EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hemisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

VLT PROGRAMME

VERY LARGE TELESCOPE

DE-CONTAMINATION REPORT of FORS1 CCD

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Introduction

The FORS 1 CCD has suffered from a slow build up of contamination since the instrument began operation in September 98. The contamination accumulates in a quadrangle pattern around the edges of the CCD, causing a decrease of QE in this area, which mostly affects the Ultraviolet band (0.6% relative loss per day in the most affected part of the quadrangle region). This contamination was removed during March-October by warming up to ambient temperature and pumping the cryostat. However, the contamination returned at the same rate, few days after the CCD was cooled down. During April to August 1999, the ODT undertook laboratory investigations to determine that the contamination comes from the use of some materials (glues, shrinking sleeves, aluminum tape, for instance) that out-gas and also from deficient cleaning procedures. Most importantly, we found that the CCD contamination can be completely removed (no permanent damages) and none of the major components (mechanical structure, electronics) was responsible for that problem.

During 17th to 31st October, the FORS 1 CCD detector and head cryostat was thoroughly cleaned using the newly developed procedures. To speed up the process, a bath cryostat was prepared in Garching prior to the mission and only the detector head and CCD was cleaned in Paranal. This new bath cryostat was intensively tested during 35 days in Garching, and showed a 0.4% relative U band QE loss in the corner region. This very tiny contamination grew during the 4 first days of the experiment and was stable the rest of the 31 days of the test.

Experimentation Protocol

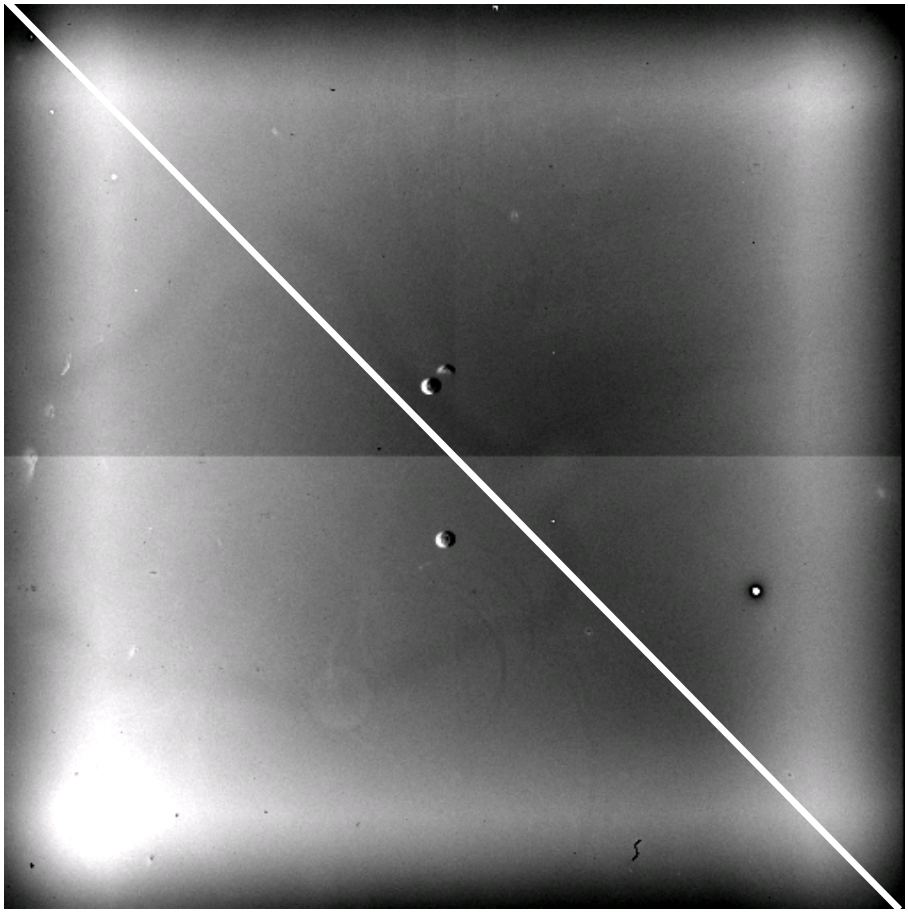
This paragraph describes how the measurement of contamination growing has been carried out. The first day of the experiment, a set of reference frames is taken, let's call FI_U, FI_B, FI_V, FI_R, FI_I the initial flat field frames and BI the initial Bias frame at T_0. Moreover, let's call F_U, F_B, F_V, F_R, F_I the flat field frames and B the Bias taken at T_0+t. To measure the uniformity of the contamination, we apply this formula for each wavelength (U,B,V,R and I), hereafter for U band :

$$D_U=(F_U-B)/ (FI_U-BI)*100.0$$

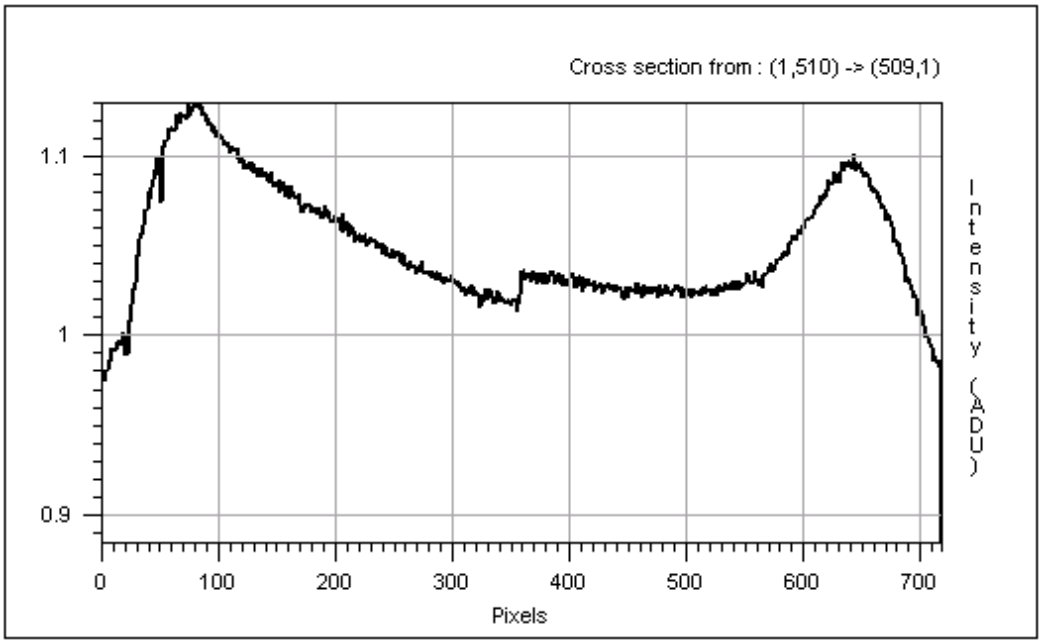
The D_u frame is binned 10x10 to attenuate the photon noise by a factor of 10. Otherwise a faint contamination layer could be hidden into the photon noise. If the CCD is free of contamination, the D_X frames should exhibit nothing but random noise around the value 100.0. Nothing **can** be assessed concerning the overall drop of QE using the D_X frame, **this frame shows the local relative pixel to pixel QE variations**. A QE comparative measurement has to be done to determine absolute QE before/after decontamination.

The next frame shows the FORS 1 D_u Frame, the F_u has been acquired the 31st of October and the FI_U the 17th. At that time, the 17th of October frame exhibited a QE loss of 13% in the corners. It took 22 days to get to this point, yielding to a QE loss rate of 0.6% per day in this area.

Note : all the frame shown in this document are **full frames** with positive visualization/displays cuts.



A D_u frame, binned 4x4.The white line shows where the cross section has been done for all the following graphs.



Diagonal cross-section of the previous D_u frame, form left-top corner to the lower-right, 13% peak-peak

FORS 1 De-contamination mission at PARANAL

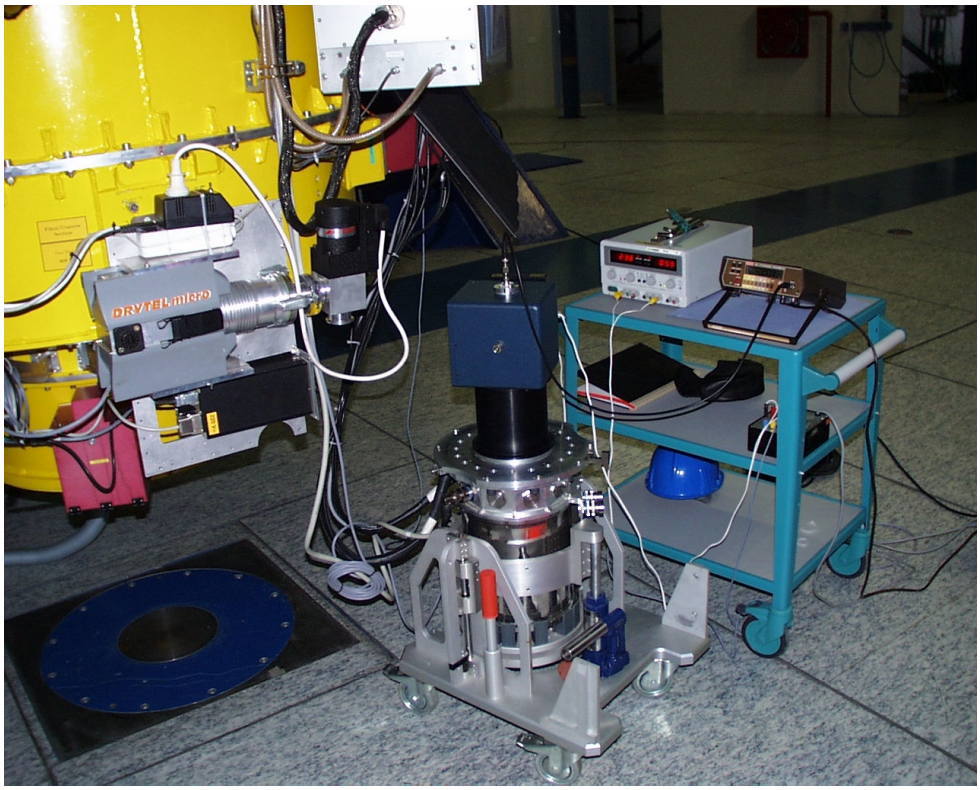
A FORS 1 de-contamination mission was scheduled, the whole process was foreseen to take 14 days. A preplanned cryostat was brought to Paranal to replace the contaminated one. Therefore, the head was dismounted completely and cleaned as follows:

- All the Parts dismounted up to the last screw.
- Metallic parts were washed with ultra-pure acetone and alcohol in ultrasonic bath, and vacuum baked at 180C for a period of 72 hours.
- Fiberglass parts were washed with ultra-pure acetone and alcohol in ultrasonic bath, and vacuum baked at 120C for 96 hours.
- CCD was standalone vacuum baked at 60C for 5 days.

The most suspicious contaminant parts (all found inside the old FORS 1 dewar) could be a glue, shrinking sleeves and aluminum tapes.
All the parts were reassembled, and the CCD position was checked with a XYZ alignment table belonging to the ESO-Infrared team. The system as pumped during 3 days. The whole system was ready 2 days before schedule, (no major problem occurred). The CCD alignment was good after remounting: no tilted CCD, and a small shift of 10 pixels (240um) has been measured from the previous position (measured by FORS1 MOS slits acquisition mode).

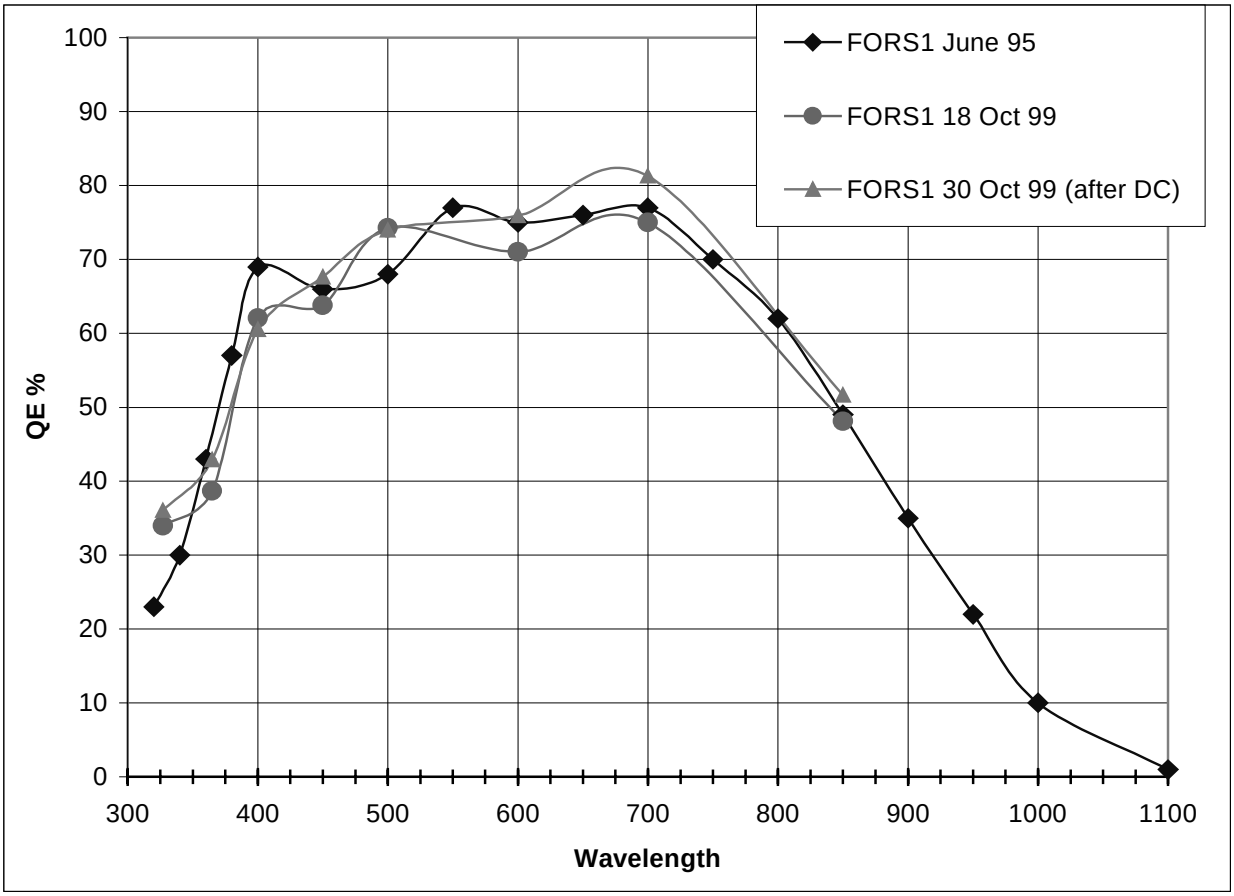
QE measurements

A portable QE measurement device was designed, built and calibrated in Garching before the mission. The goal was to measure QE at to the telescope without detaching FIERA from FORS 1 instrument.



