CHIP CHARACTERISTICS
FOR
THOMSON 31156
(ESO #19)

Sebastian Deiries Roland Reiss

ESO Garching

Optical Detector Laboratory

October 5, 1994

1 General Description

ESO S/N : # 19 (in Cryostat-tank No.:994/3)
Chip type : Thomson 31156 Grade A, front-side illuminated,UV–coated
Chip format: 1024x1024, 11? pre-scan pixels in horizontal direction
Pixel size : 19x19 μm^2
Serial No. : X56.413 A-40 (or as sketched on the back of the case: 40)

This A-Grade (Scientific Grade) Thomson CCD-chip is foreseen for the EMMI Instrument at the NTT.

The cryostat 994 with the ESO front-end part is one of the first three cryostats of this new design and not optimized in terms of "cold-time" (which depends from the goodness of the infrared reflection of all surfaces), cleanness of surfaces (to maintain a very good vacuum) and mechanical position of the shields. Beside this we could not measure the mechanical (thermal) shift of the CCD due to the cooling down from 293 to 130 K.

All this should be improved with the new manufactured cryostats, which are assembled in the near future.

Once cold (Control = 130 K, Monitor = 141.6 K), the hold-time at this temperature with one new filling is approx. 23^{+0}_{-4} hours.

The recommended operation temperature is **141.6 K (=Monitor at the ESO temperature controller)**. With a higher regulated temperature the cold-time is much shorter, because of the heating.

The pressure at this temperature in the cryostat is around 2 times 10^{-6} mBar. If the pressure is much higher, there is a leak in the cryostat (e.g. at the field-lense O-ring, at the EMMI-flange O-ring or at the vacuum valve respectively the vacuum gauge O-rings). Also if the lowest tempereration of Monitor without regulation is higher than 137 K, there is a problem with the cryostat (leak or touching of the radiation shields).

The cooling down takes approx. 6 hours, if the vacuum in the cryostat at room temperature conditions is better or equal 10^{-5} mBar.

Attention: *The final assembly of the Detector Assembly into the Cryostat has to be done in Chile according to the procedure mentioned in the Maintenance Manual[1]: CCD Cryostat for the VME-based Control Camera..* This procedure is given again in the following:

Please read carefully the corresponding chapter (page 24, page 17) of the manual and especially **the following important instructions!**

2 Instructions for the cryostat final assembly

- Do all in the following decribed works in a clean-air bench and optionally with the help of a **low** pressure antistatic air gun.
- Look for the right parts. The cryostat pre-assembly (biggest part), the Detector assembly and the Flange with the **same** CCD number (see labels !) have to be assembled.
- Remove the new Protection and Transport Securing (320-24) from the cryostat pre-assembly.
- Remove the protective tape and the “fixation cork” from the Thermal-links (320-27) and look for the delivered screws and tools.
- Remove the Cover Plate (320-38) from the separately shipped Detector Assembly and protect the detector, which now is open and unprotected, with a small plate, which can be glued with scotch tape onto the Cold-stop front surface.
- Do not open the Detector Assembly itself !!!!!!! The CCD is adjusted in x,y and z in Garching. Every opening of the Detector Assembly would damage this adjustment.
- The Detector Assembly now is **carefully** installed into the pre-assembly (after taking out from its shipping parts):

  First fix the Thermal Links(320-17) with Scotch tape to give space for the incoming Detector Assembly.

  The Thrust V-Bearing (130-19) of the Detector Assembly (and there is only one !) comes over the glass V-pin (140-11) of the pre-assembly. The Detector Assembly is gently introduced vertical with its “collet for centerdisc”(320-29) into the glass center pin (140-12 or 140-11) of the pre-assembly. **Do not break the glass pins with this procedure !!**.

- Then the three tension springs (320-14) including one with the analog ground connection are attached and screwed (!) at the Centering disc(320-02) of the Detector Assembly.

