E+05	4.6E-13
320	3.264E+08	3.20E-10	3.2E+05	2.2E-13

330	5.488E+08	5.28E-10	7.5E+05	8.3E-13
340	8.573E+08	8.11E-10	1.0E+06	1.0E-12
350	1.295E+09	1.19E-09	9.9E+05	5.5E-13
360	1.866E+09	1.64E-09	1.4E+06	8.4E-13
370	2.596E+09	2.24E-09	4.7E+06	1.1E-12
380	3.419E+09	3.13E-09	4.0E+06	1.4E-12
390	4.423E+09	4.29E-09	4.0E+06	2.3E-12
400	5.474E+09	5.55E-09	4.2E+06	2.0E-12
420	7.890E+09	8.45E-09	4.4E+06	7.9E-12
440	1.042E+10	1.15E-08	6.7E+06	8.6E-12
460	1.277E+10	1.44E-08	7.4E+06	7.2E-12
480	1.498E+10	1.72E-08	5.3E+06	9.2E-12
500	1.418E+10	1.64E-08	9.8E+06	1.3E-11
520	1.532E+10	1.79E-08	8.2E+06	1.4E-11
540	1.550E+10	1.82E-08	2.8E+06	8.5E-12
560	1.615E+10	1.91E-08	1.1E+07	8.3E-12
580	1.518E+10	1.81E-08	5.3E+06	7.3E-12
600	1.552E+10	1.86E-08	9.9E+06	7.2E-12
620	1.537E+10	1.85E-08	6.8E+06	1.2E-11
640	1.452E+10	1.76E-08	6.9E+06	9.2E-12
660	1.344E+10	1.63E-08	4.7E+06	2.7E-12
680	1.233E+10	1.48E-08	4.3E+06	6.3E-12
700	1.162E+10	1.37E-08	1.5E+07	2.2E-11
720	1.062E+10	1.21E-08	4.4E+06	2.9E-12
740	9.486E+09	1.05E-08	4.4E+06	1.4E-12
760	8.220E+09	8.72E-09	3.2E+06	2.5E-12
780	7.016E+09	7.13E-09	3.1E+06	1.8E-12
800	5.626E+09	5.44E-09	4.1E+06	3.3E-13
820	6.120E+09	5.56E-09	2.1E+06	5.6E-13
840	5.934E+09	4.97E-09	3.4E+06	7.5E-13
860	5.865E+09	4.44E-09	5.6E+06	3.7E-12
880	5.830E+09	3.93E-09	6.7E+06	2.2E-12
900	5.160E+09	3.03E-09	3.3E+06	1.6E-12
920	8.164E+09	4.06E-09	3.1E+06	1.8E-12
940	1.124E+10	4.56E-09	6.8E+06	2.0E-12
960	1.204E+10	3.81E-09	7.0E+06	1.1E-12
980	1.166E+10	2.76E-09	2.8E+06	1.3E-12
1000	1.101E+10	1.84E-09	6.0E+06	4.3E-13
1020	1.018E+10	1.14E-09	8.5E+06	4.0E-13
1040	9.487E+09	6.75E-10	6.1E+06	3.1E-13
1060	9.041E+09	4.02E-10	4.9E+06	8.3E-14
1080	8.573E+09	2.54E-10	5.8E+06	1.2E-13
1100	8.348E+09	1.58E-10	3.6E+06	9.3E-14

Table 4 Calibration with the halogen lamp

Wavelength (nm)	Flux (Photons/sec/cm2)	Current (Amps)	Error (Photons/sec/cm2)	Error (Amps)
300	2.076E+09	1.53E-09	5.8E+05	1.4E-12
310	2.550E+09	2.54E-09	1.1E+06	1.6E-12
320	3.911E+09	3.77E-09	3.0E+06	1.4E-12
330	5.326E+09	5.06E-09	4.0E+06	2.5E-12
340	6.837E+09	6.46E-09	3.0E+06	3.1E-12
350	8.570E+09	7.94E-09	7.8E+06	4.1E-12
360	1.053E+10	9.34E-09	8.2E+06	9.3E-12
370	1.242E+10	1.08E-08	3.6E+06	7.2E-12

380	1.395E+10	1.29E-08	8.3E+06	7.6E-12
390	1.545E+10	1.51E-08	4.0E+06	1.9E-11
400	1.723E+10	1.75E-08	7.3E+06	5.2E-12
420	1.864E+10	1.99E-08	1.2E+07	9.7E-12
440	1.928E+10	2.12E-08	9.0E+06	1.5E-11
460	2.252E+10	2.54E-08	8.6E+06	1.2E-11
480	2.163E+10	2.47E-08	6.0E+06	1.3E-11
500	1.551E+10	1.80E-08	1.2E+07	7.8E-12
520	1.434E+10	1.67E-08	7.4E+06	9.0E-12
540	1.277E+10	1.50E-08	5.6E+06	7.5E-12
560	1.196E+10	1.41E-08	6.8E+06	6.1E-12
580	1.026E+10	1.21E-08	8.8E+06	4.4E-12
600	9.397E+09	1.11E-08	5.9E+06	5.8E-12
620	9.279E+09	1.10E-08	1.5E+06	5.0E-12
640	7.507E+09	8.87E-09	6.7E+06	5.4E-12
660	6.448E+09	7.60E-09	9.0E+06	2.9E-12
680	6.066E+09	7.10E-09	6.2E+06	4.8E-12
700	5.032E+09	5.79E-09	7.0E+06	4.7E-12
720	4.544E+09	5.07E-09	1.5E+06	2.2E-12
740	4.357E+09	4.71E-09	3.5E+06	3.1E-12
760	4.093E+09	4.27E-09	5.9E+06	1.4E-12
780	2.161E+09	2.16E-09	1.9E+06	7.4E-13
800	2.105E+09	2.02E-09	4.9E+06	9.2E-13
820	9.628E+09	8.64E-09	8.6E+06	5.3E-12
840	4.678E+09	3.95E-09	3.8E+06	2.3E-12
860	1.583E+09	1.21E-09	4.8E+05	3.2E-13
880	1.510E+10	1.02E-08	8.1E+06	6.3E-12
900	7.900E+09	4.75E-09	3.9E+06	1.6E-12
920	1.676E+10	8.66E-09	6.7E+06	4.2E-12
940	1.295E+10	5.41E-09	7.9E+06	1.6E-12
960	5.542E+09	1.84E-09	2.2E+06	9.1E-13
980	2.587E+10	6.34E-09	4.9E+06	1.4E-12
1000	7.870E+09	1.41E-09	7.0E+06	9.8E-13
1020	3.656E+09	4.33E-10	3.4E+06	1.9E-13
1040	2.128E+09	1.59E-10	8.9E+05	6.6E-14
1060	2.439E+09	1.13E-10	5.4E+05	1.1E-13
1080	2.890E+09	8.94E-11	9.0E+05	8.4E-14
1100	1.517E+09	2.92E-11	7.0E+05	1.0E-13

Table 5 Calibration with the xenon lamp

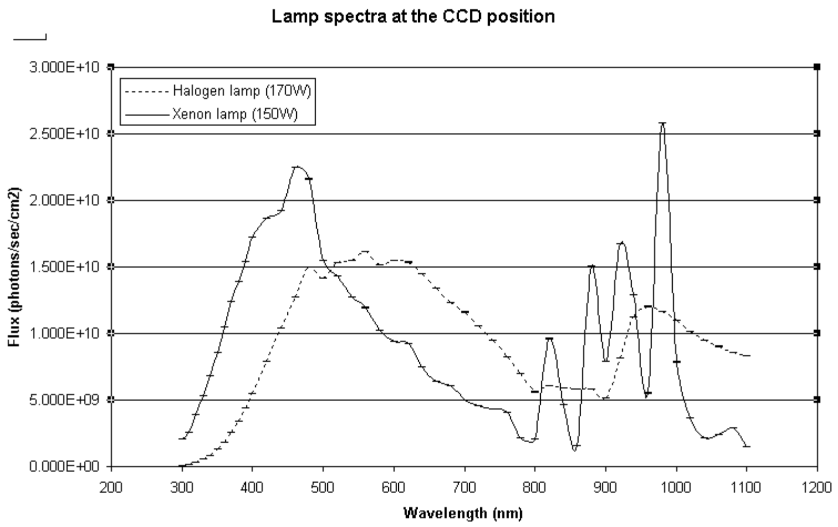


Figure 79 Spectra of the Halogen (short dashed line) and Xenon (continuous line) lamp at the CCD position

5.2 CCD measurements

5.2.1 Preliminary

Figure 80 Detector head used on the testbench: (1) Pre-ampli connector (FIERA), (2) Liquid Nitrogen input (nitrogen line), (3) Nitrogen output (vacuum controller) and (4) vacuum tap (vacuum pump).

Figure 81 Detector head used on the testbench: (5) pulpo connector (pulpo), (6) system connector (FIERA), (7) bias connector (FIERA) and (8) vacuum gauge (vacuum controller).

First of all, you should mount, in the clean room, the two CCDs you want to test in the D Marconi detector head. You must spot the position (A or B) of the two CCDs, as suggested by Figure 82.