View of the portable QE measuring device besides FORS1 instrument at UT1

This device has been used just prior and immediately after decontamination (or before telescope installation).

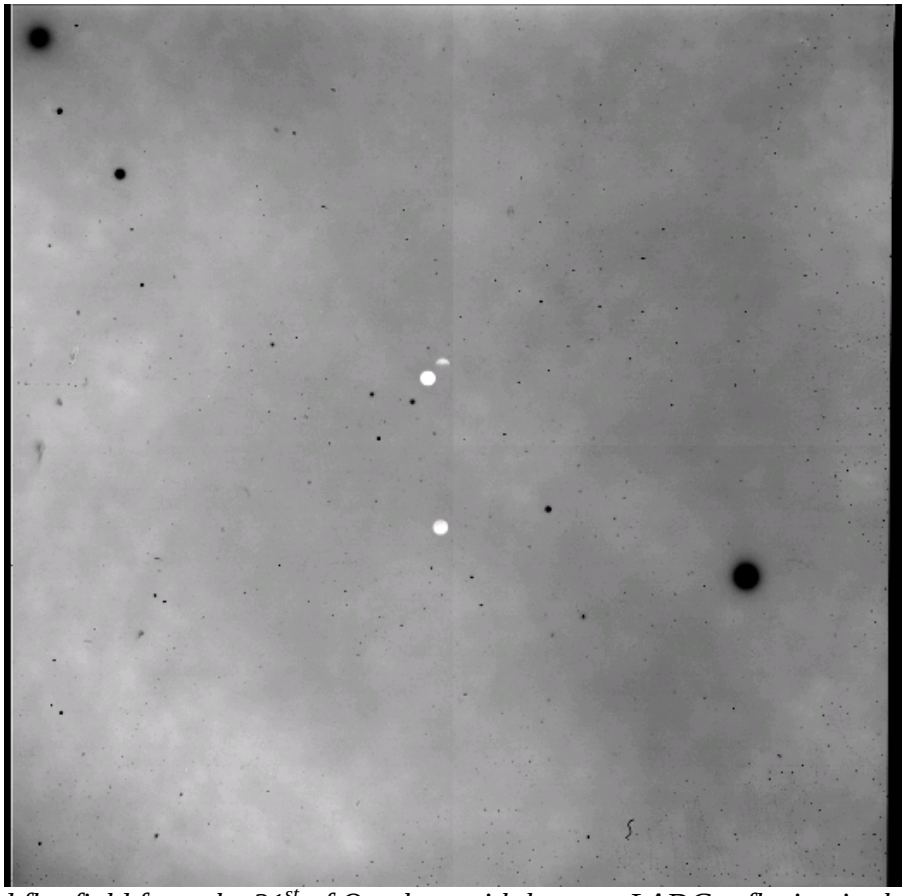


FORS 1 CCD QE measurements, central 1cm^2 area = 416x416 pixels. This central area was barely contaminated.

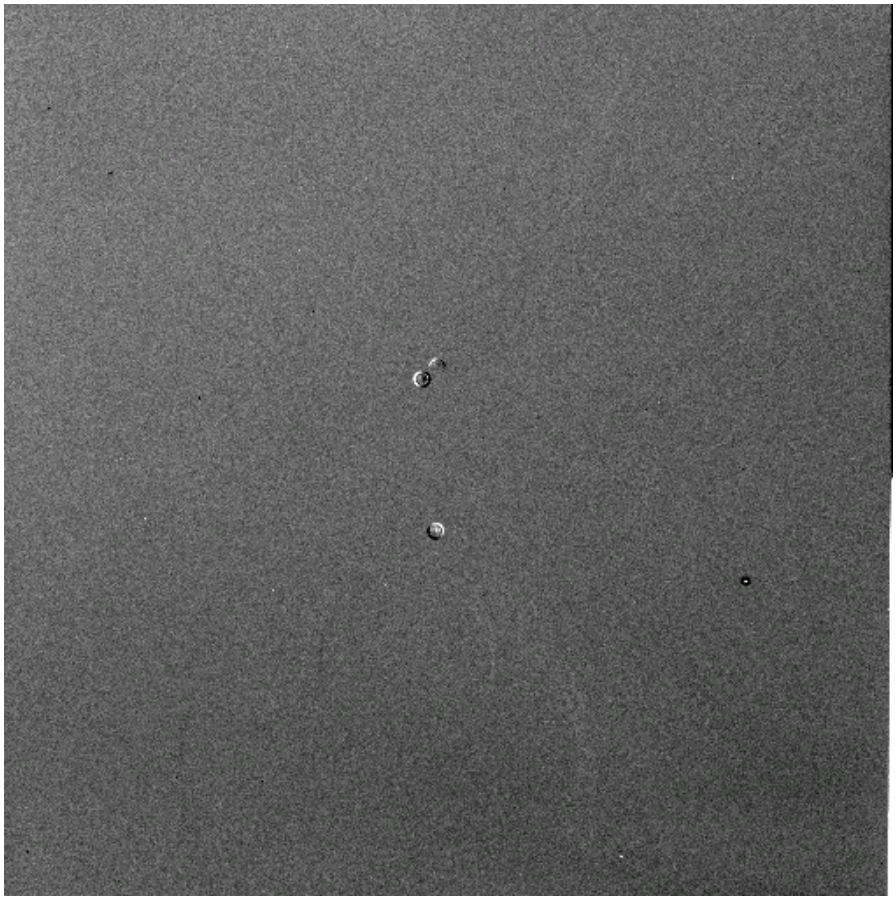
As already measured with different CCD devices in Garching, the contamination has no effect on the QE in the center part of the CCD. The 30th October curve is smoother than the one from the 18th, before decontamination, because contamination behaves like a thin optical layer, leading to a small fringing effect in the QE curve. The CCD has been cooled down the 30th of October 1999, and flat field measurements could start on the 31st. So this date will be regarded as the T_o date in the following text.

PRNU measurements (or contamination growing) after FORS 1 Decontamination

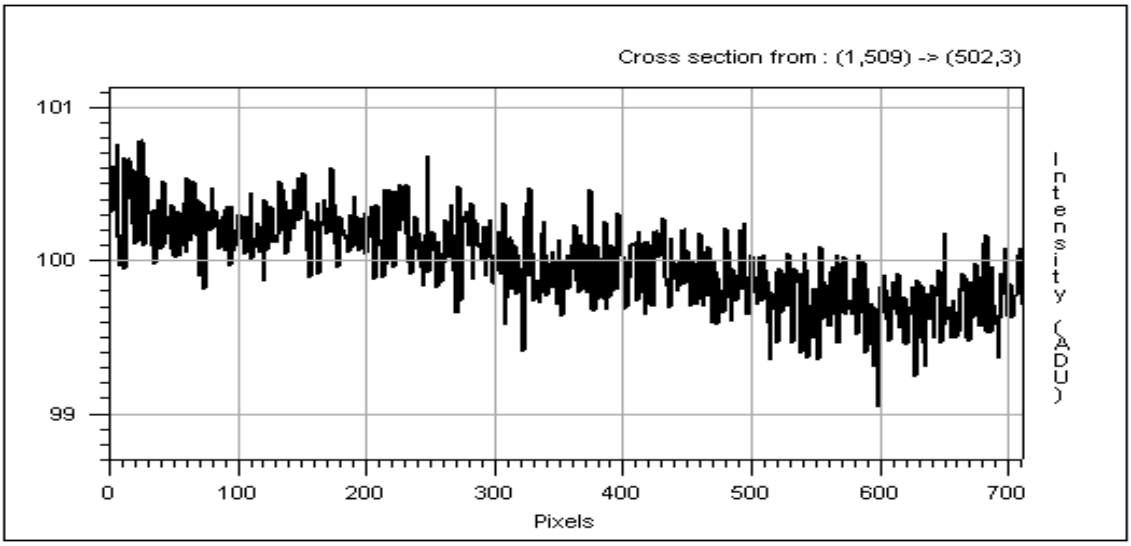
Immediately after reinstallation of the system to the telescope, a set of reference frames has been taken the 31st of October. Only screen flat fields were used because they seemed to be more stable than sky flat fields. The goal of this procedure is to monitor how contamination is growing after the cleaning process, in order to check how far the procedure is successful.
All the previous analysis performed using standard stars, showed that the U band is the most affected (QE relative loss rate of 0.6% per day in the corners), the Red band is the next most affected, V, B and I band are not strongly affected.



A U band flat field from the 31st of October, with lamp to LADC reflexion in the middle.

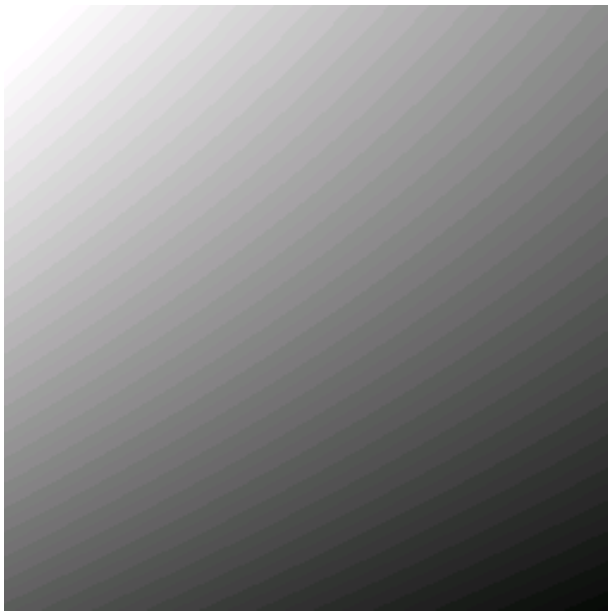


A D_u frame at To+1 day, binned 4x4. Nothing so far is visible.

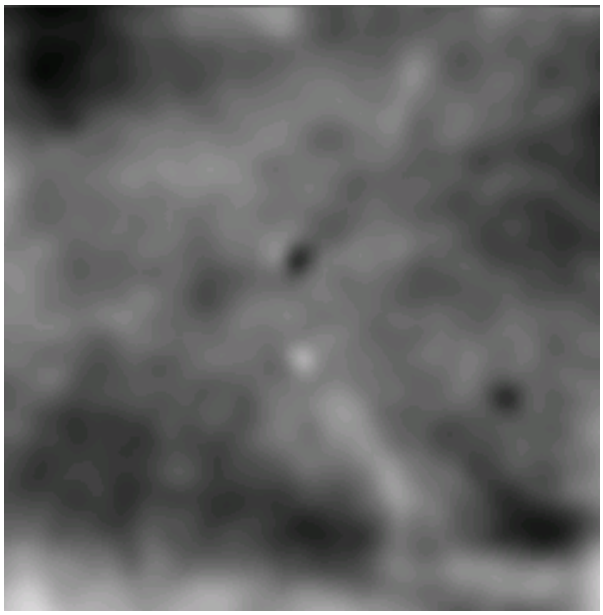


Diagonal cross-section, from top-left corner to the lower right from the previous frame. Normalized to 100,0.