- The Scotch tape has to be removed and the three Thermal Links(320-17) are screwed with the delivered screws without washers and with a special delivered ball-key (which was delivered in 1989 with the CCD-cryostat # 18 and # 19) and special delivered M3 countersunk inbus screws to the Detector Assembly. Do only use this special ball-key for these srews !!!!!!!!!!!! **Do not apply to much force with this process, not to break the glass pins!** The Thermal Links have to be placed gently into the downmost possible position before screwing.

- The two electrical flat cables (330-13, 330-14) have to be pressed into the connectors at the large green printed circuit in the pre-assembly. Note the dark-red point at the socket and at the connector of the small thermal connection (330-14), which give the right position.

- The separately delivered Radiation Shield III (320-25) is screwed (only one position is possible) onto its spacers with the delivered countersunk screws.

- **Now all the following parts and dense surfaces has to be cleaned and dust inspected very carefully, not to have a leak after the assembly procedure.**

- The O-ring surface (groove) of the housing is cleaned, the delivered O-ring cleaned and inserted in its groove, then the taped protection of the Detector at the Cold-stop removed and the detector carefully cleaned from dust with **gentle !!!** anti-static press-air.

- After this the delivered EMMI-(respectively SUSI)-flange is introduced at the right position. This means, that the **oval** hole for the parallel pin (217) in the EMMI-flange is placed at the paralell pin **opposite** to the connector side of the housing. The EMMI flange is screwed with eight delivered screws.

- Only in the case of an EMMI Cryostat the EMMI field-lense is introduced (do not forget the delivered O-ring) and screwed. Before it is necessary to treat the O-ring with vacuum grease, because the O-ring groove of the delivered EMMI-flange is not perfect!

- The vacuum valve and gauge is installed as usual with taking care not to have dust or scratches at the dense surfaces.

- If closed completely the cryostat has to be pumped at least for **48 hours**.

- **Then a leak test with helium and a mass spectrometer or a special helium leak tester has to be done !!!!!** If there is a leak no varnish has to applied, because this a very bad quick and dirty method, that does not work over a long time properly.

  Insted of this the part, where the leak has appeared, has to be removed, inspected, cleaned, probably replaced and againd carefully installed.

- The pressure at room temperature in the cryostat after 48 hours of pumping is around 2 times 10^{-5} mBar. The pressure at cold temperature several hours after liquid nitrogen filling in the cryostat is around 2 times 10^{-6} mBar. If the pressures are much higher, there is a leak in the cryostat (e.g. at the field-lense O-ring, at the EMMI-flange O-ring or at the vacuum valve respectively the vacuum gauge O-rings).

  Also if the temperature does not reach the exspected value there is a leak or a undisired touching of the radiation shields to other parts.

  The cooling down takes approx. 6 hours, if the vacuum in the cryostat at room temperature conditions is better or equal 10^{-5} mBar.

3 Precautions to protect the UV-enhancing chip-coating

The CCD is UV-coated with the solution S14(very thin orange coating). The thickness of the coating is about 1.3 μ.

This CCD chip is masked with a black painted cold-stop to reduce stray light. An additional black painted mask mounted at the inner side of the EMMI-flange is forseen (but not yet manufactured!), to have only black features in the cryostat, if seen from the outside through the field-lense.

Additional some superinsulation mylars and a red insulation foil have been added[1] to reduce the radiation losses.

In respect to the applied UV-sensitive coating we strongly recommend to keep the dewar always in the dark and we suggest to keep it as much as possible cold, to avoid thermal stresses on the coating. If it is stored for a longer period at room temperature, vacuum should not be broken.

4 Interconnection

Before connecting the video-cable with the CCD-dewar be sure, that there is <u>no</u> remaining conductive foam in the video sleeve at the cryostat ! This would produce a short-cut and could damage the chip.

Same two cables required as for all CCDs operated with the VME-System. The outer wiring of the CCD dewar head is compatible with all other new CCD cryostats, but not with the old ones.