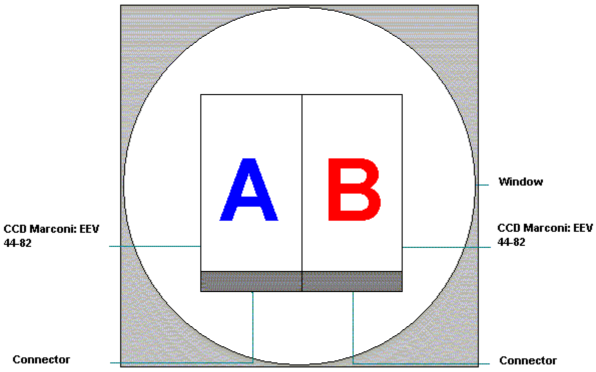


Figure 82 Denomination of the position of the two CCDs in the D Marconi head

After installing the head on the testbench as shown by Figure 2, you have to connect it to the vacuum pump, the vacuum controller, the liquid nitrogen (LN) line, the video pre-amp, FIERA and pulpo (**do not forget to connect yourself to the ground**). All the connection points are shown on Figure 80 and Figure 81. At that point, you can put online the cooling system (Figure 86), FIERA and pulpo (Figure 87) (**in this order please!**).
Then you should put online the vacuum pump. When the vacuum is good enough (< 10^{-3} mbar), you can begin to fill the dewar with LN. A few hours later, the vacuum and the temperature should be stabilised respectively around 10^{-5} mbar and -120 °C (typical temperature target).

Figure 83 Vacuum pump controller

Figure 84 Testbench vacuum pump

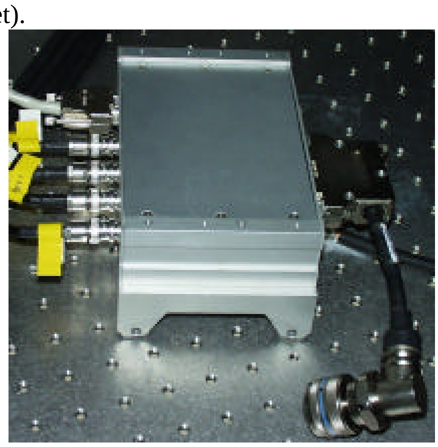


Figure 85 Video pre-amp

Figure 86 Fiera cooling system

Figure 87 Fiera and pulpo controllers

On the software part, you need fcdNoVltSrv FIERA software running (see sections 3.3.2 and 3.3.3). It is recommended to readout continuously the CCDs during their cooling down to prevent charge accumulation. Use the fcdSlcuCon interface (Figure 39). In the up left corner of the panel, check the item “forever”, choose a short exposure time (e.g. 1s) and a readout mode (e.g. 2). Then, press the START button.
You should be aware that the images given by the system are the concatenation of the images of the 2 CCDs. Therefore, you must know precisely the position and the size of each CCD array to be able to extract the subimage corresponding to each CCD.

5.2.2 Dark acquisitions

Be careful: the lamp must be switched off and the shutter closed.
The script “DarkandBiasAcquisition.pgm” drives these kinds of measurements.
After initialising the file names, the path directories… and checking whether the temperature is locked on the desired value (typically –120 ^{o}C), the script reads the “InfoDark.txt” file that contains the acquisitions to perform and then executes the lines sequentially.
As you can see, 3 readout modes (225kpix, 625kpix and 50kpix), 3 exposure times (1 hour, 15 minutes and bias) and two gains (low gain=LG and high gain=HG) are tested. For each configuration, 5 images are requested. Throughout its execution, the script updates the first field of this file so that if for any reason the script has to be interrupted, the next time it will be launched it would restore the execution at the same level.

Number of acquisitions already done	Initial start number of acquisitions	Number of acquisitions to perform	Info string
1	1	5	Acquisition dark LG 225kpix 1h
1	1	5	Acquisition dark LG 225kpix 15mn
1	1	5	Acquisition bias LG 225kpix
1	1	5	Acquisition dark HG 625kpix 1h
1	1	5	Acquisition dark HG 625kpix 15mn
1	1	5	Acquisition bias HG 625kpix
1	1	5	Acquisition dark HG 225kpix 1h
1	1	5	Acquisition dark HG 225kpix 15mn
1	1	5	Acquisition bias HG 225kpix
1	1	5	Acquisition dark HG 050kpix 1h
1	1	5	Acquisition dark HG 050kpix 15mn
1	1	5	Acquisition bias HG 050kpix

Table 6 Acquisitions performed by the script "DarkandBiasAcquisition.pgm" as it appears in the “InfoDark.txt” file

When the acquisitions are done, the script performs a basic reduction. For each group of acquisitions, it extracts and saves separately the images of the two CCDs and then for each CCD calculates a median image and also a binned one. Every image is saved in an appropriate directory. For example, see Figure 88: the dark and bias of the CCD named “Lepus” are archived first by gain (LG or HG), then by frequency readout (50kpix, 225 kpix and 625 kpix) and finally by type (bias, dark of 15min and dark of 1 hour).

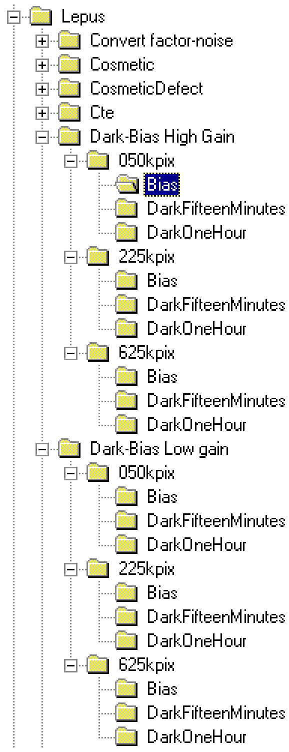


Figure 88 Dark acquisition directories

5.2.3 Light acquisitions

The script “LightAcquisition.pgm” drives these kinds of measurements. The lamp should be switched on 2 hours before the acquisitions.
After initialising the file names, the path directories… and checking whether the temperature is locked on the desired value (typically –120 ^{o}C), the script reads the “InfoLight.txt” file that contains the acquisitions to perform and then executes the lines sequentially.

Acquisition state	Info string
1	Conversion factor and noise 0= To do; 1= Done
1	Cosmetic 0= To do; 1= Done
1	Linearity method TDI 0= To do; 1= Done
1	Pocket pumping 0= To do; 1= Done
1	Quantum efficiency 0= To do; 1= Done

Table 7 Acquisitions performed by the script "LightAcquisition.pgm" as it appears in the “InfoLight.txt” file

This script has the same capability as “DarkandBiasAcquisition.pgm” concerning the recovery of the session after an interruption of the script.

- Conversion factor and noise: for readout frequency at 50kpix and 225kpix, 2 bias and 2 flats are taken and passed to the PRiSM function “GetConvertfactor” that calculates the conversion factor and the noise for each CCD; then, the results are written in a text file.
- Cosmetic: for 5 wavelengths (350, 475, 600, 750, 900 nm), 2 readout frequencies (50kpix and 225kpix) and 2 gains (LG and HG), 2 flats are taken …
- Linearity: at 632 nm, 1 specific exposure and 2 flats
- Pocket pumping:
- Quantum Efficiency:

Every image is saved in an appropriate directory. For example, see Figure 89 (CCD named "Lepus").

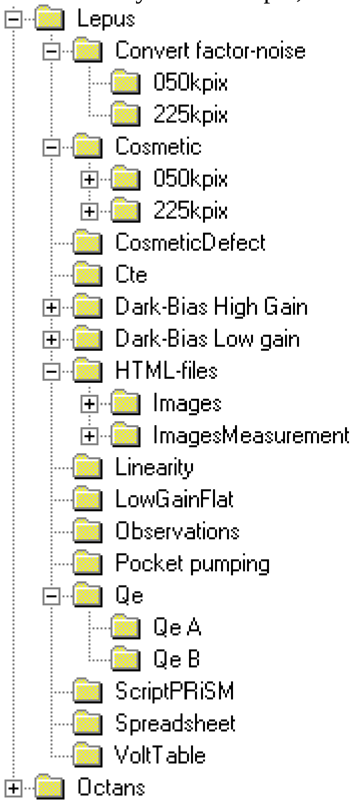


Figure 89 Light acquisitions directories

6 Data reduction

This section is not up to date. See F. Christen and C. Cavadore.