After 1 day, nothing so far is visible, except a light gradient due to changes in illumination of the FORS instrument flat field screen. To avoid this gradient to hide a slight contamination, it was removed by dividing the D_u frame by a second order polynomial synthetic flat field, as shown hereafter:



Second order polynomial synthetic flat field



DG_u frame, divided by the synthetic flat field and a FWHM=5 gaussian filter was applied, the final binning of this image is 8x8 to remove all photon noise

The To+1 ultra processed D_u frame does not show a quadrangle contamination pattern.
All the following frames will be processed by this way : Binned 8x8 D_u frame + gradient removal + FWHM=5 Gaussian filter : lets call this frame **DG_U**. U subscript for U band for instance.
<u>One has to be aware that this is an extremely enhanced way to watch the growing of the contamination layer even though the time span is very short, and to our knowledge, no observatory has investigated this effect so rigorously.</u>

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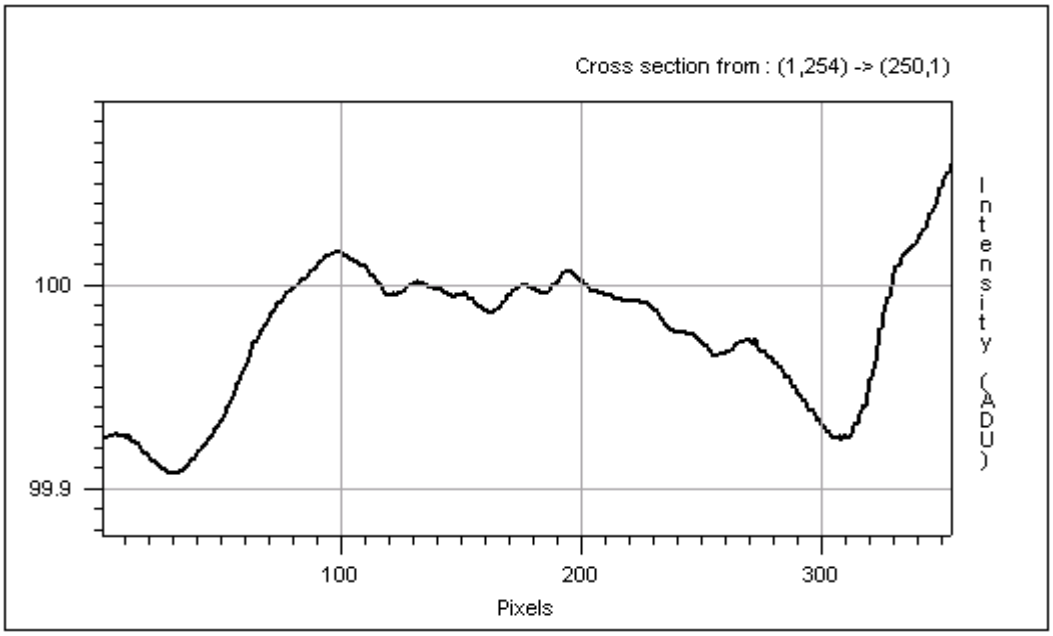
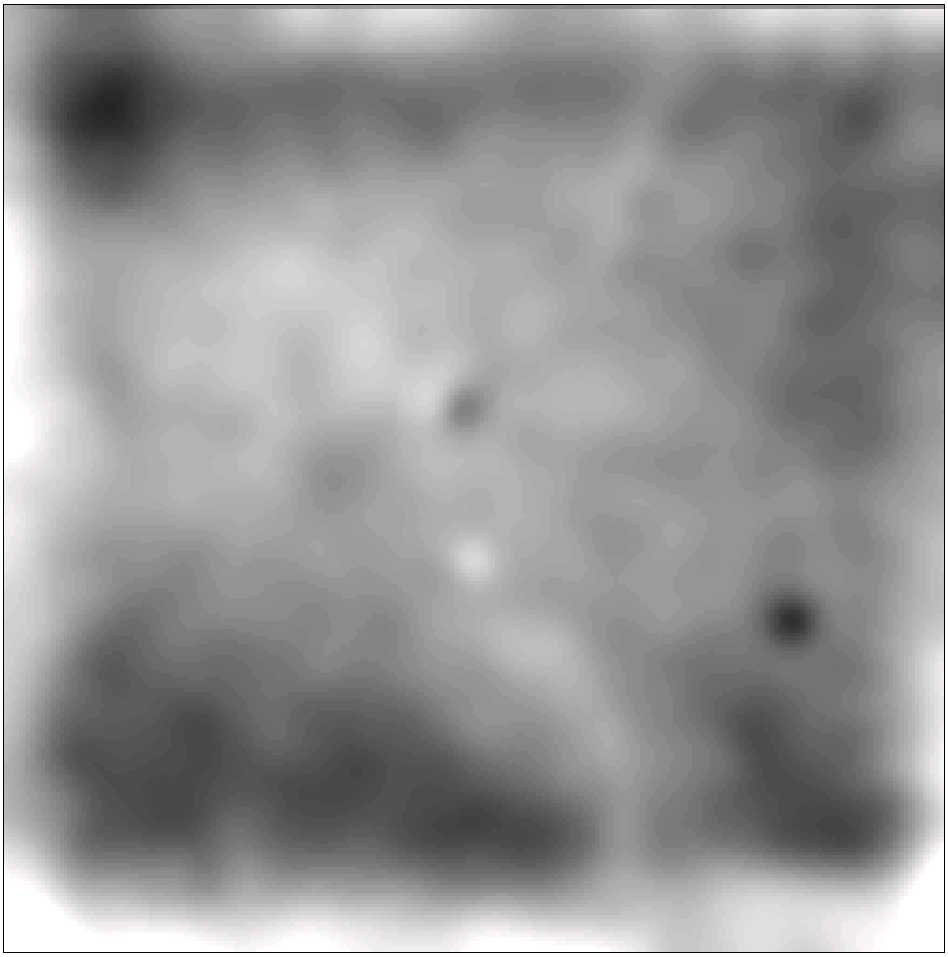
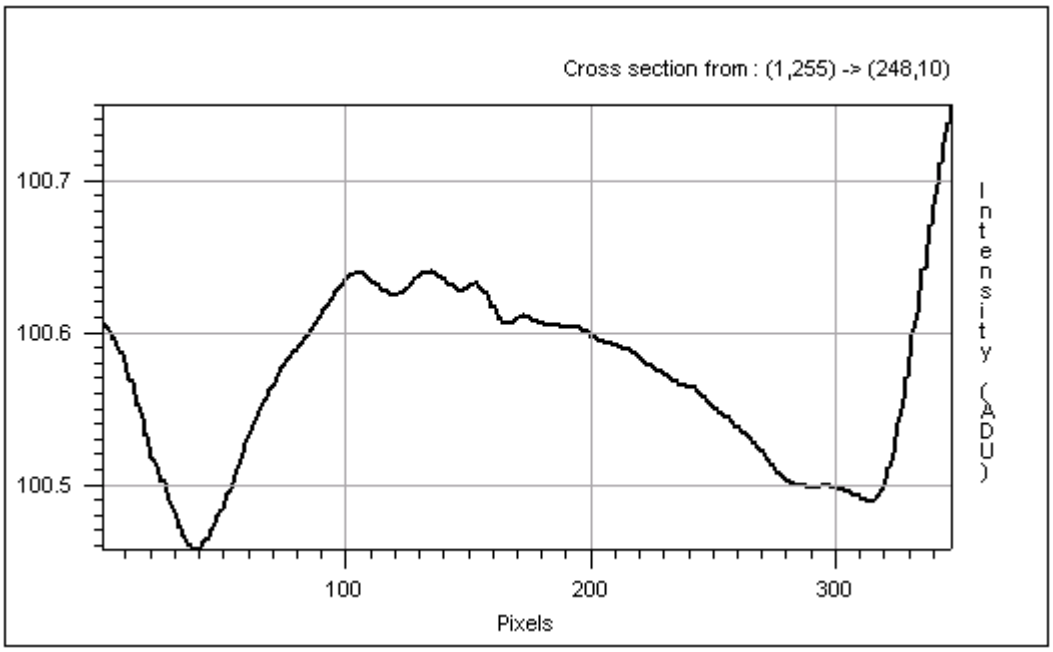


Diagonal cross-section, form left-top corner to the lower right from the DG_U ultra processed frame at To+1 day. Normalized to 100,0.

At To+4 days, the DG_u frame exhibits a quadrangle contamination pattern :

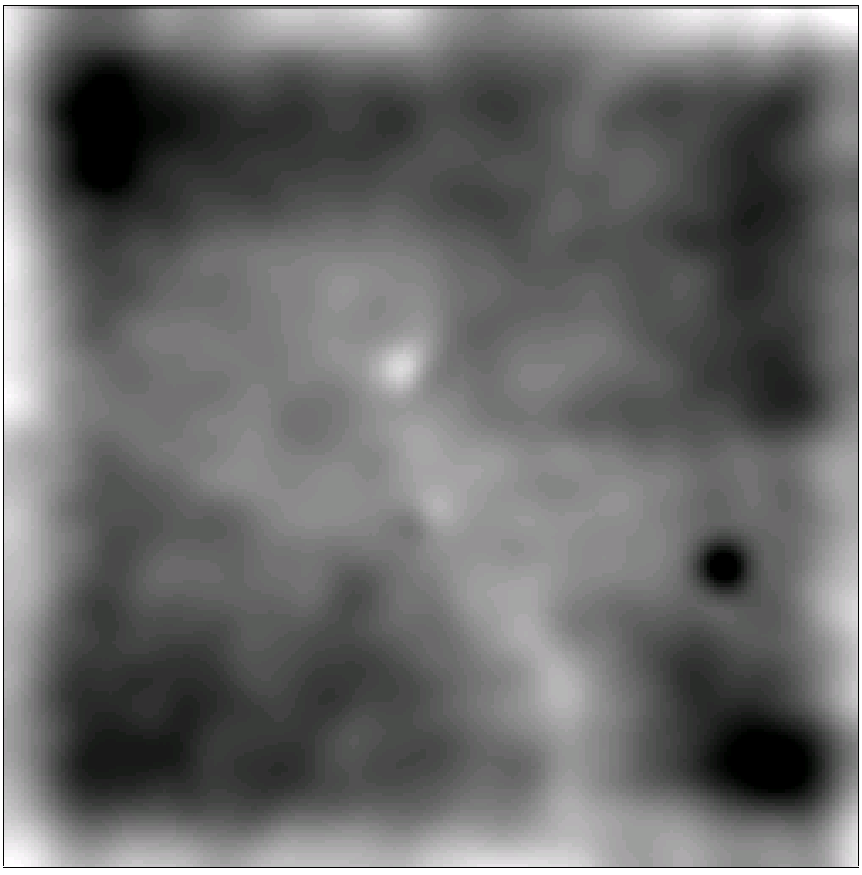


DG_u Frame at To+4 days

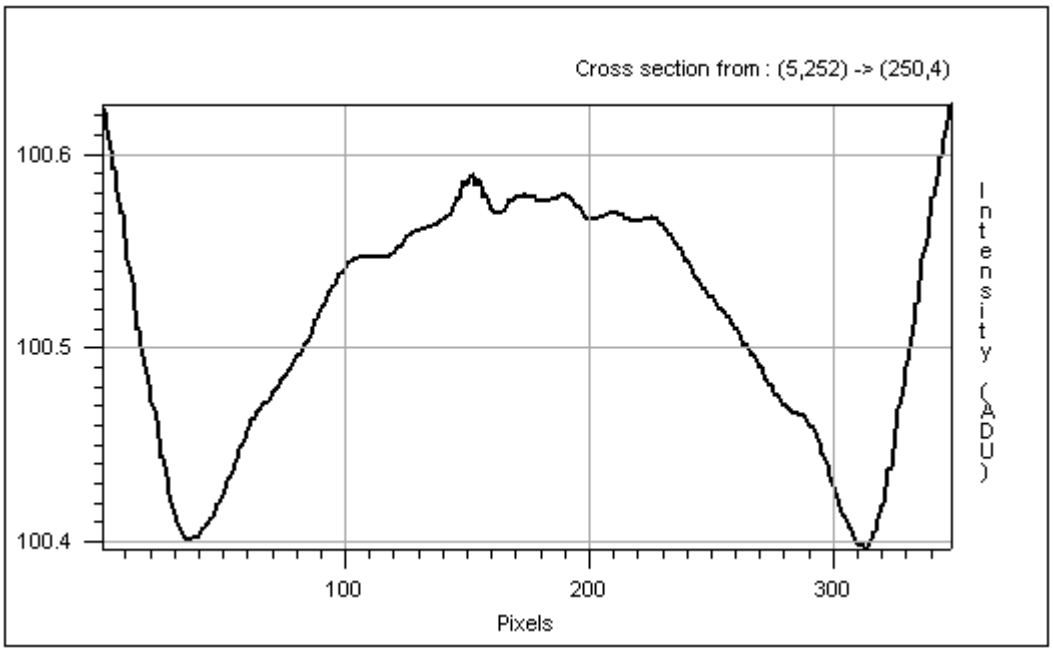


Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+4 days, 0.2% relative QE loss in the corners. Normalized to 100,0.