[1] Only with this modification we have reached in the lab a "cool-time" of 23 hours of the cryostat, if it is filled with LN_2 again after cooling down to Control = 130 Kelvin

5 System Setup

This chip we have tested with the ESO VME CCD camera system in Garching. Table 1 shows all parameters in the CCD system setup table and the used clock-pattern, which are slightly modified, and which *must* be changed to guarantee proper operation. Most parameters are set to their correct values by executing the INITCCD file "THO1K".[2]

Table 1: System SETUP table

The preamplifier current source has been set to the minimal value with a 20 kOhm resistor in the cryostat.

All tests were performed at a temperature (Monitor) of 141.6 K, if not otherwise stated.

6 Voltage Setup

See table 2 on page 6 for all voltage values. Please note that especially the values VDD, VDR, VGS, RLO and RHI have a rather high influence on the gain. They should be adjusted as acccurate as possible.

7 Noise and Gain

The total gain is 2.12 ± 0.05 e$^-$/ADU.

[2]See [2] for details

HLO1	2.00	VLO1	0.99	VDD1	23.03	VGS1	4.06
HHI1	14.82	VHI1	11.85	VDR1	13.99	VSS1	0.00
HLO2	2.01	VLO2	1.01	VDD2	19.89	VGS2	3.97
HHI2	14.88	VHI2	11.87	VDR2	13.07	VSS2	0.00
RLO1	0.99	RHI1	9.93	RLO2	1.03	RHI2	9.90

Table 2: Telemetry voltage values

measured with the above voltage setting. The system was set to the high gain value (SUBPATT 27) and to the above mentioned setting.

The readoutnoise was approx. 4.30 ± 0.35 **e$^-$RMS.**

This value only was achieved with an electrical isolation of the Detector Assembly[3] from the Cryostat-tank. To check this, you can measure between the housing-case and the Video-connector pin F. These two have to be isolated from each other.

In this case a connection from the signal ground of the CCD camera to the cryostat case was applied, but perhaps not necessary.

The noise and gain was measured using the desk top procedure "measure confac" at different illumination levels and additional as a cheque (of the first measurements) the IHAP batch 'CONT56' at illumination levels around 8 000 counts (16 bit ADC).

With lower system gain (SUBPATT 1) it was achieved a gain of approx. 8.5 e$^-$ per ADU and a readoutnoise of approx. 15 e$^-$.

8 Quantum Efficiency

The RQE was measured using an automatic mode, using the testbench computer. The values listed below might be no more accurate as ±3% (relative), because the measurement of CCD conversion gain in e$^-$/ADU is the biggest uncertainty. We have assumed the worst case for the quantum efficiency.

The peak value for RQE of the **un**coated chip was around 43 % at 600 nm. Table 3 on page 7 shows the details for the coated CCD. Figure 1 on page 11 shows a plot of the obtained values.

9 Charge Transfer Efficiency

The CTE in horizontal and vertical direction looks good[4] with the method of point sources (cosmic rays). Exact values are difficult to measure, because at the edges of the CCD the pixels are semi-masked.

[3] see [1] Maintenance Manual No.5 "CCD Cryostat for the VME-based Control Camera"
[4] it is the same as with other Thomson 31156-CCDs we have tested

CCD SENSITIVITY CALIBRATION: 18 Apr 1990 10:17:43

==========================

Detector ID	: TH56A40
Calibrated against	: INTERNAL
Detector area (cm2)	: 3.61E-06
e-/[ADU]	: 2.12
Misc.Comments	: UV-COATED WITH S14 1.2MU

CCD System values		Scanned CCD area	
Hor. act. Pixels	1100	First pixel	460
Tot. vert. Lines	1040	Last pixel	510
Hor. Binning	1	First line	490
Vert. Binning	1	Last line	540