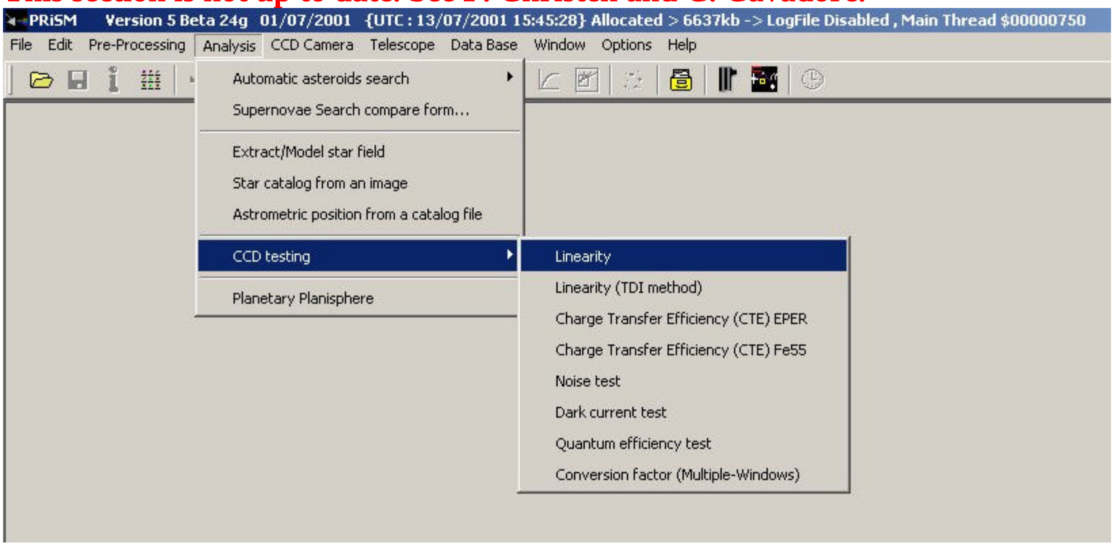


Figure 90 Menus of the CCD test data reduction package

This user manual is intended to explain how the images have to be acquired and processed with the PRiSM CCD testing package.
The parameters determining the CCD performances (such as linearity, dark current, conversion factor...) will not be explained in this page. The user should have the basic knowledge about CCDs. Many books about this subject has been written (see references section).
Those procedures are used at ESO in order to characterise CCD cameras before being installed to the telescope or for CCD preliminary testing.
For a given test, requiring many images, they ALL must have the same amount of pixels (i.e.

width/height) and being the same data file type (i.e.: integer or floating point data). Mixtures of image seize and/or data type will result directly in a failure.

6.1 Non-Linearity and Conversion Factor (e-/ADU)

This measurement is used to get the conversion factor (e-/ADUs) and the CCD linearity.
The CCD must be illuminated by a very stable light source, the resulting image has to be as "flat" as possible.
10 couples of images, at least, must be acquired with different exposure times, ranging from the full dynamic (intrinsic CCD dynamic or Analog to Converter dynamic) to the bias level.
For instance: (16 bit camera ranging from 0 to 65535 ADU)

PRISM file image (CPA of FITS file type)	Exposure time (Sec)	Mean (ADU)
image1.cpa	10	12152
image2.cpa	10	12155
image3.cpa	2	2178
image4.cpa	2	2185
image5.cpa	50	62535
image6.cpa	50	62534
……	……..	…….

Take at least 16 couples of images and try to achieve up to 95% of saturation level, to explore the all range.
Avoid to take images with increasing or decreasing exposure times as for instance 2,5,10,50 sec, use instead a random order as 2,50,10,5 sec.
When the PRISM software dialog box pops up, you have to enter a window where the statistics will be achieved (X1,X2,Y1,Y2). Keep in mind not to include defects in this window. The statistics can be either "median" or "classic" type. Set the "median" to avoid the effect of out of range or defective pixels, median is less sensitive to local contaminants.

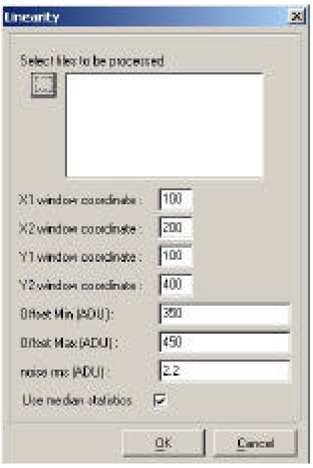


Figure 91 Linearity dialog box

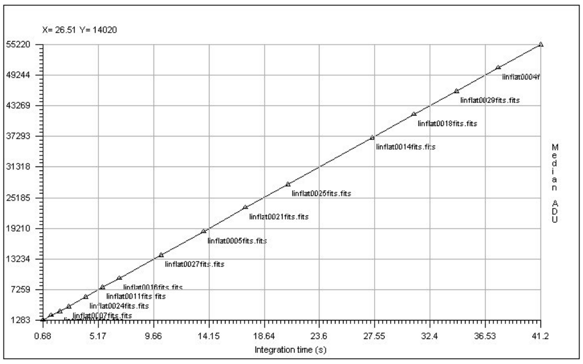


Figure 92 Linearity curve according to exposure time

The range (offset min et max.), comes from the offset image mean. In that case supply : Offset/bias level min = Offset -10% and Offset max= offset +10%), this allows to optimize the offset deviation effect with respect to shutter errors. To known this figure (Bias level), you have to measure it form a set of bias images.
!! Multiples files can be selected by keeping the ALT key down while selecting files in the open dialog box!!
PRISM software computes automatically the conversion gain in e-/ADU and the residual non-linearity expressed in % units, using the whole double exposure set of images. A photon-transfer curve is plotted as an output.

<u>Results</u>
Console output :

Optimum offset(ADU) (1): 368
Non linearity (Peak to peak) : (1): 0.4367% / -0.8695%
Optimum offset(ADU) (2): 368
Non linearity (Peak to peak) : (2): 0.3741% / -0.1807%
Conversion factor e-/ADU : 1.9926
-> RMS error : 0.12428
Readout noise (e-) : 4.7822

The data(1) uses the first set of images and data(2) the second set.
The following curves are displayed, no need to make a table sheet for a plotter like Excel.

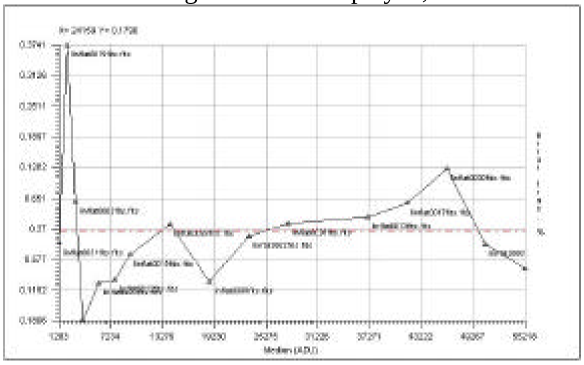


Figure 93 Residual non linearity curve

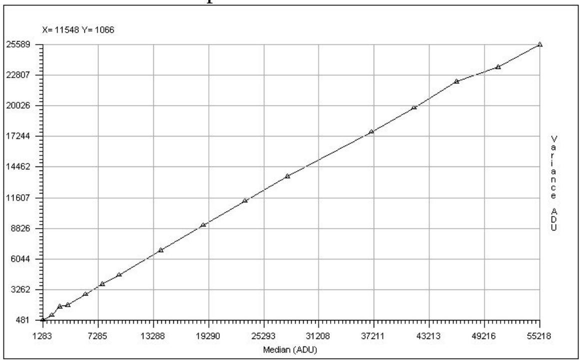


Figure 94 Photon transfert curve (used to compute the conversion factor e-/ADU)

The method used is described by Janesick [2].
VERY IMPORTANT: be aware that FITS files are coded sometime as a true 16 bit data (0-65535). PRISM adapts data type according to the input file and to save memory space, but we recommend strongly to open the "Option/FITS options" menu, and to set the "Load 16bits unsigned FITS file to floating point data" as checked.

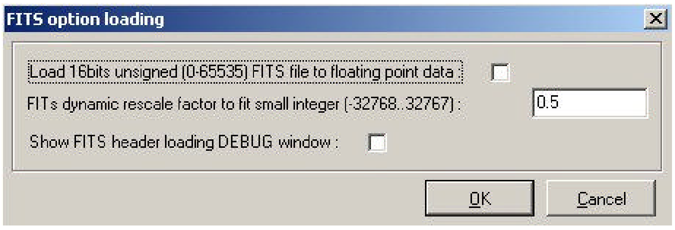


Figure 95 FITS option loading

6.2 *Charge transfer Efficiency (CTE): EPER method*

The dialog box related to CTE measurement is presented in Figure 96.