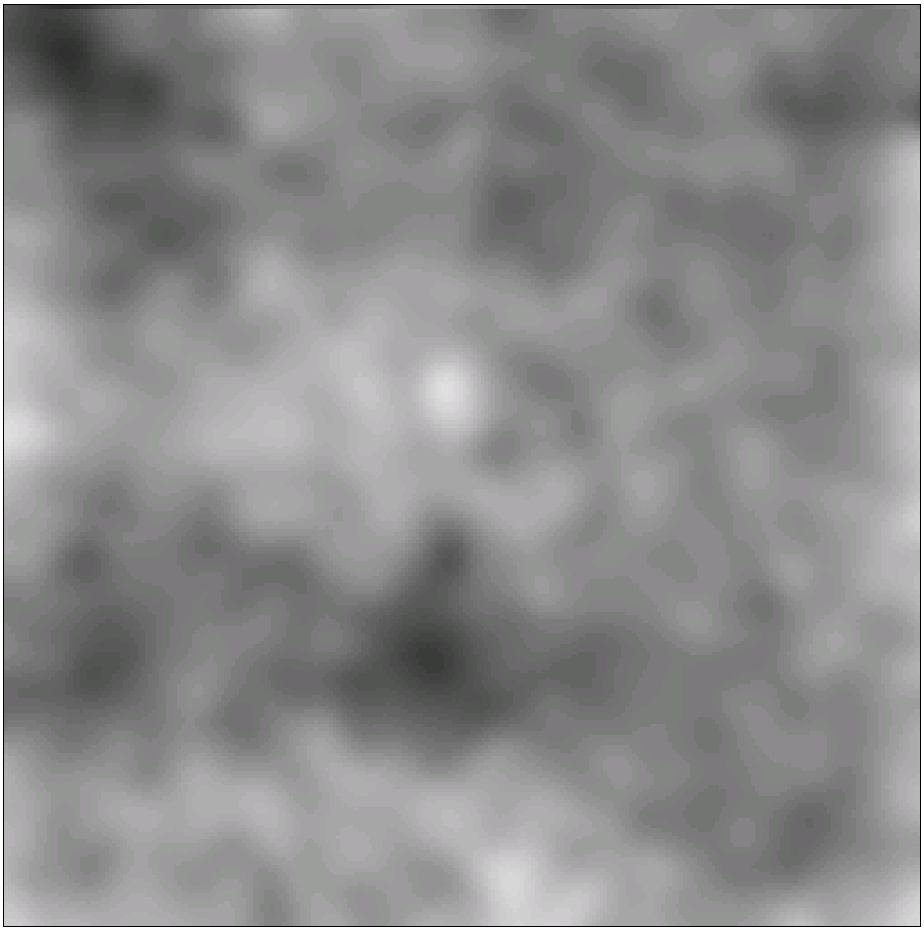
At To+5 days, the DG_u frame shows again the quadrangle contamination pattern.
To remind the reader, nothing <u>at all</u> is visible into the U band flat field frame itself.



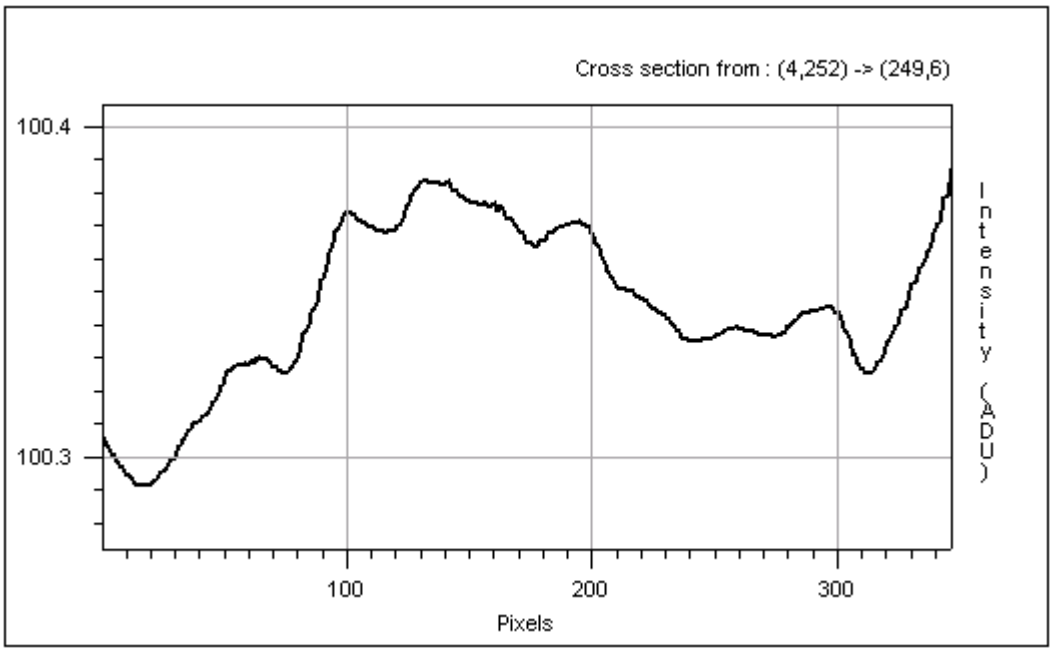
DG_u Frame at To+5 days (the display cuts are narrower than the To+4 image)



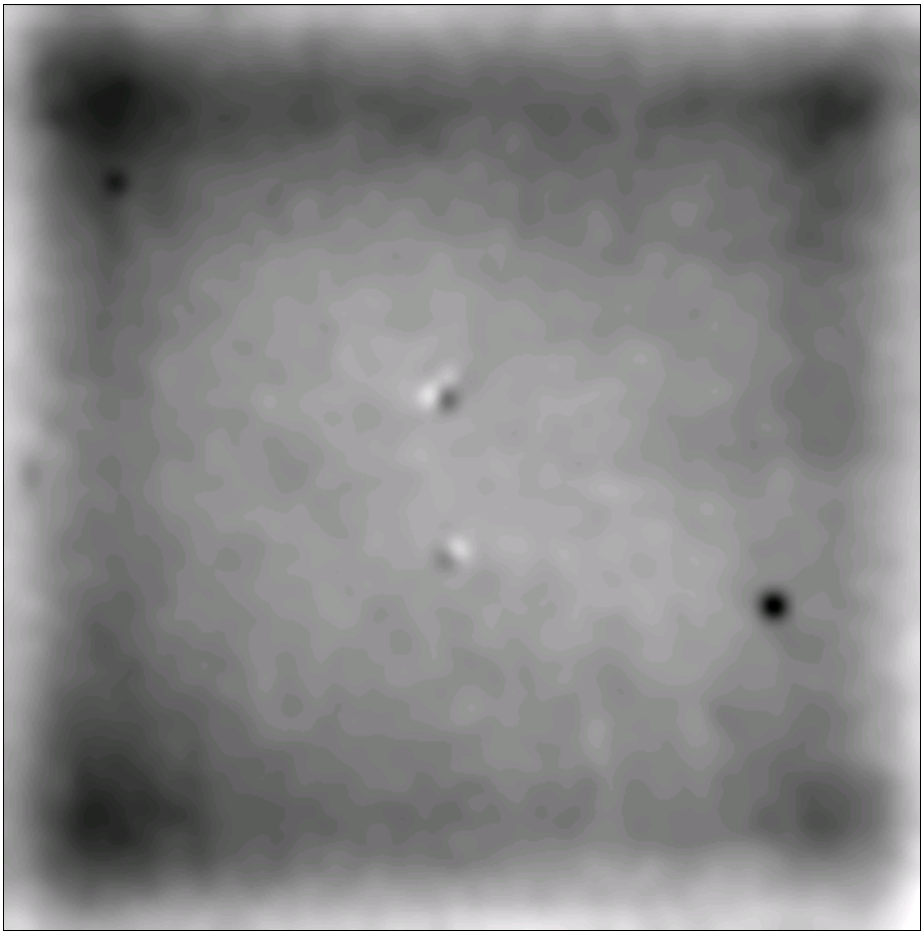
Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+5 days, 0.2% relative QE loss in the corners. Normalized to 100,0.



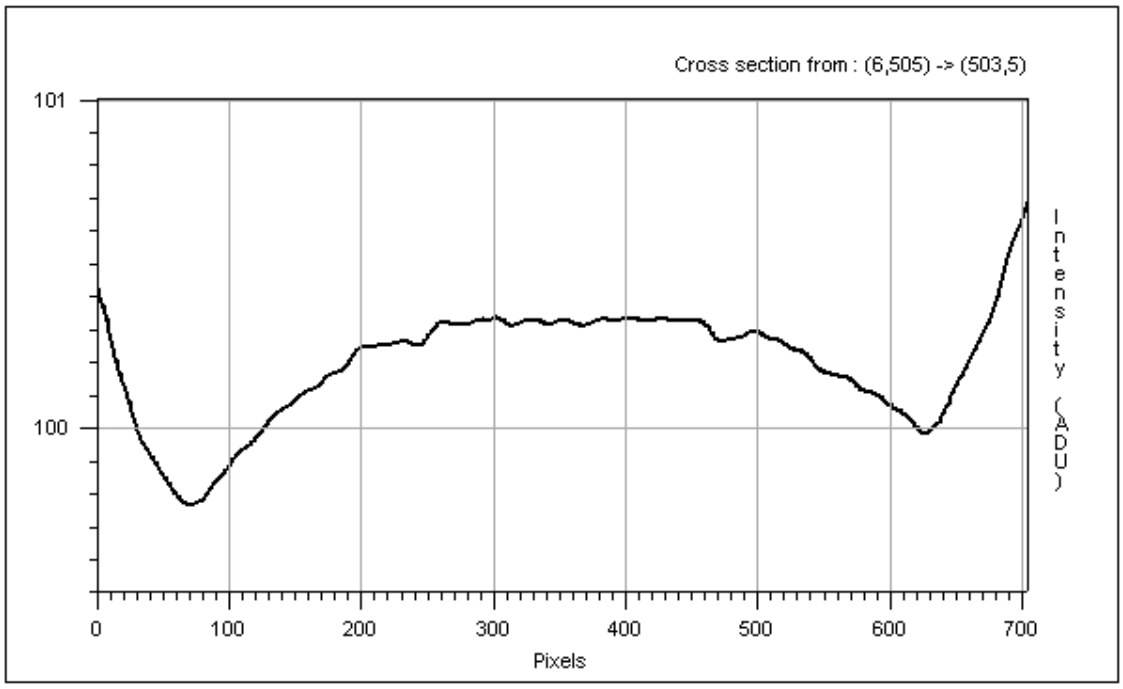
DG_{Red} Frame at To+5 days.



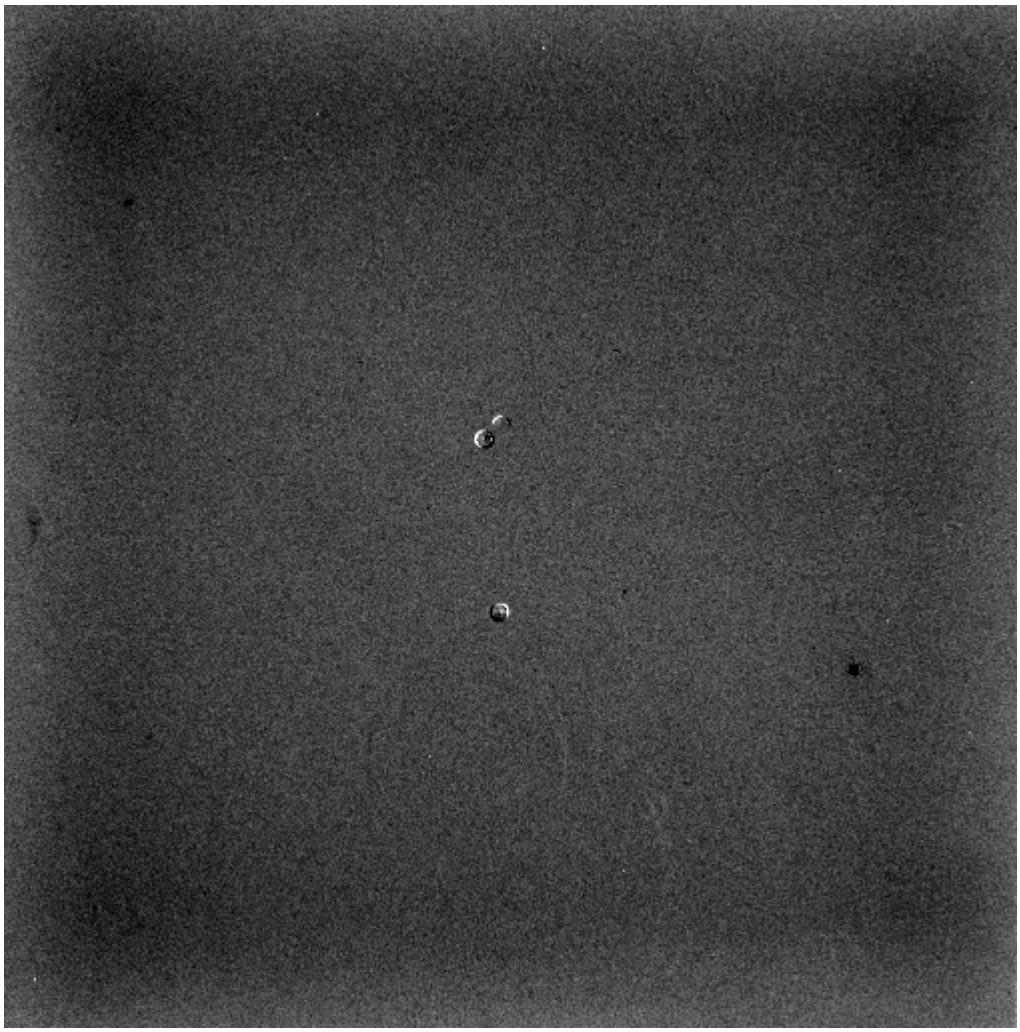
Diagonal cross-section, form left-top corner to the lower right from the DG_{red} frame at To+5 days, less than 0.1% relative QE loss in the top-left section. Normalized to 100,0.