Lambda [nm]	Time [sec]	Dens [log]	Temp [K]	Counts [ADU]	RQE [%]	Sensitivity [A/(W/cm2)]	Photon flux [Phot/cm2]	Irradiance [W/cm2]
320	300	0.0	136.4	384	10.76	+1.008E-07	+6.984E+06	+4.308E-12
340	300	0.0	136.4	1846	14.27	+1.416E-07	+2.532E+07	+1.475E-11
360	300	0.0	136.4	1948	14.98	+1.571E-07	+2.546E+07	+1.403E-11
380	60	0.0	136.5	1545	16.57	+1.837E-07	+9.123E+07	+4.756E-11
400	40	0.0	136.5	1733	15.94	+1.852E-07	+1.596E+08	+7.938E-11
450	10	0.0	136.5	1620	19.32	+2.527E-07	+4.922E+08	+2.175E-10
500	10	.3	136.5	2605	33.39	+4.858E-07	+4.582E+08	+1.820E-10
550	10	.3	136.5	7491	41.60	+6.663E-07	+1.058E+09	+3.816E-10
600	10	.9	136.5	2667	44.11	+7.692E-07	+3.551E+08	+1.177E-10
650	10	.9	136.5	3121	45.00	+8.426E-07	+4.072E+08	+1.257E-10
700	10	.9	136.6	3760	45.21	+9.204E-07	+4.885E+08	+1.387E-10
750	10	.9	136.5	2450	34.56	+7.534E-07	+4.163E+08	+1.104E-10
800	10	.6	136.5	3619	26.90	+6.256E-07	+7.902E+08	+1.964E-10
850	10	.3	136.5	7485	18.93	+4.687E-07	+2.322E+09	+5.420E-10
900	10	0.0	136.6	4586	11.92	+3.121E-07	+2.259E+09	+4.987E-10
950	10	0.0	136.6	2295	5.68	+1.569E-07	+2.371E+09	+4.965E-10
1000	20	0.0	136.6	2021	1.86	+5.412E-08	+3.184E+09	+6.338E-10

File _TH56A40_3 stored on :,800,0,4 at 18 Apr 1990 12:59:44

Table 3: RQE measurement protocol for UV–coated chip

10 Dark Current

The dark current was measured with some 1 hour dark exposures at different temperatures. These measurements were undertaken after all remanence effects were over. This means: The CCD was in the dark at 140 K or lower for at least 5 hours and wiped every minute. See table 4 for details.

The mean dark current rate is less than 2.0 ± 0.3 $e^{-}/pixel/hour$ **at 140 K.**

The "zero-level" is 328.2 ± 0.3 **ADU.**

We got the same results using the overscan area of long exposures.

Exp. Time [min]	Temperature [K]	Mean e^- [$1.6 \cdot 10^{-19}$ Cb]
60	183	38.0 ± 6.5
60	168	4.5 ± 0.5
60	158	3.0 ± 0.4
60	153	2.8 ± 0.4
60	147	2.5 ± 0.3
60	145	2.3 ± 0.3
60	136	1.0 ± 0.1

Table 4: Dark Current

11 Linearity

Linearity was measured taking 10 sec and 100 sec exposures at different light levels at 700 nm from about 4 photons/pixel up to $1.1 \cdot 10^6$ photons/pixel. See table 5 for details. There's no significant deviation from the average value of 0.213 counts/photon at low light levels. At very high levels we got a little deviation from the average value at a low system gain (SUPPAT 1) near the region of saturation.

The saturation value (capacity of one pixel) has the calculated value of $1.6 \pm 0.2 \cdot 10^5$ **e^- per pixel.**

12 Cosmic Ray Events

The Cosmic Ray Event rate was measured using our standard method (IHAP Batch: COSRAY) to count *events* independently of their actual size.

The cosmic ray event rate is 1.5 ± 0.2 $events/min/cm^2$**.**

13 Blemishes

There a no hot spots, no hot or dark lines.

At low light levels (e.g.: 30-100 e^- per pixel) appear approx. 3 traps, which consume maximal 2500 e^-, and 6 “trap-lines”; one has a capacity of approx. 3000 e^- and the other less than 1600 e^-.

Both traps and “trap-lines” has to be mapped.