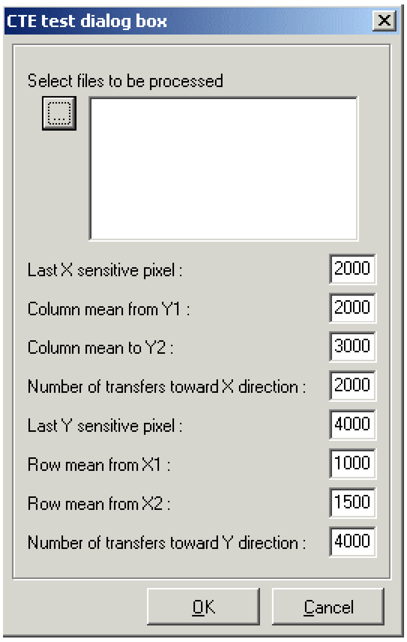


Figure 96 CTE dialog box

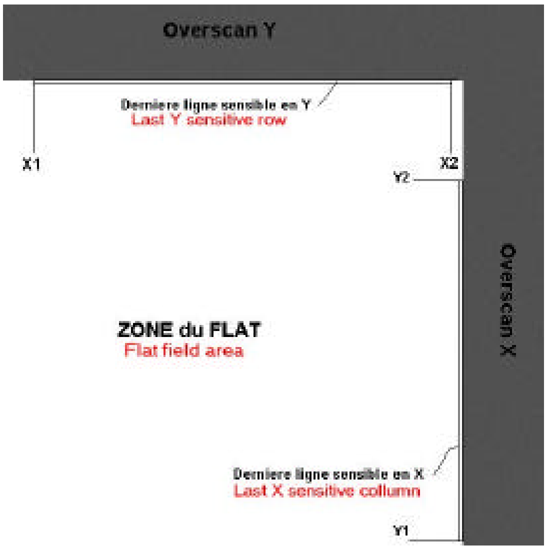


Figure 97 CTE measurement method

For this purpose, you should acquire a single flat field image reaching 95% of the ADC dynamic range. The camera shall be able to read the array beyond the photosensitive area. This area beyond the image is called "OVERSCAN", and contains fake pixels having the bias value provided by the electronic readout chain and CCD. This area shall be extended both in X and Y directions. This kind of image has to be provided to PRISM software to compute CTE.

Y1, Y2 is the area to perform the mean of the last light sensitive row and the X1, X2 is the range to compute the last mean column (Figure 97). The number of transfer across X and Y is typically the light sensitive image part.

Console output:
Loading: F:\Images\Frankie\CTE\Cte_0001
Mean -> Last X: 58491.6583936574 Last X+1: 469.123061013444 Overscan area: 449.922095829024
Horizontal CTE = 0.999999838470179 / 6 nines
Mean -> Last Y: 65510.6978248089 Last Y+1: 495.093474426808 Overscan area: 445.12810646144
Vertical CTE = 0.999999625037444 / 6 nines
Method used:
The method employed here is the EPER (Extended Pixel Edge Response). This method is not really accurate and the IRON 55 tests are much more reliable. Some CTE figures greater than one can be measured with this method!
References:
http://www.stsci.edu/instruments/acs/ctewg/papers/jones_fpr.pdf

6.3 Quantum efficiency and PRNU (Photo Response Non uniformity)

This is a really difficult measurement, because the result has to be provided in absolute values, and you MUST have to input calibration data.
Basic knowledge regarding QE measurement must be known!! Read this document for more information about how QE is computed.
The usual scheme is to use absolute quantum efficiency calibrated photodiode installed at the same position as the CCD will be, and to use flat field images made in the front of an integrating sphere, fed by one or two monochromators. This setting allows you to get different flat field images at different wavelengths and short bandwidth.
The incoming light wavelength is typically ranging from 300 to 1100 nm, with a short bandwidth, such as 5nm. The photodiode current is measured, and the photodiode manufacturer calibration curve

enables you to compute the amount of photons per square centimetre and per second. This is an example of a photodiode calibration file (as a text file):

 # No TABS
 # ratio bdw 4 # col 1 Wavelength
 # col 2 Flux on the CCD surface, expressed in photons/sec/cm2
 # col 3 Current that is measured at integrating sphere level or closeby to the CCD
320 1.1e+8 0.209e-9
340 2.55e+8 0.544e-9
360 5.18e+8 1.115e-9
380 9.27e+8 2.124e-9
400 1.44e+9 3.646e-9
450 2.9e+9 7.94e-9
500 3.54e+9 10.207e-9
550 3.9e+9 11.5e-9
600 3.97e+9 11.74e-9
650 3.6e+9 10.85e-9
700 3.09e+9 8.96e-9
750 2.35e+9 6.67e-9
800 1.54e+9 4.224e-9
850 1.66e+9 4.52e-9
900 1.42e+9 3.871e-9
950 3.4e+9 8.6e-9
1000 3.16e+9 7.65e-9
1100 2.42e+9 1.224e-9 Afterward, the optical transmission of the dewar window according to the wavelength as to be provided (as a text file).# Window transmission
 # col 1 Wavelength
 # col 2 Relative transmission
320 0.94
340 0.97
360 0.98
380 0.98
400 0.99
450 0.99
500 0.99
550 0.996
600 0.9856
650 0.9615
700 0.926
750 0.889
800 0.8517
850 0.8153
900 0.7873
950 0.7627
1000 0.7466
1100 0.723

IMPORTANT: For all the wavelengths used, calibration photodiode text file and window calibration transmission file MUST match each other. It means that the same wavelengths must be entered in the two calibration files (Otherwise an error will occur). FITS files must include the following HEADER Keywords:
WAVLG = 550 // Central wavelength: Expressed in mn
BANDW = 5 // Bandwith : Expressed in mn
FLUX = 1.2E-5 // Photodiode current expressed in Amps
or
1_FLUX = 1.2E-5 // Photodiode current expressed in Amps
Regarding the CPA image file: if images have been acquired with PRISM, the previous figures are entered automatically into the CPA file header.
A reference offset/Bias image (resulting from a median stack of 10 offset/bias images) is mandatory, also the integration time must be limited in a way that the CCD dark current remains negligible.

Once having entered all the calibration files in the software dialog box, the analysis window X1,X2,Y1,Y2 must be chosen so that it must not contain any serious defects (black hole, bright pixels).

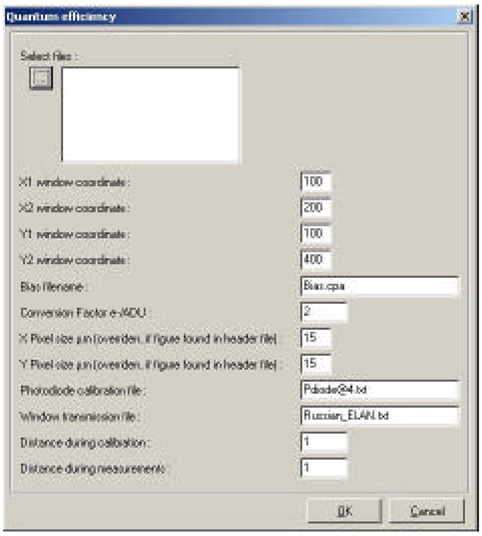


Figure 98 QE computation dialog box

Conversion factor must have been measured previously (see method 1 or 2).
Distance during calibration/measurements allows the reference photodiode not to be at the same distance as the CCD, and to apply a $1/d^2$ correction. This correct for few centimetres effects.

Results:

This is the console output results, for each FITS files, it yields to:
Wavelength in nm; Flux in Amps; Exposure in sec; Count values in e-

Filename	*Wavelength*	*Flux*	*Exposure*	*Mean*	*Stddev.Rms*	*Median*	*Mean-Median*
QE0002.fits	*320*	*1.749E-10*	*180*	*21400*	*484.08*	*21400*	*-0.051972*
QE0034.fits	*340*	*4.754E-10*	*180*	*60662*	*1281.8*	*60678*	*-15.768*
QE0004.fits	*360*	*1.0234E-9*	*79.523*	*60965*	*1260.3*	*60976*	*-11.264*
QE0032.fits	*380*	*2.0072E-9*	*36.67*	*60579*	*832.35*	*60568*	*10.537*
Qe0006.fits	*400*	*3.5871E-9*	*20.472*	*60341*	*578.48*	*60342*	*-1.3613*
QE0030.fits	*450*	*8.4612E-9*	*9.223*	*60576*	*473.26*	*60582*	*-6.0853*
QE0008.fits	*500*	*1.1307E-8*	*7.248*	*60050*	*462.21*	*60052*	*-2.3795*
QE0028.fits	*550*	*1.3328E-8*	*6.904*	*64220*	*478.24*	*64226*	*-5.6408*
QE0010.fits	*600*	*1.4012E-8*	*6.438*	*59948*	*446.82*	*59952*	*-4.0484*
QE0026.fits	*650*	*1.3279E-8*	*7.296*	*59910*	*442.79*	*59914*	*-4.2144*
QE0012.fits	*700*	*1.1196E-8*	*9.48*	*59680*	*450.23*	*59686*	*-5.5382*
QE0024.fits	*750*	*8.4697E-9*	*14.39*	*59830*	*481.27*	*59838*	*-8.0172*
QE0014.fits	*800*	*5.4537E-9*	*27.831*	*59990*	*533.66*	*60004*	*-13.601*
QE0022.fits	*850*	*5.9775E-9*	*33.177*	*59951*	*508.76*	*59960*	*-9.061*
QE0016.fits	*900*	*5.1913E-9*	*58.056*	*59327*	*941.36*	*59162*	*165.3*
Qe0020.fits	*950*	*1.2662E-8*	*49.111*	*61606*	*2471.5*	*62156*	*-549.94*
QE0018.fits	*1000*	*1.0568E-8*	*171.99*	*62739*	*3667.6*	*64178*	*-1438.6*
QE0036.fits	*1100*	*1.7114E-9*	*180*	*1006*	*82.472*	*994*	*12.022*