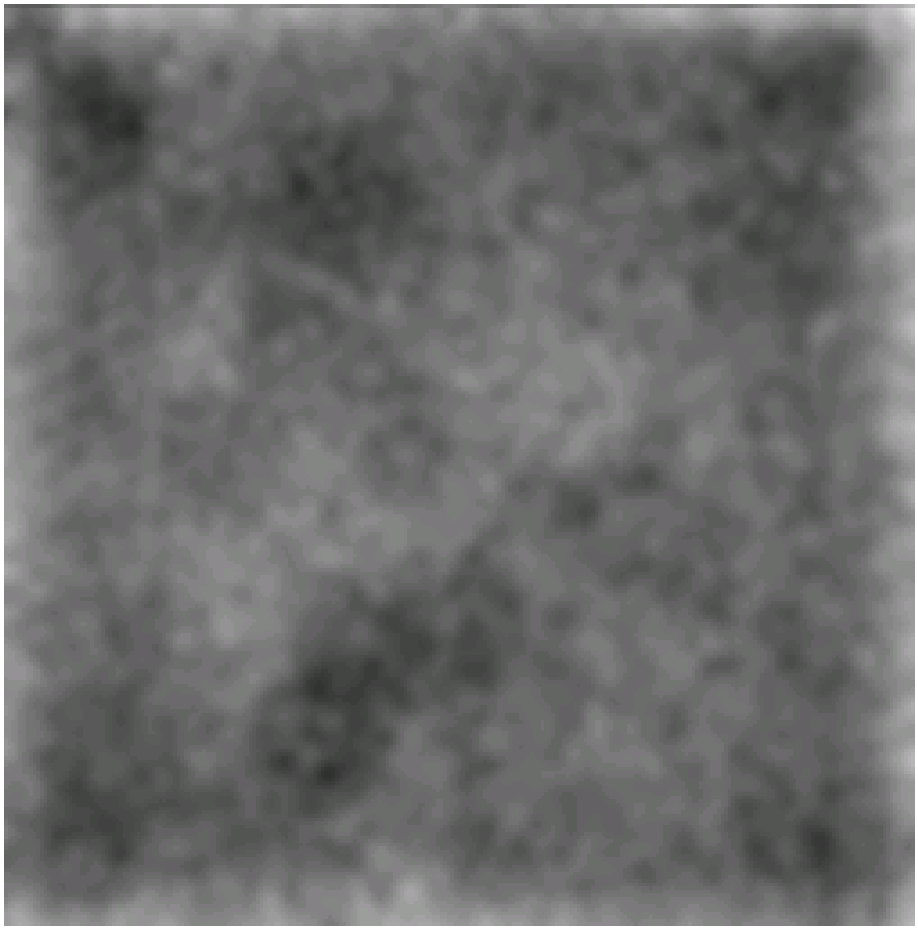
DG_u Frame at To+11 days, binned 8x8



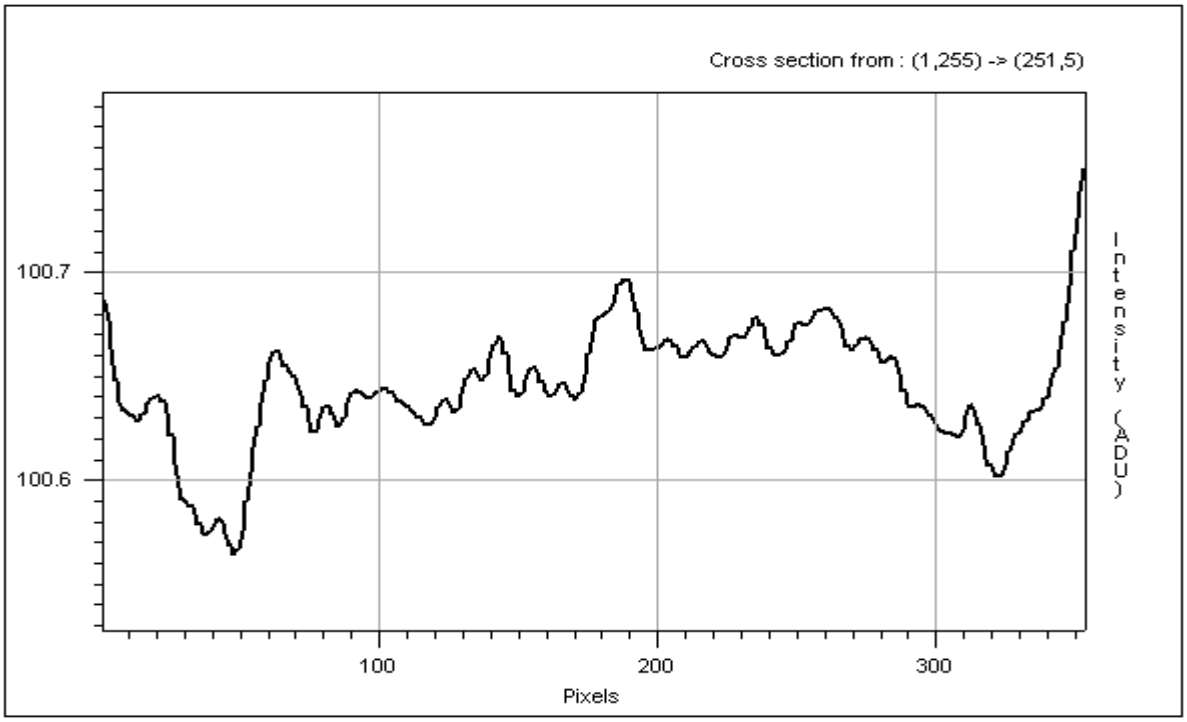
Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+11 days, 0.5% relative QE loss in the corners. Normalized to 100,0.



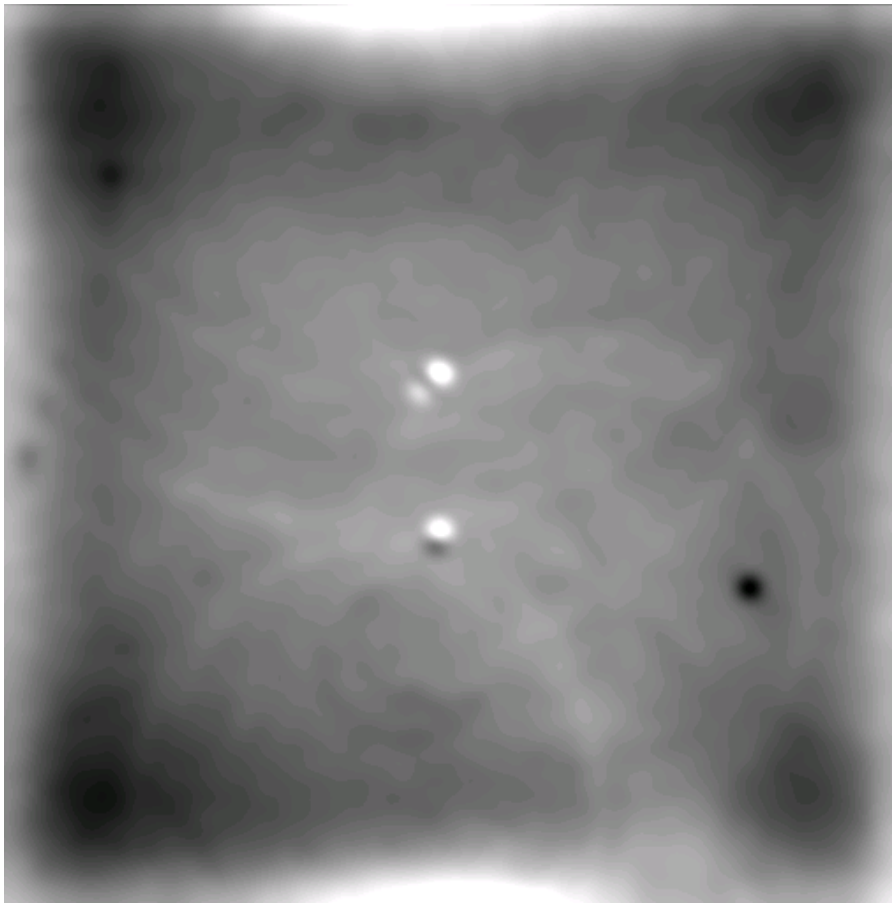
D_u Frame at To+11 days, binned 4x4



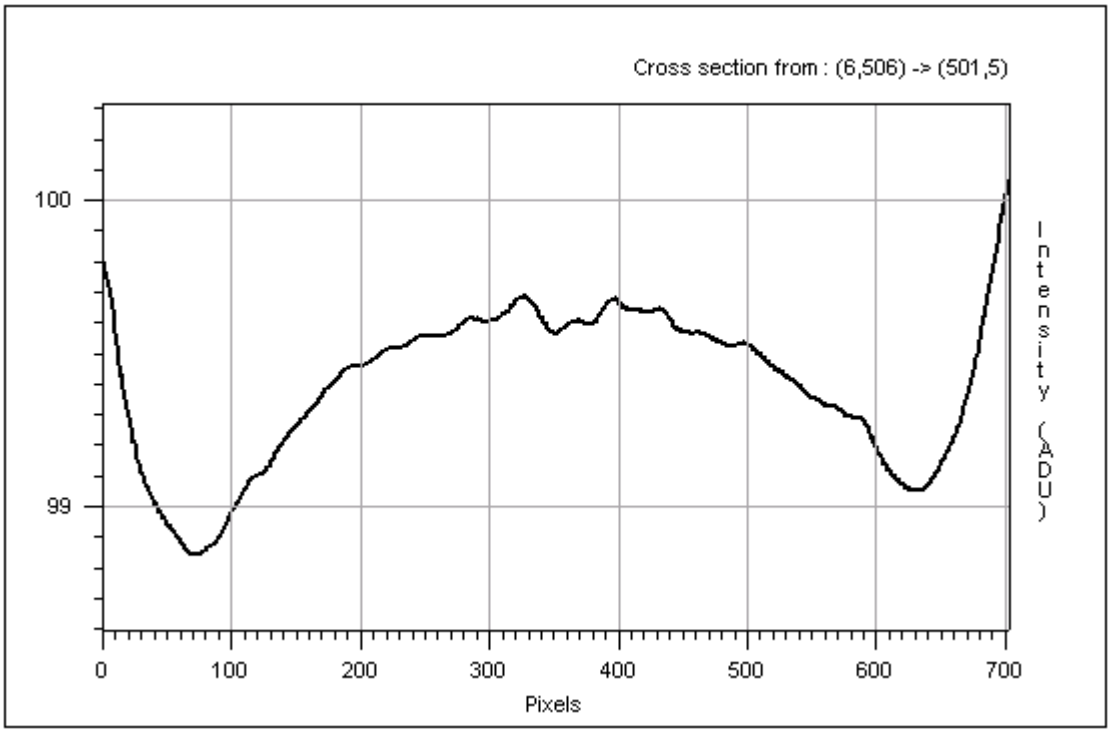
DG_{Red} Frame at To+10 days, binned 8x8



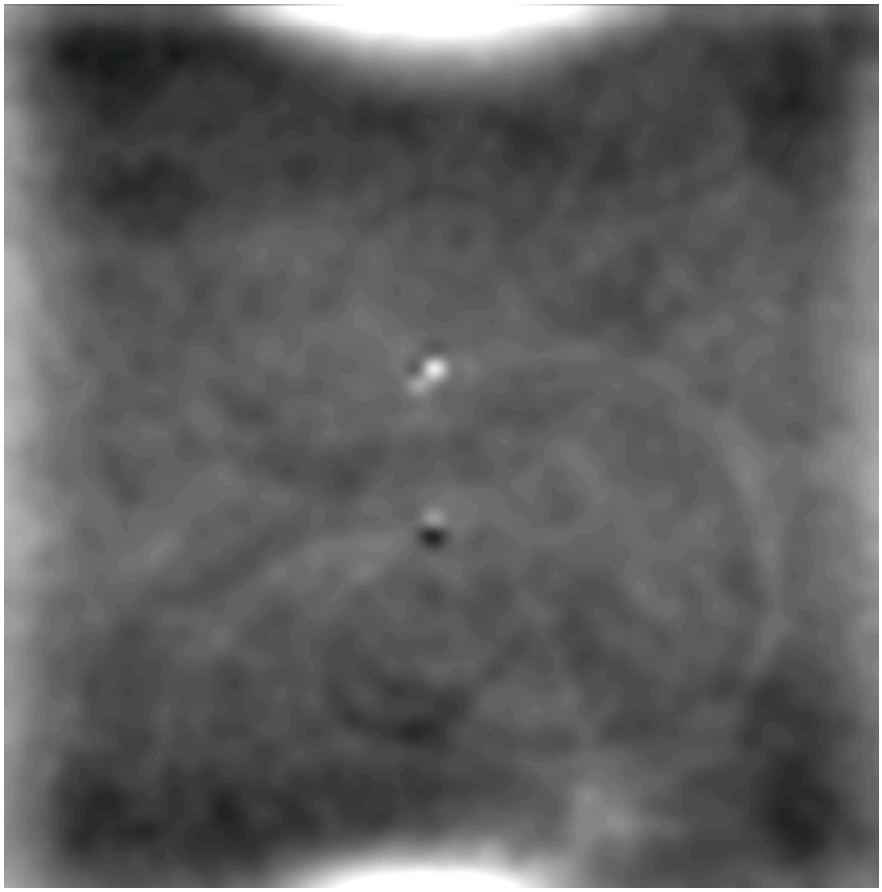
Diagonal cross-section, form left-top corner to the lower right from the DG_{red} frame at To+10 days, less than 0.2% peak-peak relative QE loss in the top-left section. Normalized to 100,0.