14 Uniformity

The flat-field exposures show no blemishes, which are not erasable with flat-fielding, except a little fringing of the UV-coating. Values of deviations from homogenity are

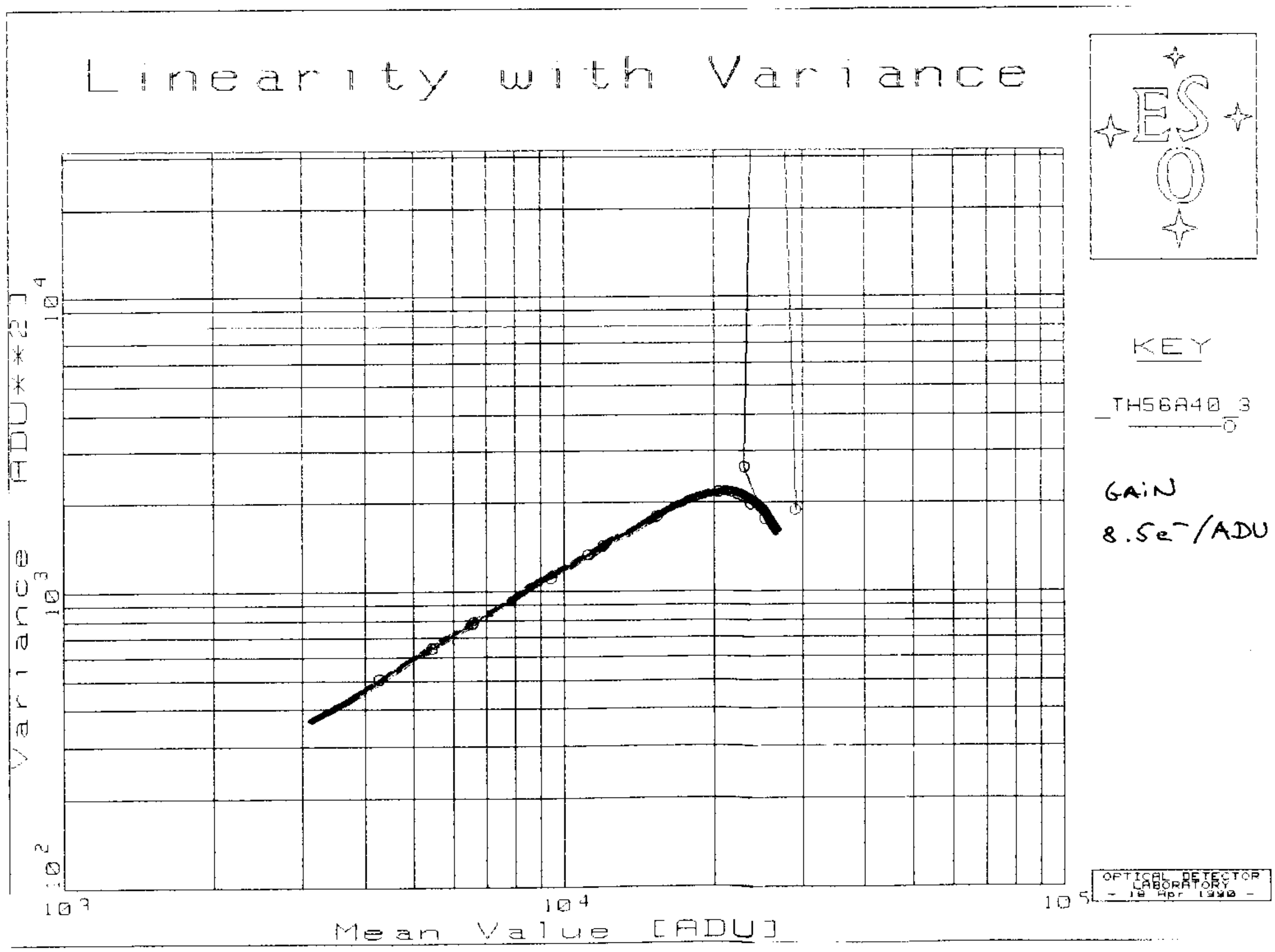

Table 5: Linearity Measurement at the gain: 8.5 e^- per ADU

given in table 6.