Image #1 Bandwidth :5
PhotoDiode calibration Bandwidth :4

Filename	*Wav.*	*PRNU%*	*QE%*	*FDio/FDio.cal*	*Ph/pix/sec*	*e-/pix/sec*	*%Wind*
QE0002.fits	*320*	*2.262*	*61.065*	*0.83684*	*207.12*	*118.89*	*94*
QE0034.fits	*340*	*2.1125*	*69.312*	*0.87389*	*501.4*	*337.1*	*97*
QE0004.fits	*360*	*2.0669*	*73.139*	*0.91787*	*1069.8*	*766.77*	*98*
QE0032.fits	*380*	*1.3742*	*85.51*	*0.94499*	*1971*	*1651.7*	*98*
Qe0006.fits	*400*	*0.95867*	*93.401*	*0.98385*	*3187.7*	*2947.5*	*99*
QE0030.fits	*450*	*0.7812*	*95.421*	*1.0656*	*6953.3*	*6568.6*	*99*
QE0008.fits	*500*	*0.76969*	*94.847*	*1.1078*	*8823.7*	*8285.3*	*99*
QE0028.fits	*550*	*0.74462*	*91.842*	*1.1589*	*10170*	*9302.7*	*99.6*
QE0010.fits	*600*	*0.7453*	*88.622*	*1.1935*	*10661*	*9312.2*	*98.56*
QE0026.fits	*650*	*0.73904*	*86.151*	*1.2239*	*9913.7*	*8211.9*	*96.15*

QE0012.fits	*700*	*0.75434*	*78.263*	*1.2496*	*8687.5*	*6296*	*92.6*
QE0024.fits	*750*	*0.8043*	*69.666*	*1.2698*	*6714.2*	*4158.3*	*88.9*
QE0014.fits	*800*	*0.88938*	*56.584*	*1.2911*	*4473.7*	*2156*	*85.17*
QE0022.fits	*850*	*0.8485*	*44.878*	*1.3225*	*4939.4*	*1807.3*	*81.53*
QE0016.fits	*900*	*1.5912*	*30.209*	*1.3411*	*4284.7*	*1019.1*	*78.73*
QE0020.fits	*950*	*3.9762*	*14.732*	*1.4724*	*11264*	*1265.6*	*76.27*
QE0018.fits	*1000*	*5.7147*	*5.0888*	*1.3814*	*9821.7*	*373.16*	*74.66*
QE0036.fits	*1100*	*8.297*	*0.10033*	*1.3982*	*7613.2*	*5.5222*	*72.3*

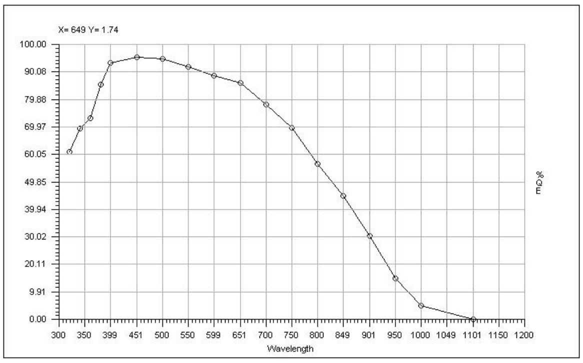


Figure 99 Quantum efficiency as a function of wavelength

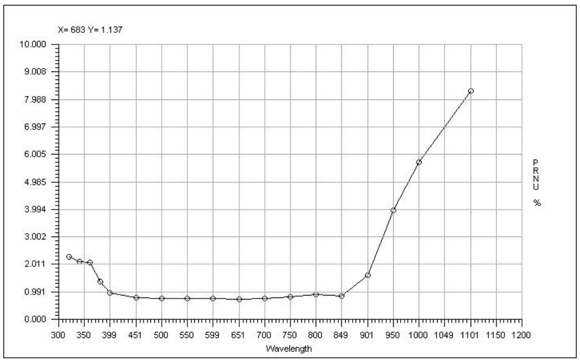


Figure 100 PRNU as a function of wavelength

The PRISM software provides the quantum efficiency plot in Figure 99 and a PRNU curve (Figure 100).

The following images (Figure 101, Figure 102 and

Figure **103**) were taken at different wavelength, from the same area of the CCD (bandwidth=5nm and CCD EEV44 backside illuminated).

Figure 101 At 320 nm uniformity degraded by the implantation of P+ passivation layer annealed by laser after thinning)

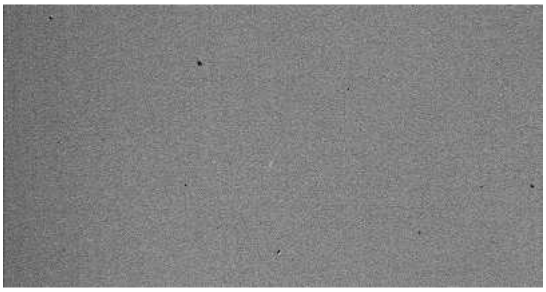


Figure 102 At 650 nm, very good uniformity

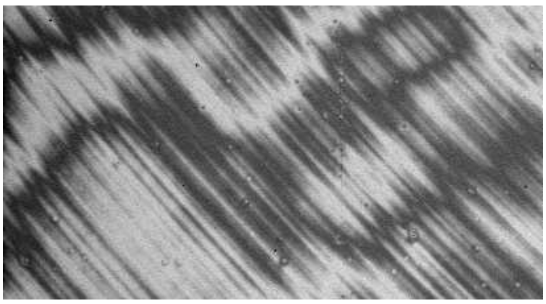


Figure 103 At 950 nm, nice fringing!

The method employed here for QE is straightforward and based on the ratio between the amount of photon falling to the CCD surface for a given wavelength and the effective amount of photoelectrons read out at the output of the CCD. This is achieved by all the data coming from the calibration text files and figures found in the image file header, such as pixel size, exposure time, flux, wavelength, etc ...
The PRNU computes the histogram (Figure 104) of the selected (X1,X2,Y1,Y2) area, and provide two figures : the intensities at 5% and 95% percentile. Let's call those figures Int1 and Int2, the PRNU is (Int2-Int1)/(Int1+Int2)*100%

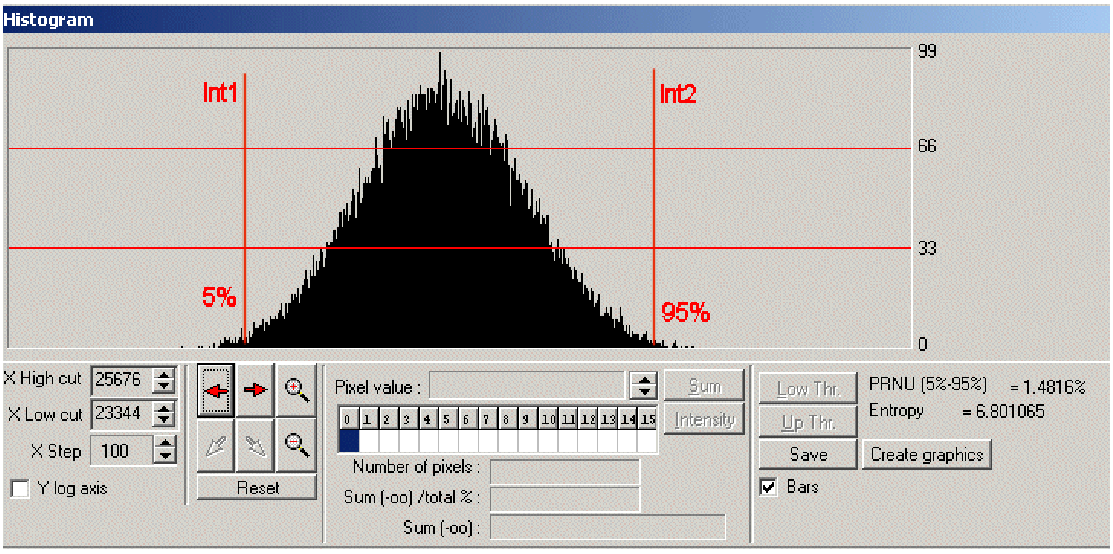


Figure 104 PRNU Histogramm

6.4 Readout noise

The data acquisition process is straightforward: acquire at least five images in the total darkness having all zero sec exposure.