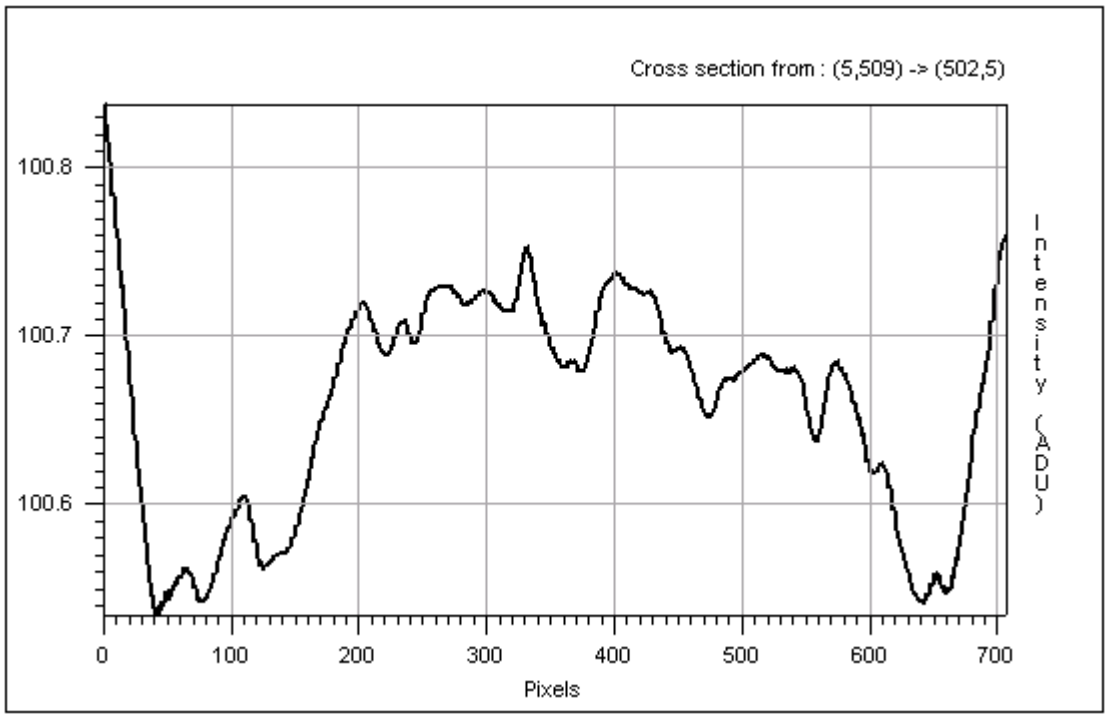
DG_u Frame at To+17 days, binned 8x8, something completely unusual like a reflection is visible in the top and bottom section of the image (not related to contamination)



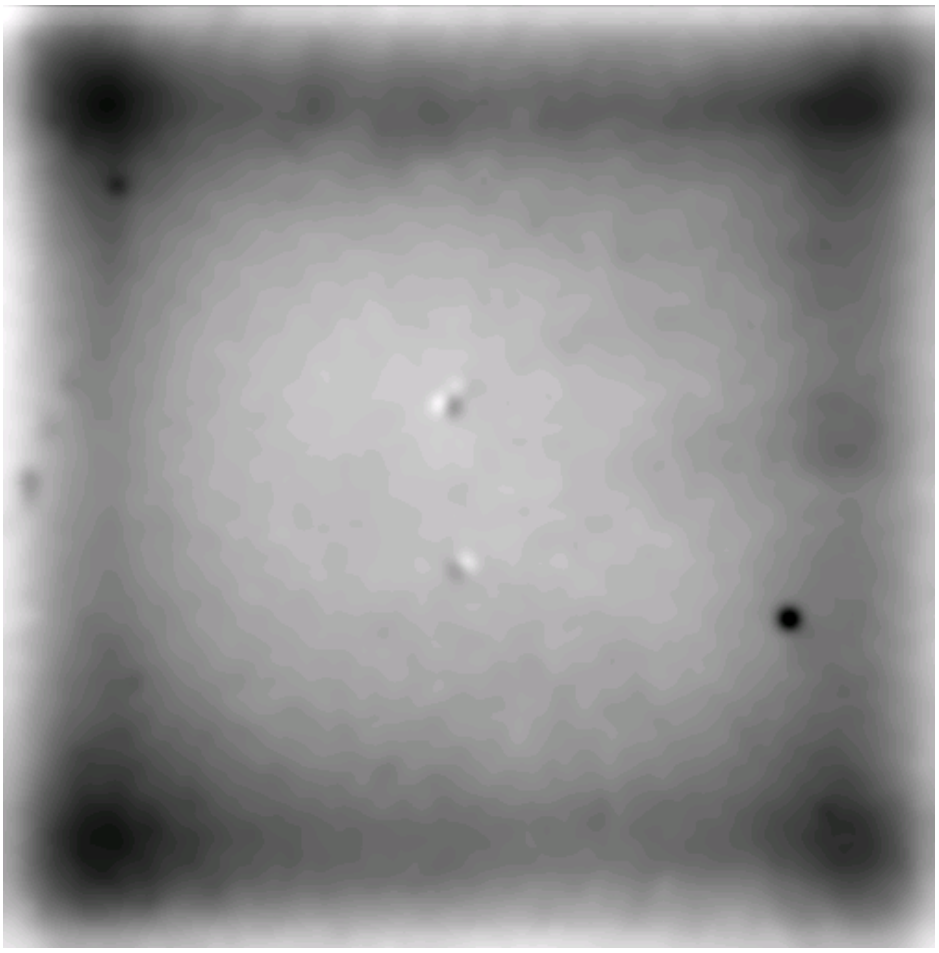
Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+17 days, 0.9 % relative QE loss in the corners. Normalized to 100,0.



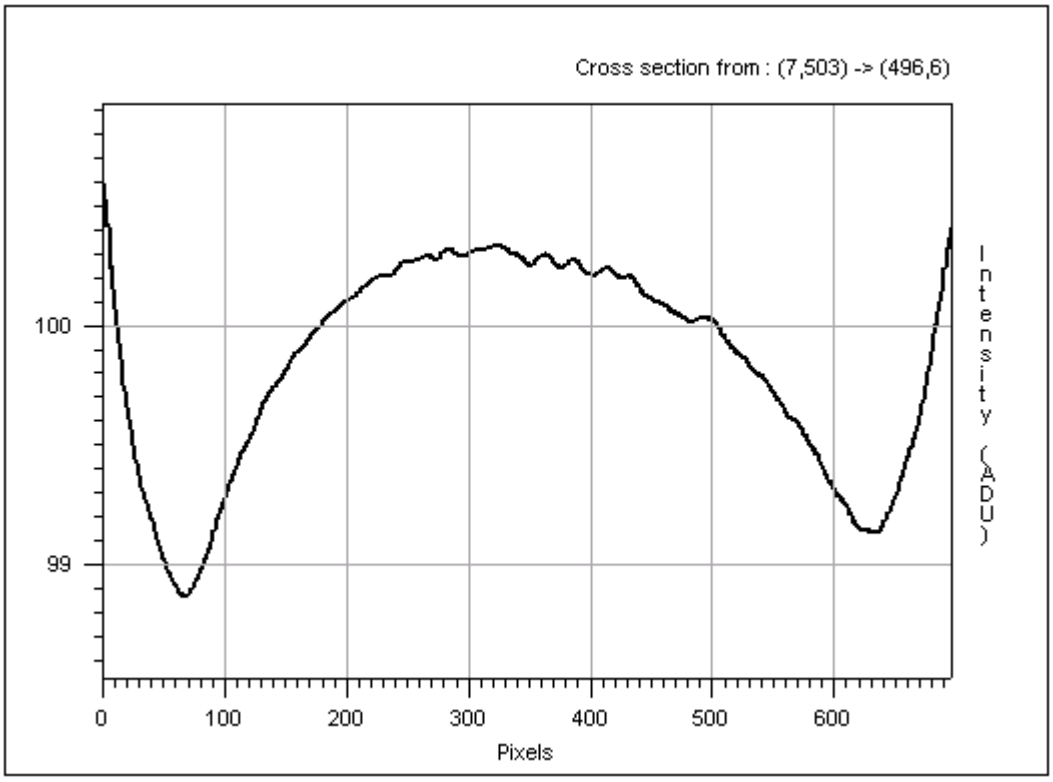
DG_{red} Frame at To+17 days, binned 8x8, something completely unusual like a reflection is visible in the top and bottom section of the image (not related to contamination)



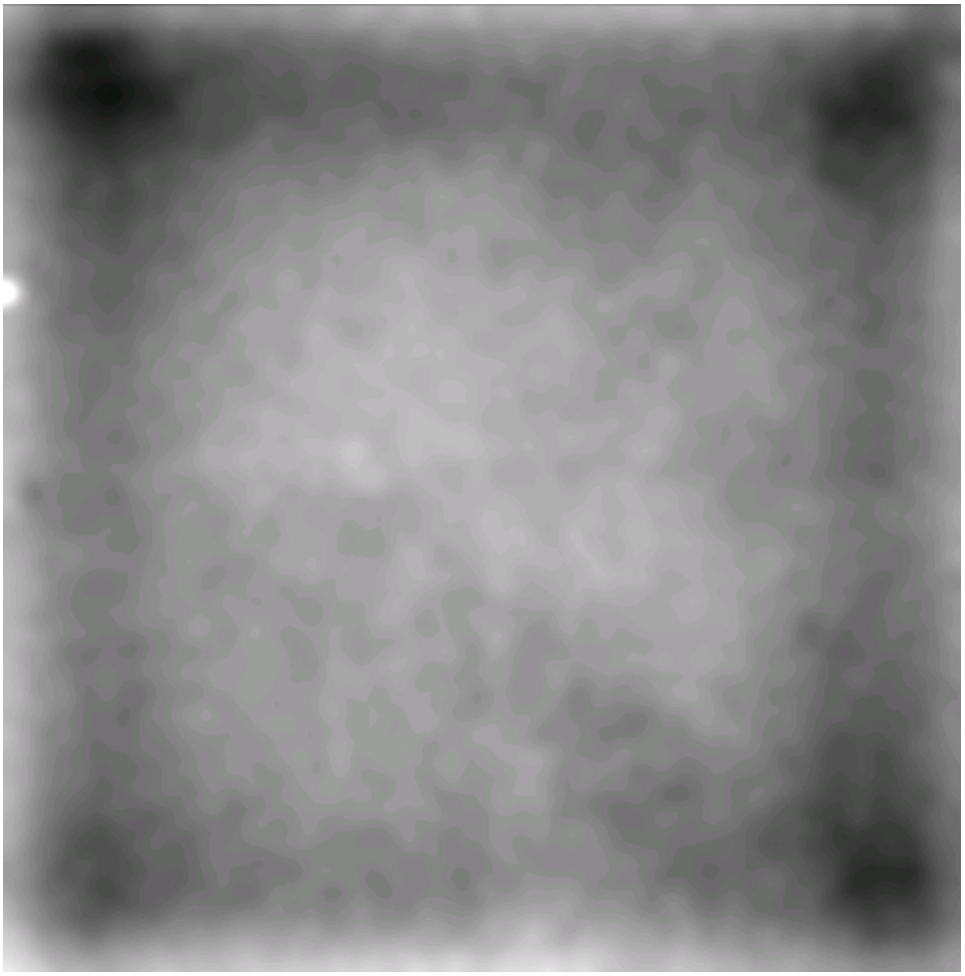
Diagonal cross-section, form left-top corner to the lower right from the DG_{red} frame at To+17 days, 0.2% peak-peak relative QE loss in the top-left section. Normalized to 100,0.