Flatfield at the wavelength in [nm]	Maximum Deviation from mean value in [%]
340	4.0
400	4.0
550	3.0
700	6.0
850	6.5
1000	5.0

Table 6: Uniformity of the CCD

15 Remanence

The remanence, which is significant, can not more be reduced, because with this chip negative clock values are not possible. If the chip is single saturated with 160000 e^- per pixel, on the next 10 minute exposure there is no remanence detectable.

All remanence values were measured at a temperature of around 150 K.

At double saturation level there is nearly no effect. The remanence is within the read-outnoise level and approx. 1 e^- after a 10 minute dark exposure.

Significant remanence appears at the 4-fold, 8-fold and 16-fold saturation level. The first 10 minute exposure after 16-fold saturation shows a remanence or ghost image of about maximal 400 e^- per pixel.

Further dark exposures show less remanence, but to delete all remanence one have to wait approx. 4 hours with the chip in the dark and some wipes.

On table 7 the exact values are shown in vertical and horizontal direction. The remanence was produced during this test with a cross grid pattern.

Light level in e^-	Remanence horizontal in [e^-]	Remanence vertical in [e^-]
200000	0	0
400000	0	1
800000	1	50
1600000	60	120
3200000	110	400

Table 7: Remanence of the CCD with a rectangular test grid measured on an immedeately following ten minute dark exposure

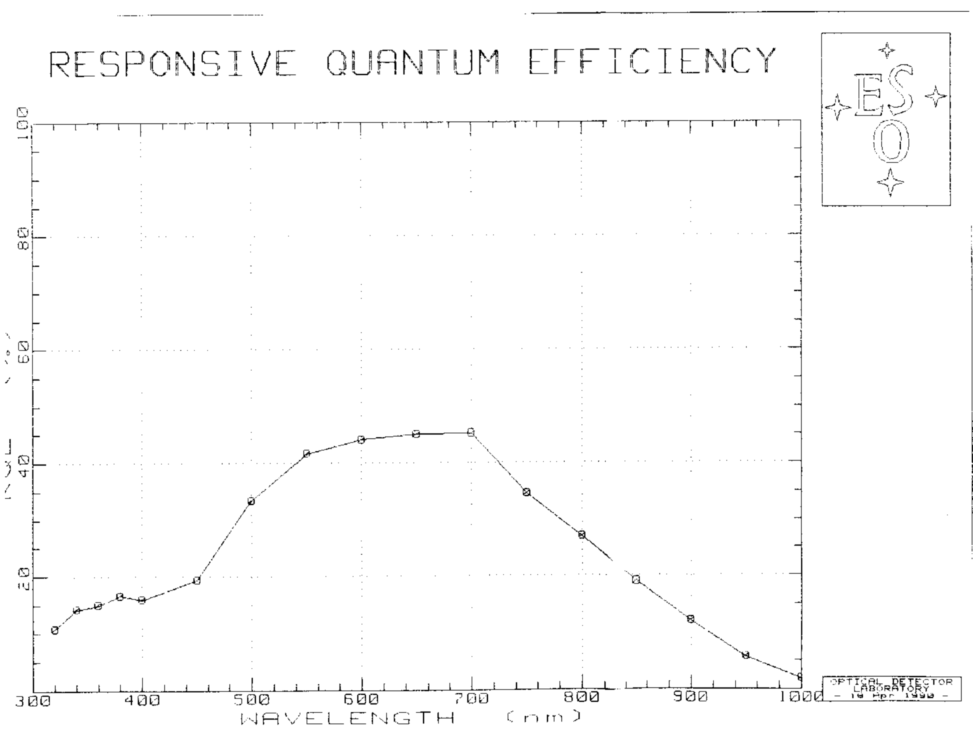

Figure 1: Plot of RQE values

References

[1] Sebastian Deiries, Martin Cullum: Maintenance Manual No.5 –July 1989: CCD Cryostat For The VME-based Control Camera

[2] Roland Reiß: The VME-CCD Camera: Universal Introduction

[3] IBM. PC–DOS 3.10 Reference Manual.

[4] IBM. IBM XT Hardware Reference Manual.

[5] Miller. FORTH Compiler Manual.