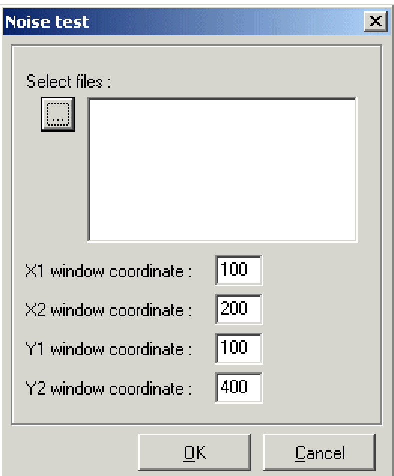


Figure 105 Noise test dialog box

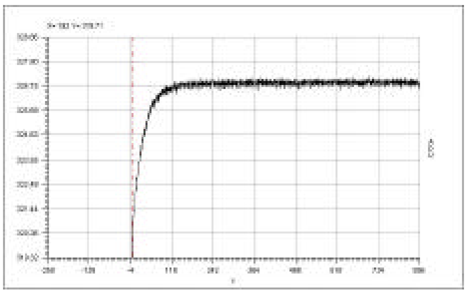


Figure 106 Noise collapse

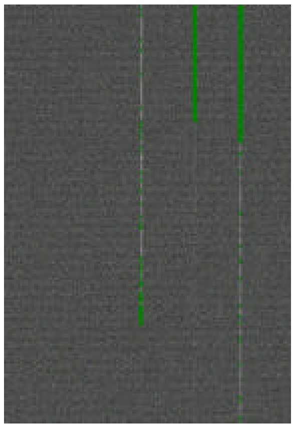


Figure 107 Noise defects

The input window X1,X2,Y1,Y2 is the window where the noise computation will take place. Take a window without any kind of defect and showing pure random noise (avoids hots pixels clusters).
Results:
The curve in Figure 106 is a stacked column mean over all the columns, and allows you to display effect that would be drawn or hidden by the readout noise.

To trace noise patterns, a Fast Fourier Transform (FFT) of the image is sometime recommended.
This image (Figure 107) shows cosmetic defects (green cross) over a CCD bias image: these are pixels that are 5 sigma above the median noise + mean.
Console output:
Pixel amount taken to provide median frame:
noise0005 ->1 42.53%
noise0003 ->2 57.43%
noise0004 ->3 57.65%
noise0002 ->4 42.39%
Noise: 2.286 ± 0.005463 ADU
Pixel amount above 5 sigma: 17100 threshold (ADU): 6.584

BEWARE: This measurement could be biased if care has not been taken concerning the file format.

The RMS value is computed throughout the selected area. The final noise is the median noise from the set of the images. To trace bias defect, a median stack is performed to get rid of cosmic rays, and every pixel which is above or below five 5σ is referenced as a bad pixel and mapped.

See also section 6.7.

6.5 Dark current

As input image data, at least 3 images in total darkness have to be achieved, having the same exposure time for each (from 5 minutes to 2 hours depending on the cooling efficiency and CCD temperature).
A mean clean Offset or Bias image MUST to be done as the result of the median stack of many individual bias frames. Also the conversion factor must be known accurately.
Be aware that sometimes residual image can disturb dark current measurement, especially if the CCD is cooled at -120C. Avoid acquiring the data just after having acquired high level flat fields. To watch this out, take ten dark frames at the same temperature and check whether or not the mean dark level is decreasing. Wipe the CCD many times before in the darkness. For instance take 10 dark exposures of one hour, and do not use the first four images.

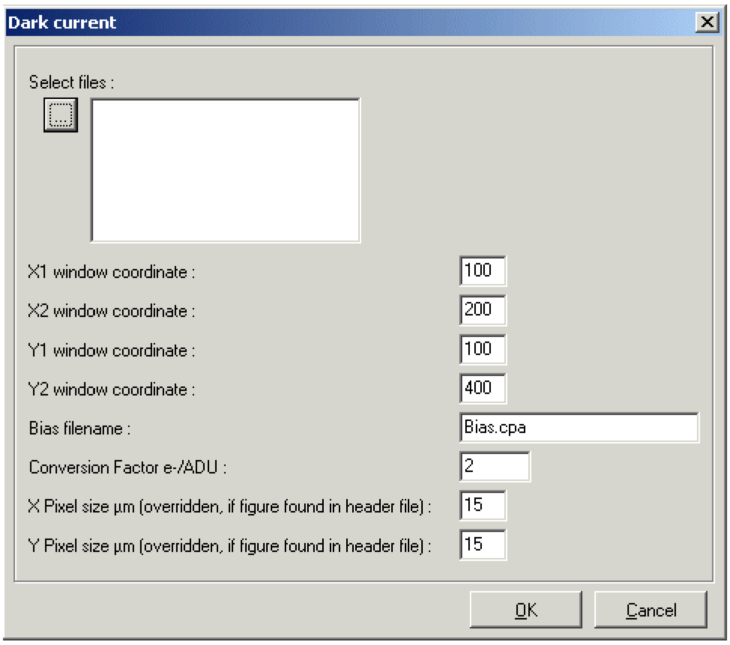


Figure 108 Dark dialog box

As usual, the X1, X2, Y1, Y2 window is the window where the computation will be performed and must be clean of bright defects.
Results

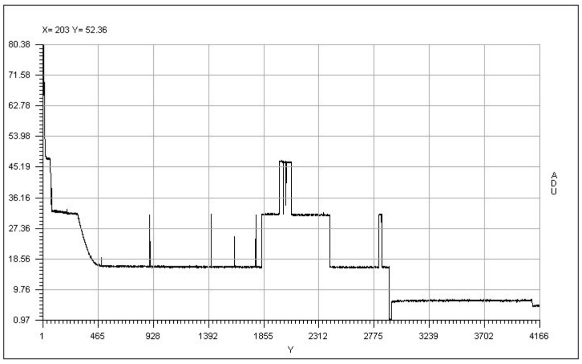


Figure 109 Dark collapse

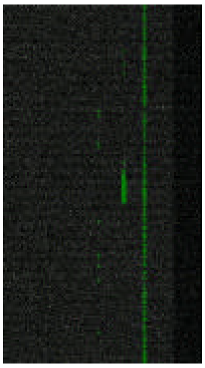


Figure 110 Dark defect: hot pixels map

This is the mean of all the columns sent to a single resulting column (Figure 109). The steps in the curve show the defect induced by defect columns… The same is displayed for the rows.

Here a hot pixels map is provided (Figure 110). All pixels above 5σ (noise+mean) are shown and could be regarded as defects.
Console output:
Loading: F:\Images\Frankie\dark\run1@-120\dark0004.fits
Pixel size information NOT present or NULL in file header, so I take 15 x 15(µm)
Loading: F:\Images\Frankie\dark\run1@-120\dark0003.fits
Loading: F:\Images\Frankie\dark\run1@-120\dark0002.fits
Loading: F:\Images\Frankie\dark\run1@-120\NoiseMedian.cpa
Integer data type...
Median search:
Compute median frame...
Pixel amount taken to provide median frame :
dark0004.fits ->1 27.92%
dark0003.fits ->2 44.71%
dark0002.fits ->3 27.37%
Offset -> Mean: 327.1 Median: 327 ADU
Exposure time (s) = 1800
Dark current: 1.333 ± 0.4714 ADU
Dark current: 5.333 ± 1.886 e-/hour/pixel
Cosmic event rate: 1.195 ± 0.04297 events/min/cm²
Pixel amount above 5 sigmas: 10659 threshold (ADU) : 10.51
Dark current using median frame after median filtering: 5.128 e-/hour/pixel

Even, the software is able to provide the cosmic ray hit rate automatically.

The software computes a median stack out of the N provided images and subtracts the bias file to it. The dark current is the remaing amount of adu above the bias image (positive data). The defects are subtracted automatically as the difference between individual frames and the median stacked frame.

6.6 Linearity using TDI method

This method provides the same results as the classical method (section 6.1), the differences are the following:

- Only one image is necessary (whereas the other method requires many images and takes long time to be carried out).
- Absolutely insensitive to shutter errors.
- The output curve providing the residual non-linearity versus the measured signal is continuous (whereas the other method provide discrete points)
- The measurement accuracy is much better than the one obtained by the classical different exposure method (section 6.1).
- Not limited by the PRNU of the CCD

This method has, nevertheless, constraints, where the main drawbacks are:

- The ability to open the shutter while the CCD readout process has already began, moreover the shutter must be placed at the entrance of the integrating sphere, but in any case to share the same focal plane as the CCD. This, sometimes, can not be achieved with CCD controllers that do not allow to open the shutter during the readout process. Nevertheless, manual opening can be used if the CCD is not read out to fast.

The method consists in illuminating the CCD by flat field illumination as uniform as possible. The intensity of this flat field light (called here Flux=Fl) must be such as the resulting image must be like a flat field of intensity close to 95% the full ADC dynamic, the CCD being exposed during a T exposure time yielding to a light intensity of Fl.
In an another way, if the dynamic is equal to 16bits, the image must shows up a uniform spatially Flat Field at about 62000 ADUs (in T seconds and with a Fl flux). Let assume that the flux has been set so as to get 62000 ADUs in 20sec (neutral filter, slit settings). It means that the CCD MUST be clocked in the way that it takes about 20 sec to read it out to achieve TDI linearity method.

The image used for the measurement must be acquired using this way. The CCD is started to be readout (shutter closed) and, once the readout of the first 100 first row has been achieved, the shutter is opened (the shutter open delay must be neglected compared to the row readout time). The CCD must be let reading out, being continuously illuminated with a flux equal to Fl. It is advised to hide also the first 100 rows using a mask (light shielded), because the readout circuitry might be disturbed (depends on the CCD) during readout by the continuous light flux to it, and might bias the results.