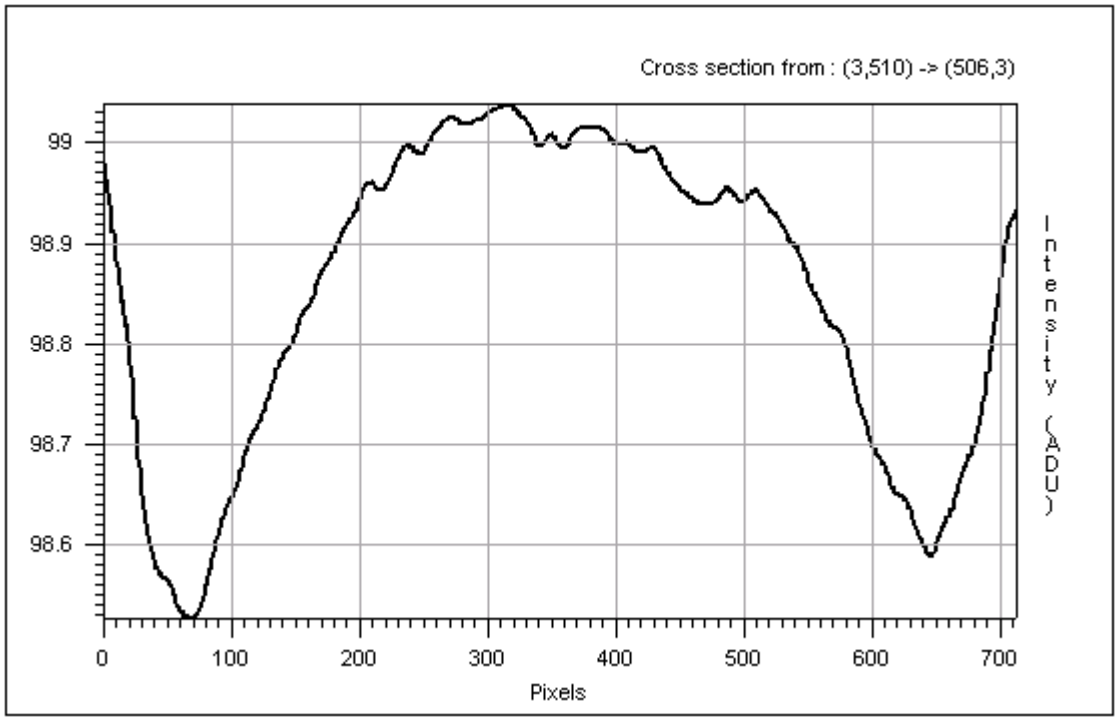
DG_u Frame at To+26 days, binned 8x8



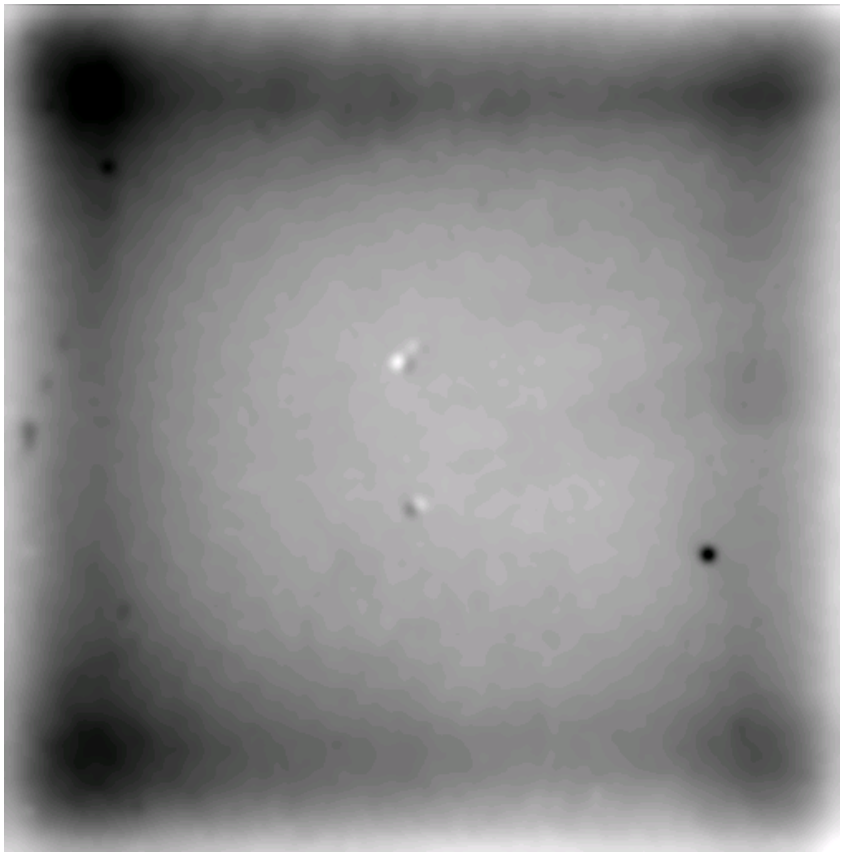
Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+26 days, 1.5 % relative QE loss in the corners. Normalized to 100,0.



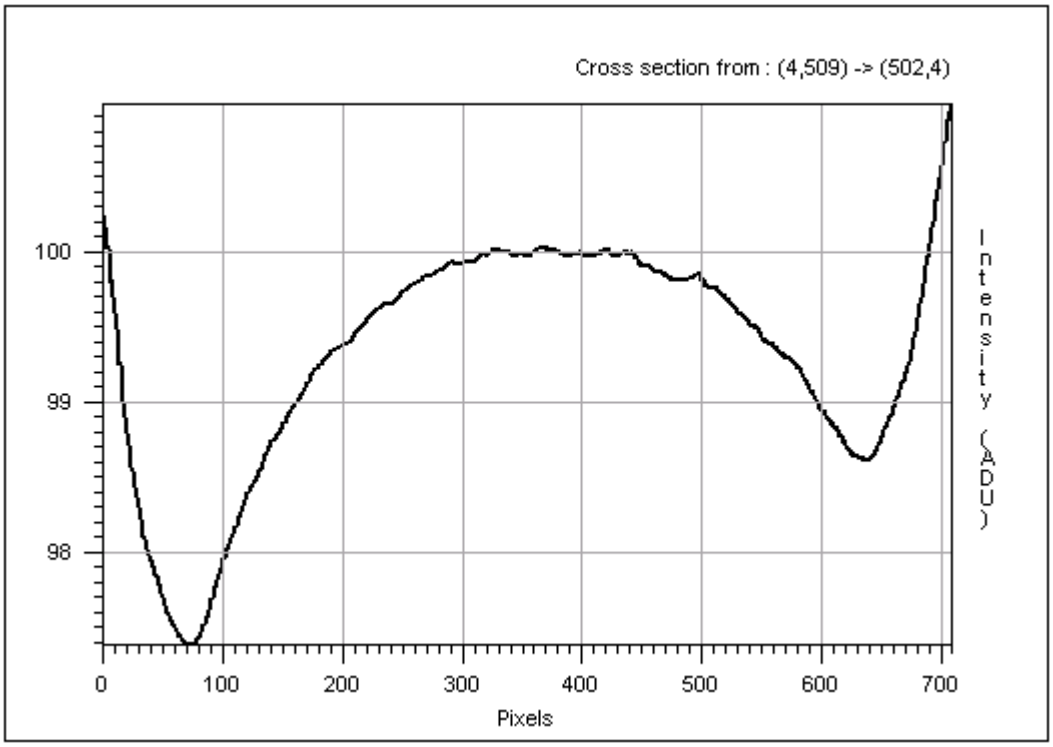
DG_{red} Frame at To+26 days, binned 8x8, contamination pattern is now visible …



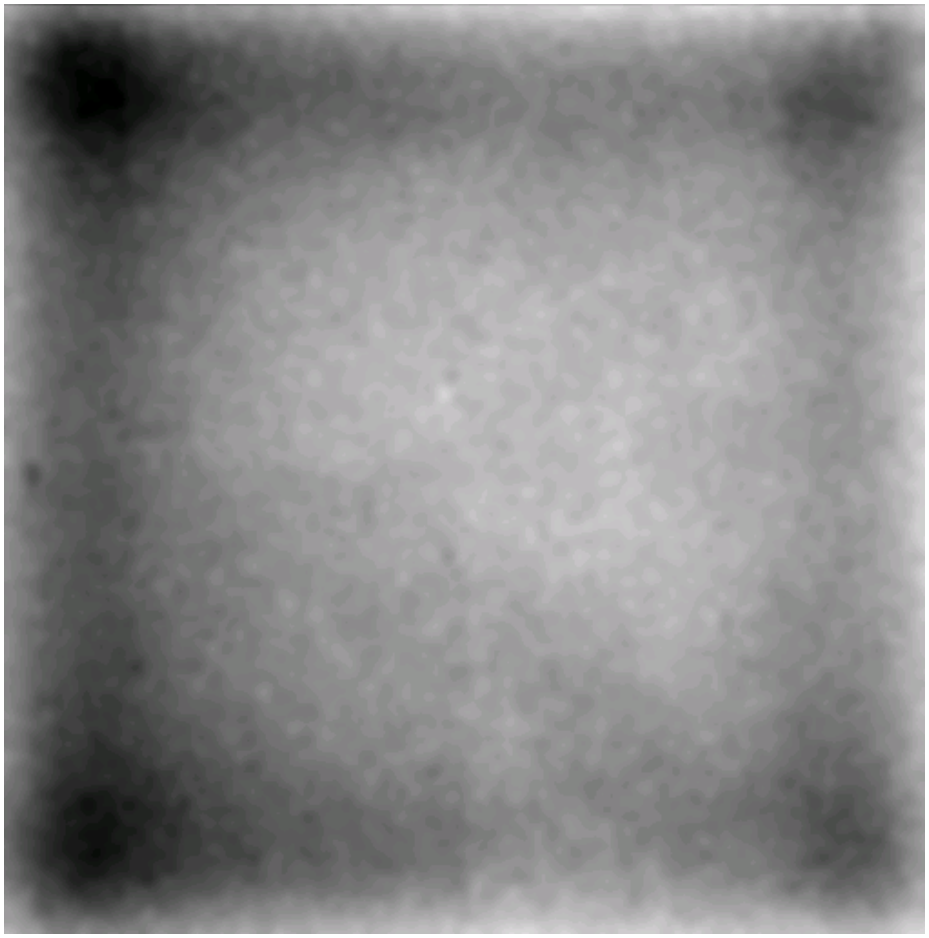
Diagonal cross-section, form left-top corner to the lower right from the DG_R frame at To+26 days, 0.5 % relative QE loss in the corners. Normalized to 100,0.



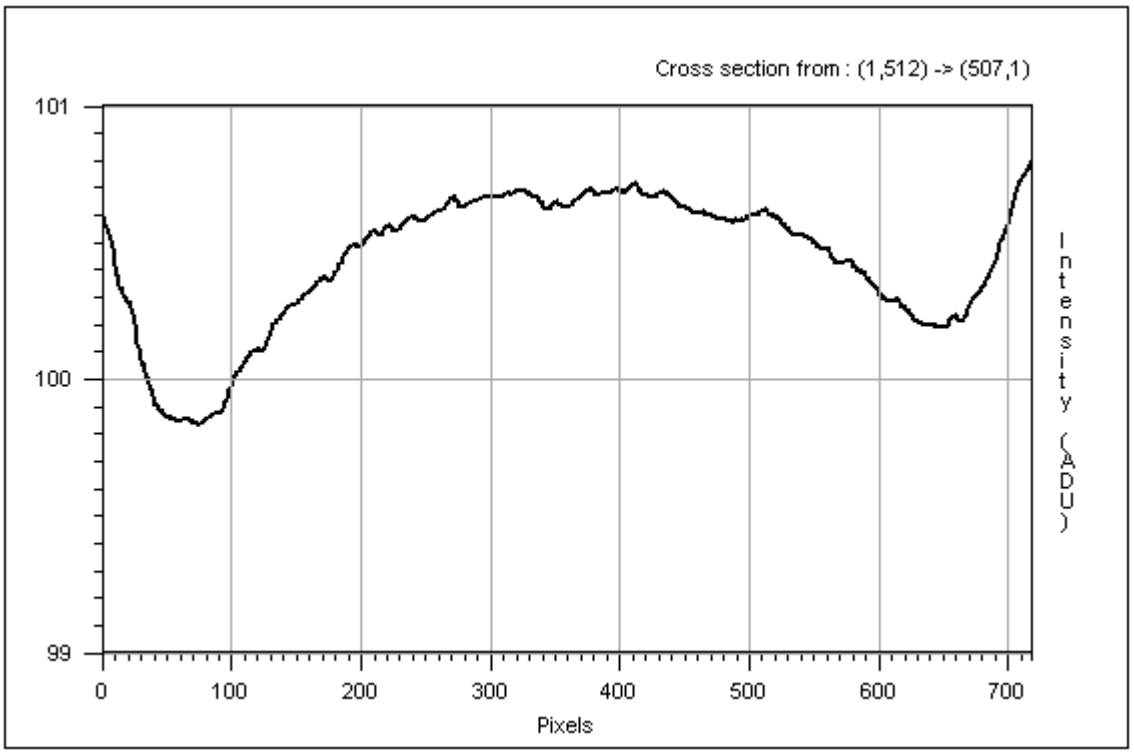
DG_u Frame at To+45 days, binned 8x8



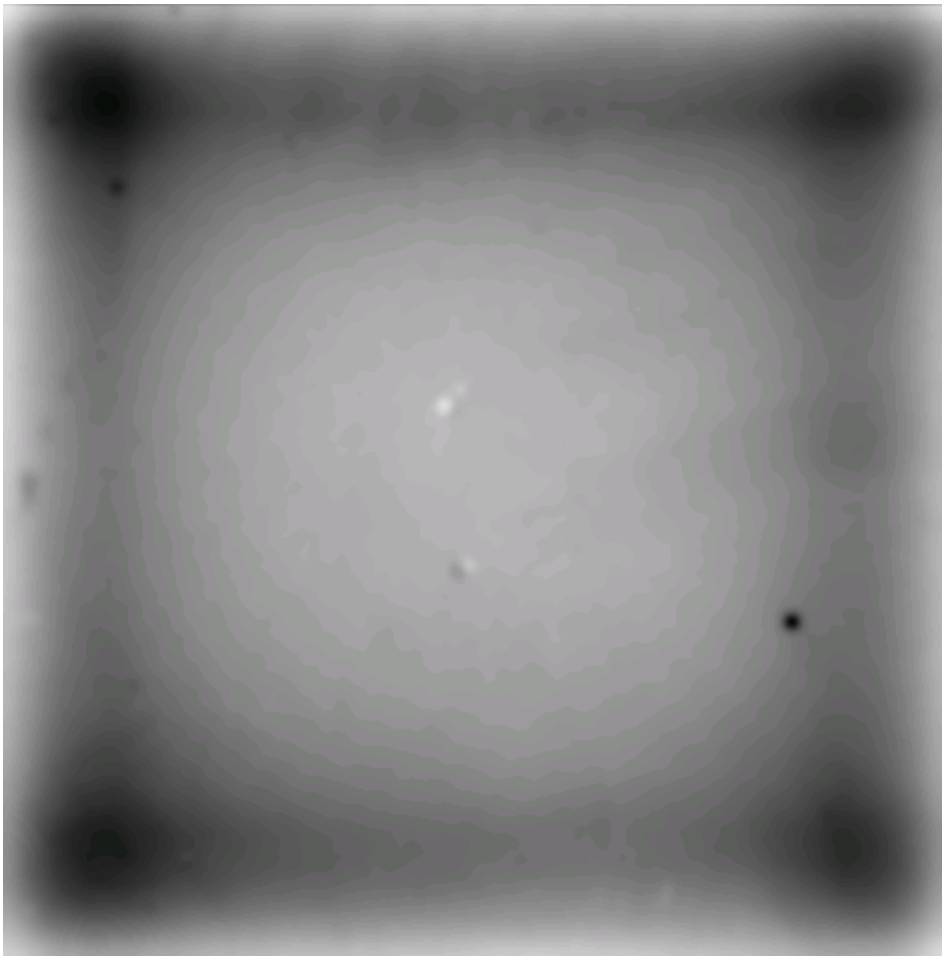
Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+45 days, 3 % relative QE loss in the corners. Normalized to 100,0.