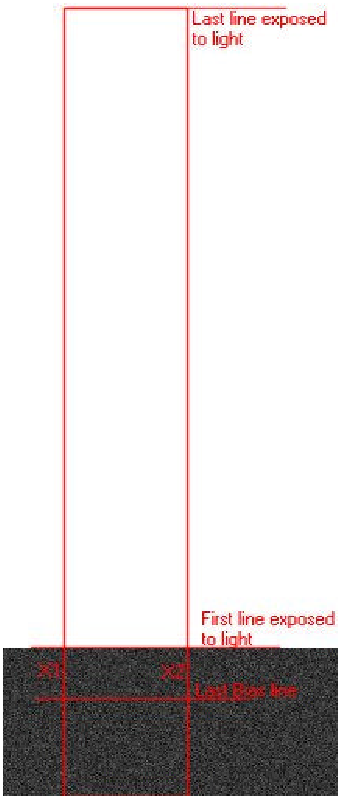


Figure 111 Resulting image (display cuts are set to +/-1% of the Bias level)

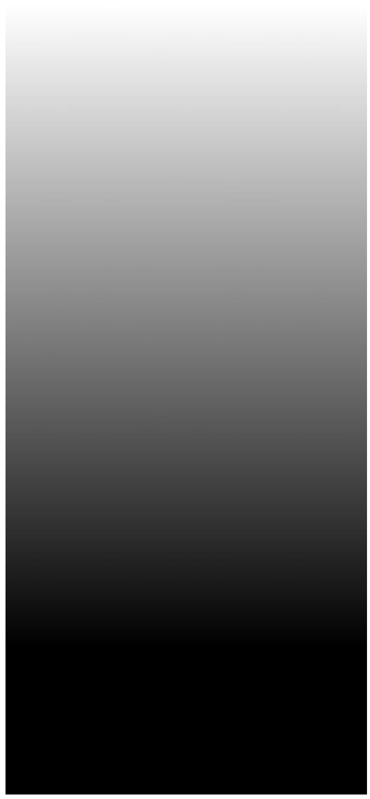


Figure 112 Same image as the right one, with display cuts having the full ADC dynamic range from 0 to 65535, the ramp must be uniform and smooth

So, to reduce this data, the TDI dialog box (Figure 113) has to be filled up as following:
- X1 and X2 horizontal defines the vertical stripe.
- The last and the first row exposed to light (sometimes it's better to take the 5th row exposed to light).

- The last row that defines the CCD Bias frame level.
- Minimum flux value is meant to threshold the lower range of the intensity dynamic, to be taken into account for computations and plots.
- Filter: sets how far the output plot curve will be filtered.
- Flat field image is mandatory to correct the data from pixel to pixel non-uniformity: it must be an image taken with the same wavelength and bandwidth as the TDI image and subtracted from by its bias image.
- Folder: location of the flat field folder (TBC).

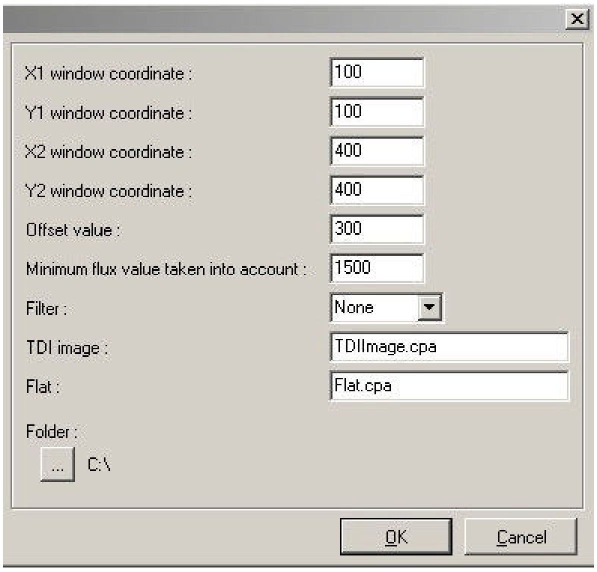


Figure 113 TDI dialog box

Results

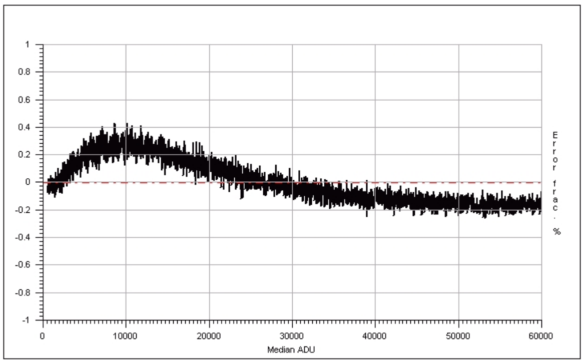


Figure 114 Residual non linearity curve, this CCD is linear with +0.43/-0.3 peak-peak and 0.16% rms deviation from the perfect slope

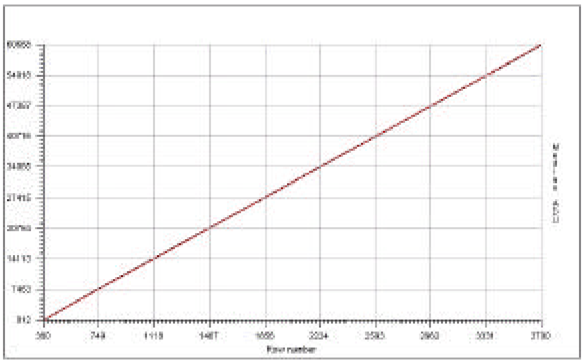


Figure 115 This curve is a vertical cross section from the selected area, more exactly the median across this area

<u>Console output</u>:
Loading: G:\CCDtest\UvesRed\NewLin\eevLeftPort.cpa
Regression slope: 17.978; regression Offset :-5956.5
Regression slope: 18.028
Regression optimum Offset: -6037
Non linearity (Peak to peak): 0.43% / -0.2912%
Non linearity (Mean dev.): -1.875E-13% / rms dev 0.1569%

The TDI image is median collapsed towards a single column : a 1D slope is achieved. The flat field image is used to correct the slope from the fact that all the pixels of the CCD do not have the same sensitivity. A best linear fit is found from the slope and non-linearity plot computed. Beware that an infinity of slope can be found out of a cloud of points, depending on the criteria: less mean square, weighted points, etc etc...

This is a new method developed at ESO.

6.7 Conversion factor using two dark and two flats method

This method is very useful for computing the conversion factor during system development because it is fast and the accuracy is pretty good.
It just needs two biases and two flat field images. It performs conversion factor measurement using NxM sub windows to avoid any problems due to local defects. PRISM asks for the amount of windows that are needed across the X and Y-axis. Note that subwindows less than 50x50 pixels can lead to wrong results, so for a 1x2K CCD for instance, set 10 windows for the X direction and 20 for the Y direction. To remove any prescan/overscan area set the X1,Y1,X2,Y2 windows so as to avoid them and then select the files.

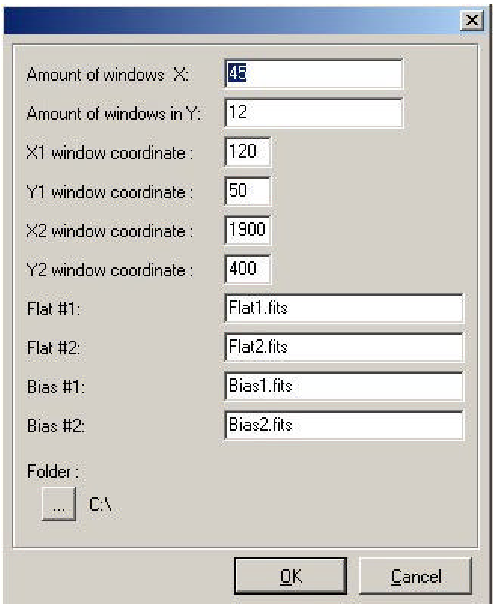


Figure 116 BF dialog box

<u>Console output</u>:
Loading :Flat1.fits
Loading :Flat2.fits
Loading :Bias1.fits
Loading :Bias2.fits
For all the windows (540) the results are the following :
window 1=4.49799e-/ADU X1=120 Y1=50 X2=158 Y2=78
window 2=4.11412e-/ADU X1=120 Y1=79 X2=158 Y2=107
window 3=4.31269e-/ADU X1=120 Y1=108 X2=158 Y2=136
window 4=4.14792e-/ADU X1=120 Y1=137 X2=158 Y2=165
window 5=4.0549e-/ADU X1=120 Y1=166 X2=158 Y2=194
....
window 536=4.45689e-/ADU X1=1836 Y1=253 X2=1874 Y2=281
window 537=4.55087e-/ADU X1=1836 Y1=282 X2=1874 Y2=310
window 538=4.23658e-/ADU X1=1836 Y1=311 X2=1874 Y2=339
window 539=4.01395e-/ADU X1=1836 Y1=340 X2=1874 Y2=368
window 540=4.50764e-/ADU X1=1836 Y1=369 X2=1874 Y2=397
Conversion Factor=4.3775e-/ADU ± 0.012608 for 3457.054ADU
RMS noise =7.0774e- ± 0.092687

Note that the algorithm supports flats fields that have different levels of illuminations, tests have been carried out with flats having means with factor of 50 between the two images and the feature passed it pretty well! This method subtracts the biases from the flat field images, divides the two previous flat images and computes the RMS value (named N here) and the mean Signal for each window. Then computes the $D=2*S/N^2$ figure, from D, the bias noise is removed and yields to the conversion factor. The corrections due to the different flat field levels are performed by the software, but not mentioned in this explanation (to remain clear).