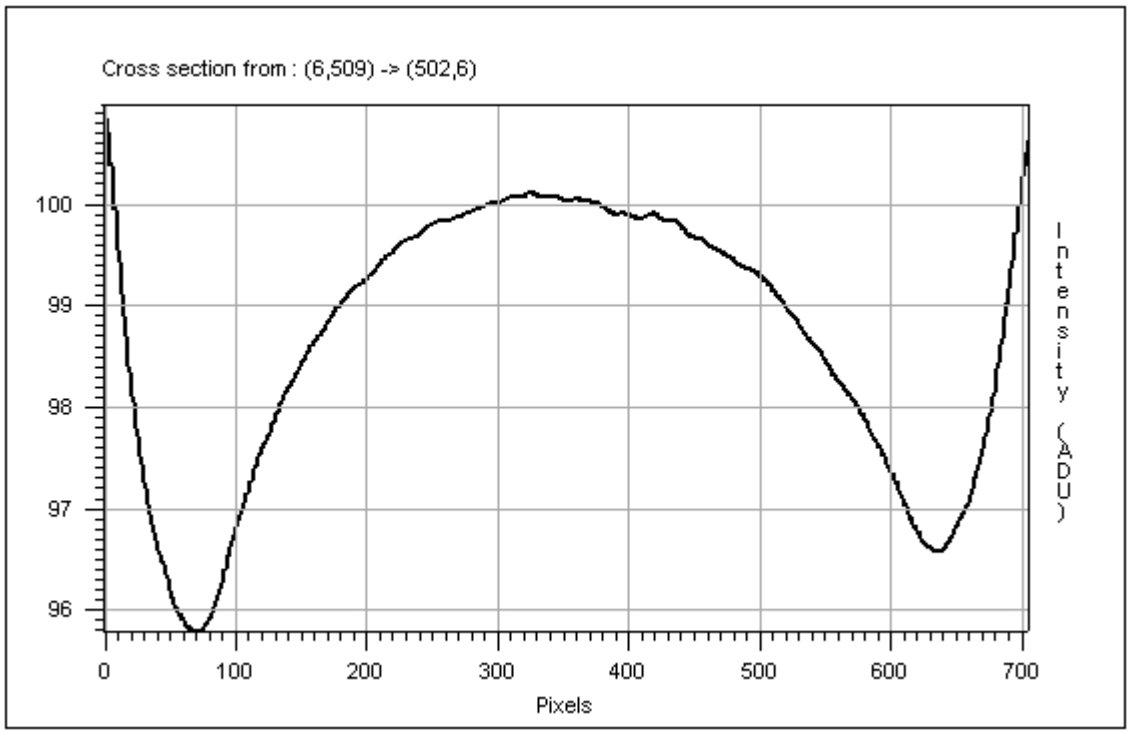
DG_R Frame at To+45 days, binned 8x8



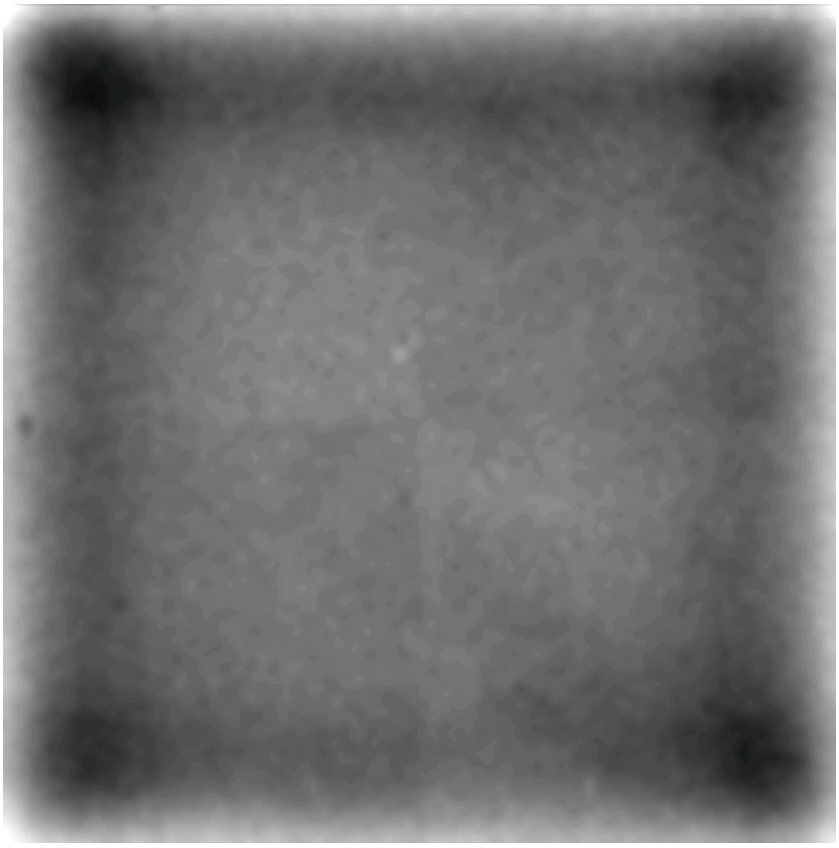
Diagonal cross-section, form left-top corner to the lower right from the DG_R frame at To+45 days, 0.8 % relative QE loss in the corners. Normalized to 100,0.



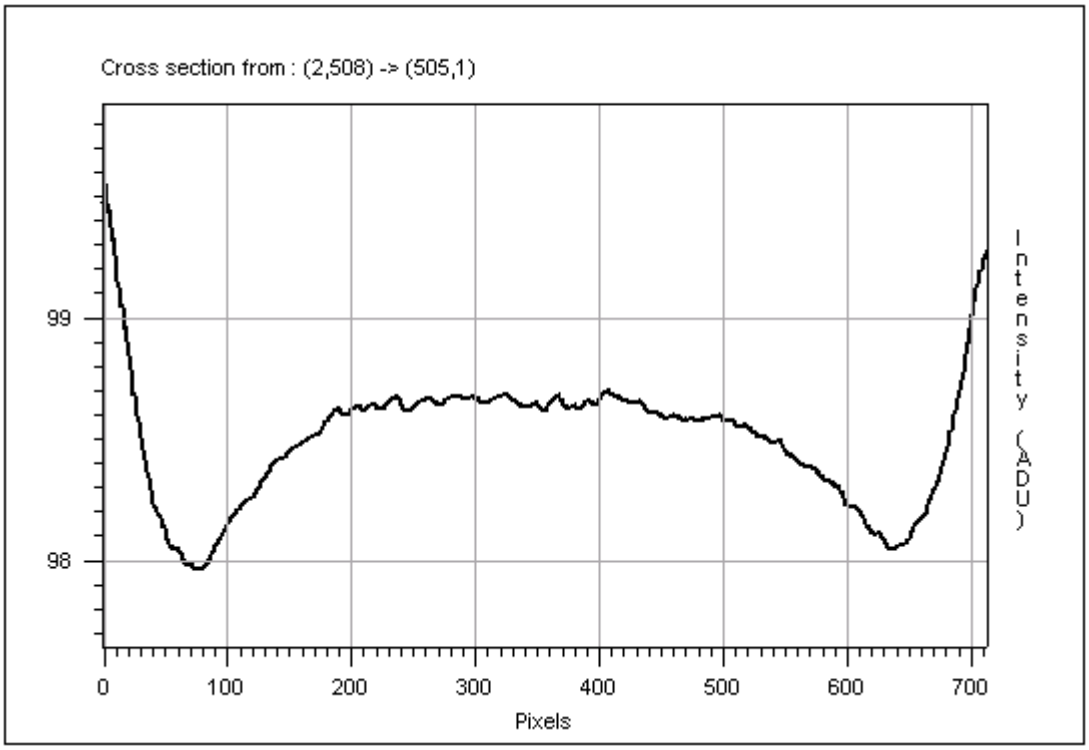
DG_u Frame at To+66 days, binned 8x8



Diagonal cross-section, form left-top corner to the lower right from the DG_u frame at To+66 days, 5 % relative QE loss in the corners. Normalized to 100,0.



DG_R Frame at To+66 days, binned 8x8



Diagonal cross-section, form left-top corner to the lower right from the DG_R frame at To+66 days, 1.1 % relative QE loss in the corners. Normalized to 100,0.

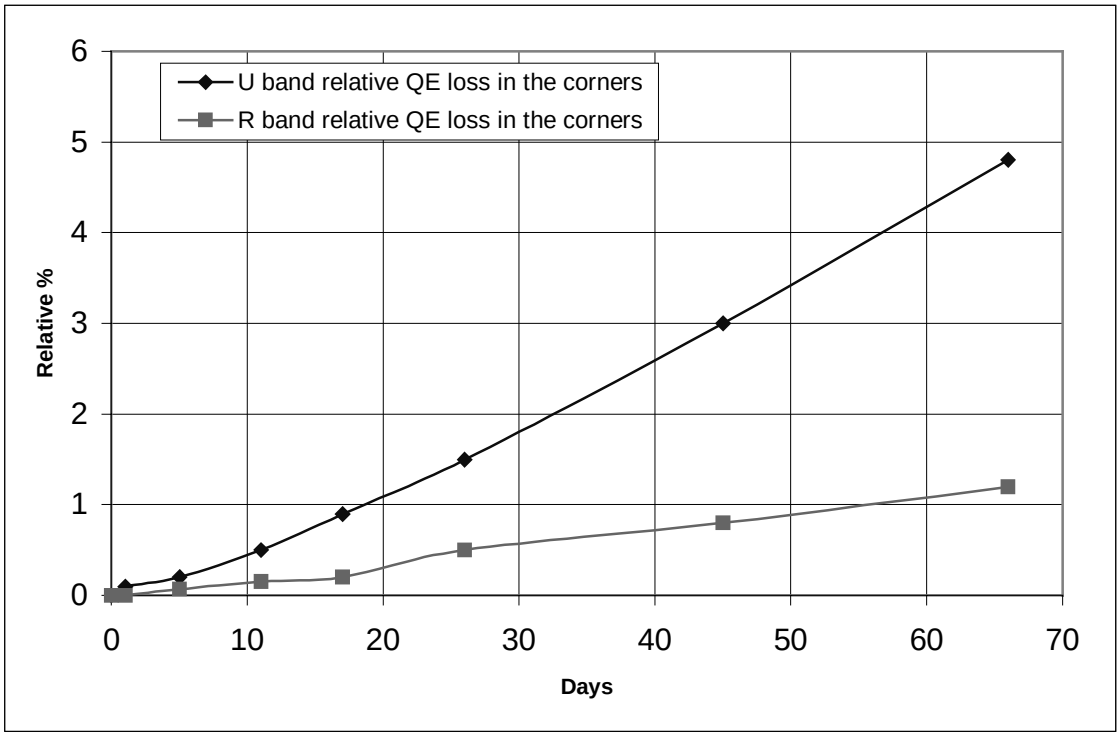
Conclusion

No major problems occurred during the cleaning phase of FORS1. Since the dewar has been prepared and tested in Garching, things went much better.

The analysis concerning the growing of the contamination layer showed that:

- The growing of the contamination from 31/11/99 to 17/11/99 is 0.9% peak-peak relative QE loss in the U band (which is 0.05% per day compared to 0.6% before decontamination, contamination rate has been decreased by a factor of 12). Just to remind the reader that within 17 days the contamination in U band frames was 13%.
- A long trend analysis should be carried out, by monitoring the growing of this pattern **once a week**. In the R band, which was the second most affected band, after 5 days, nothing significant is visible. After 17 days, barely 0.2% has been measured.

- One has to remember the test made in Garching with the new FORS 1 dewar and the EEV44 CCD: at To+5 days a 0.3% pp contamination pattern was visible: this figure stayed stable during the whole month, and at T0+35days at 0.4% PRNU pattern was measured. I (the author of this document) think a similar this trend could apply also for the new FORS 1 cryostat +cleaned head. **Anyway, it needs to be monitored once a week. A long-term analysis will tell whether or not this operation has been completely successful.**



Variation of relative QE loss over time (U band and R band).

- One has to be aware that a leak in the tank could lead to contamination. During these tests about FORS 1 in Paranal, the pressure was always $5x10^{-6}$ mbar, which is a good vacuum.