6.8 Charge transfer efficiency using Fe55 source

This is a very powerful experiment used to derive the vertical and horizontal CCD charge transfer efficiency (CTE) and also can provide a extremely accurate measurement of the conversion factor. An Iron (Fe55) radioactive source is installed 100 mm from the CCD, in the vacuum. This source produces X-rays (5.9Kev photons) that reaches the CCD surface, creating inside the CCD bulk 1620e- in a 0.5/1um sphere. If these 1620e- are produced within a single pixel, they should be detected at the output of the CCD readout node as 1620e- times the conversion factor. Because of "failures" during the charge transfer, some electrons are lost and remain in the next pixel, and this is not. This can happen either during the vertical transfer or the horizontal transfer (serial register). Since the amount of electrons produced by the Fe55 are well defined, it is possible to compute the horizontal and vertical CTE.

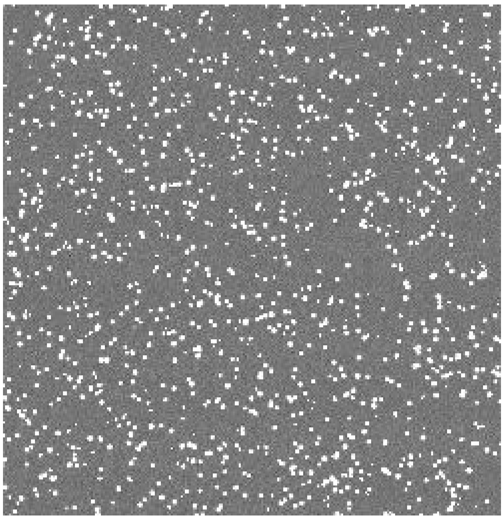


Figure 117 A 30 seconds exposure image, CCD in front of a Fe55 source

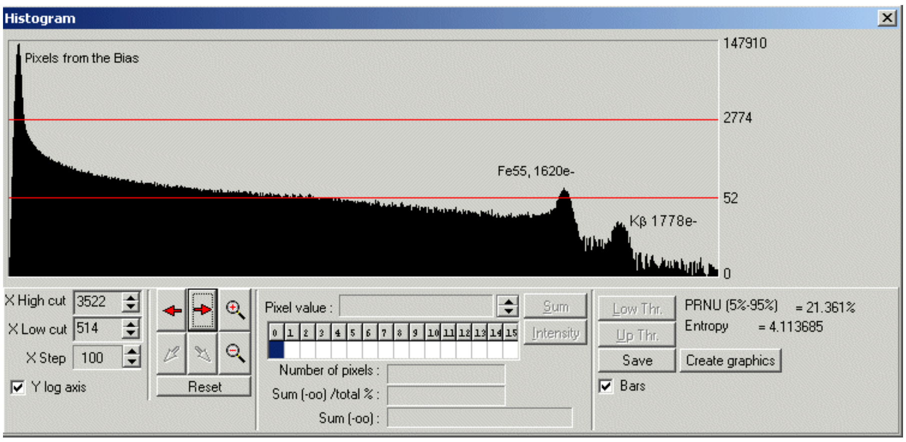


Figure 118 Histogram plot of the whole CCD, pixels from the bias level and the two peeks of Fe55 (Ka1620e- Kb1778e-) are visible

In the dialog form, enter the window to be processed (X1,Y1,X2,Y2). Then the readout direction (CCD output port direction left/right). The conversion factor must be known within 5% accuracy. The bias offset level as also to be provided (accurate, from overscan areas or master bias frame). Select more than one image is recommended for better accuracy, as so as to enter more than 2 lines for each packet. Those packets are used to bin the histogram of a line/column N time.

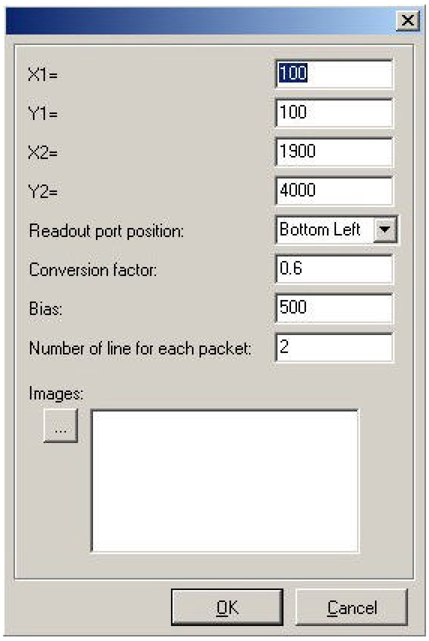


Figure 119 Fe55 dialog box

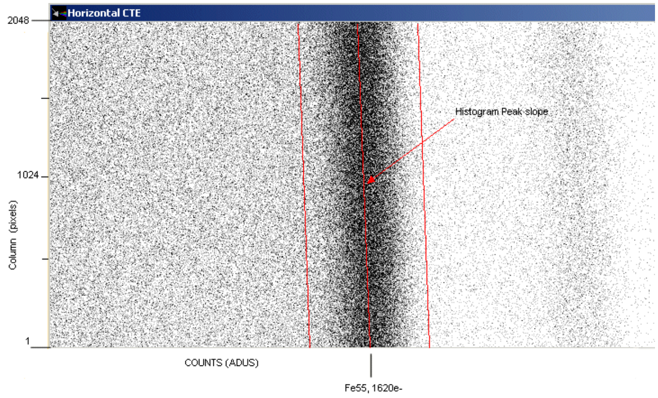


Figure 120 Horizontal CTE histogram as an image the fact that the slope is left tilted showed that CTE is lower than 1.0

<u>Console output</u>:
Load image: iron-1.cpa
Load image: iron-3.cpa
Load image: iron-2.cpa
Load image: iron-4.cpa
CTEV=1.000000101
CTEH=0.999997222
Conversion factor=0.680809

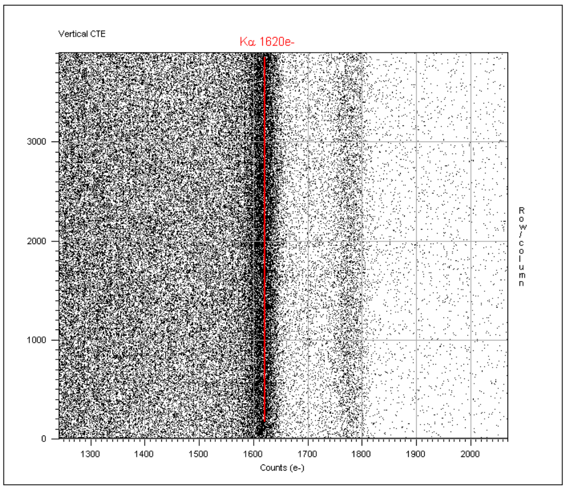


Figure 121 Vertical CTE histogram as a printable plot (very good V.CTE)

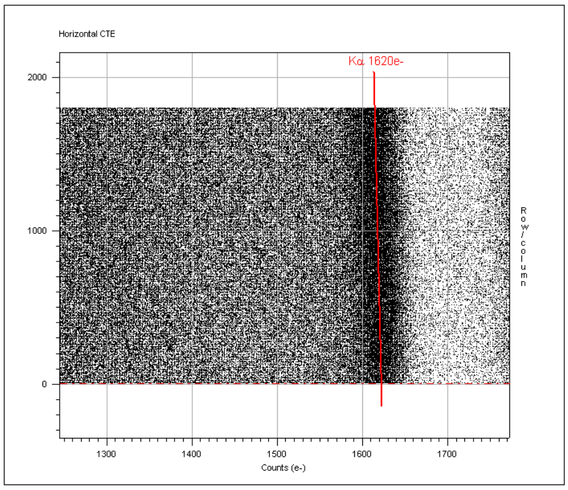


Figure 122 Horizontal CTE histogram as a printable plot (H.CTE =0.999997222)

The software performs vertical histogram gathering N columns so as to have a better Signal to Noise measurement, it also uses more than one image to improve the measurement. Then displays an image where the X-axis is the counts in ADUs, Y the column number and Z the number of pixels having the given X counts. The softwarefinds the histogram peaks for every column and fits the best slope. As you can see on the image above, the slope that joins all the peak is slightly tilted to the left, showing that the 1620e- created at the end of the serial register (column 2048) are indeed less than 1620e-, thus showing a CTE not equal to 1. The software, according to the histogram peak slope can compute the HCTE.

The same method applies for the horizontal CTE, just swap the word vertical with horizontal and the word column with rows.

7 References

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