LYRA Pulsed LED Tests: Data Analysis

IED, 14 Feb 2007
(rev. 06 Mar 2007 after additional information from Silvio Koller)

Test Description

On 30 Nov 2006, the LYRA team at ROB received several test data files from Silvio Koller (PMOD/WRC, Davos). We were informed that LYRA had been put in their vacuum chamber, and measurements regarding temperature and LED pulsing were performed.

It was reported that the commanding by the EGSE software had not been very accurate, and thus the LED on/off temporal behaviour had quite a jitter. The serial link together with the EGSE software was too slow to acquire data with 100 Hz. Therefore, data were sampled with 50 Hz, or 20 ms integration time.

The LED frequency was roughly 3.7 Hz, i.e., the LEDs were commanded on/off approx. every 270 ms. This leads to 13 or 14 steps of 20 ms integration per cycle, one half of the cycle being recorded with LEDs "on" and the other half with LEDs "off".

The LED field - column 13 of the Telecommand Packet containing binary number PUV1, PUV2, PUV3, PVIS - changes from "0000" (off) to "1111" (on), which usually means that all LEDs, ultraviolet and visual, are switched on and off simultaneously; in this test set, the command was used although there was no power supply available for the ultraviolet LEDs, thus *only* the effect of *visual* LEDs was recorded.

Two test runs were performed: the first one starting 30 Nov 2006 15:47:29, testing LYRA heads 1 and 2 in parallel, the second one starting 15:49:04 the same day, testing heads 2 and 3 in parallel. The tests consisted of approx. 200 on/off-cycles each, thus taking less than 1 minute.

Pulsing of LEDs appears to be a suitable tool for calibration, because several parameters can be tested without facing some of the drawbacks, like long-term drifts. This applies for MSM and AXUV detectors which displayed reliable parameters during the tests. The situation for PIN detectors appears to be more complicated.

Pulse Examples

Figures 1a and 1b show examples of some typical pulses taken 7 or 8 seconds after test start. Red lines mark the telecommands that switch the LEDs on and off, black lines mark the various resulting detector reactions, versus observation time in seconds. LYRA output signals are displayed in kHz, which – at this low activity level – appears more suitable than measuring currents in Ampere (often showing bad numerical resolution, and negative values occurring due to the voltage-frequency converters).

The general behaviour can be clearly observed: Overshooting reactions after LEDs are switched on, steady decline until they are switched off again, drop and sometimes undershoot after switch-off, more or less stable levels of dark current. Only the PIN detectors (channels *-2) behave differently: First they *drop* after switch-on, then they recover more or less fast. Their reaction signal is not very significant, but rather close to the dark current level instead.

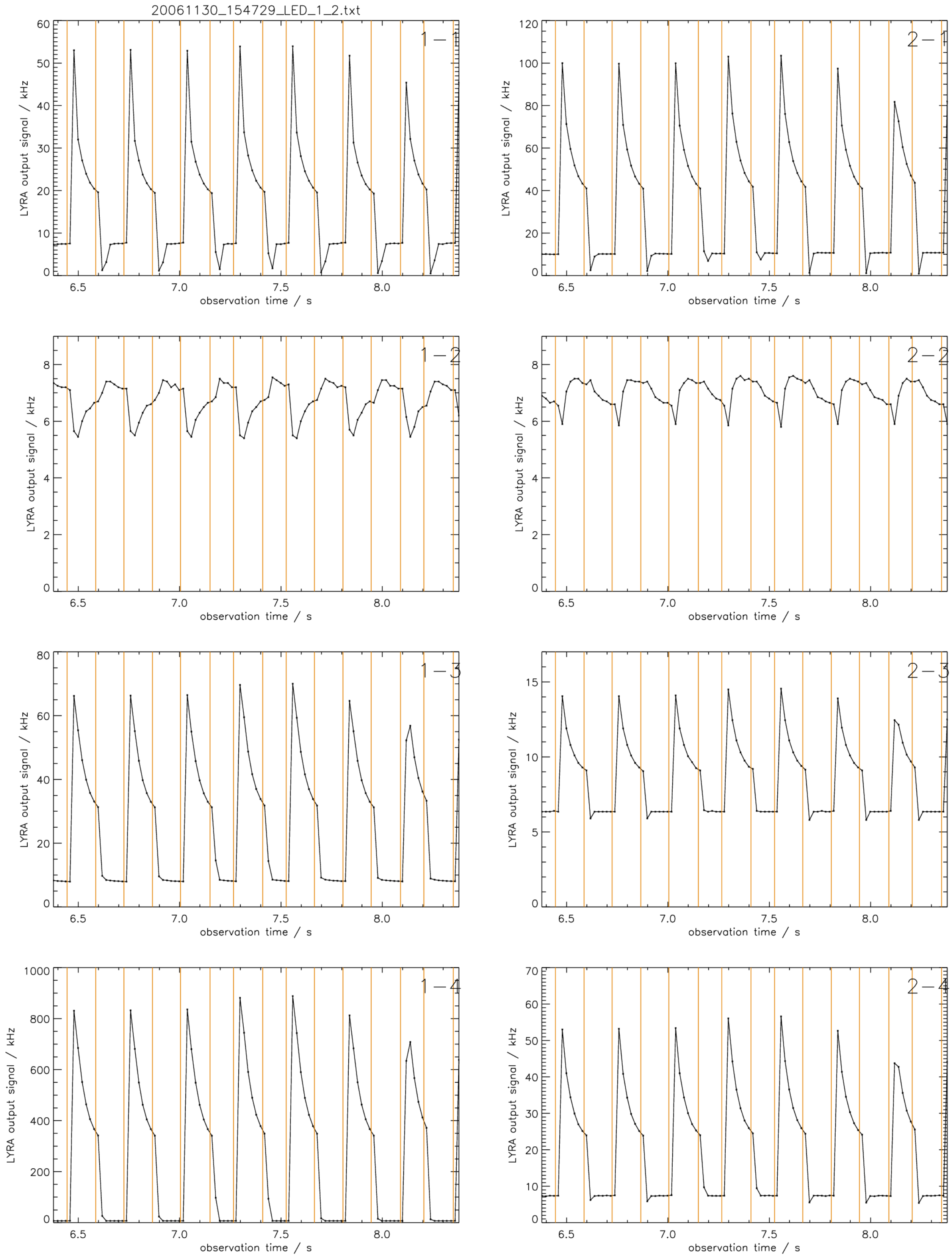

Figure 1a: Sample pulses from first test (heads 1 and 2)

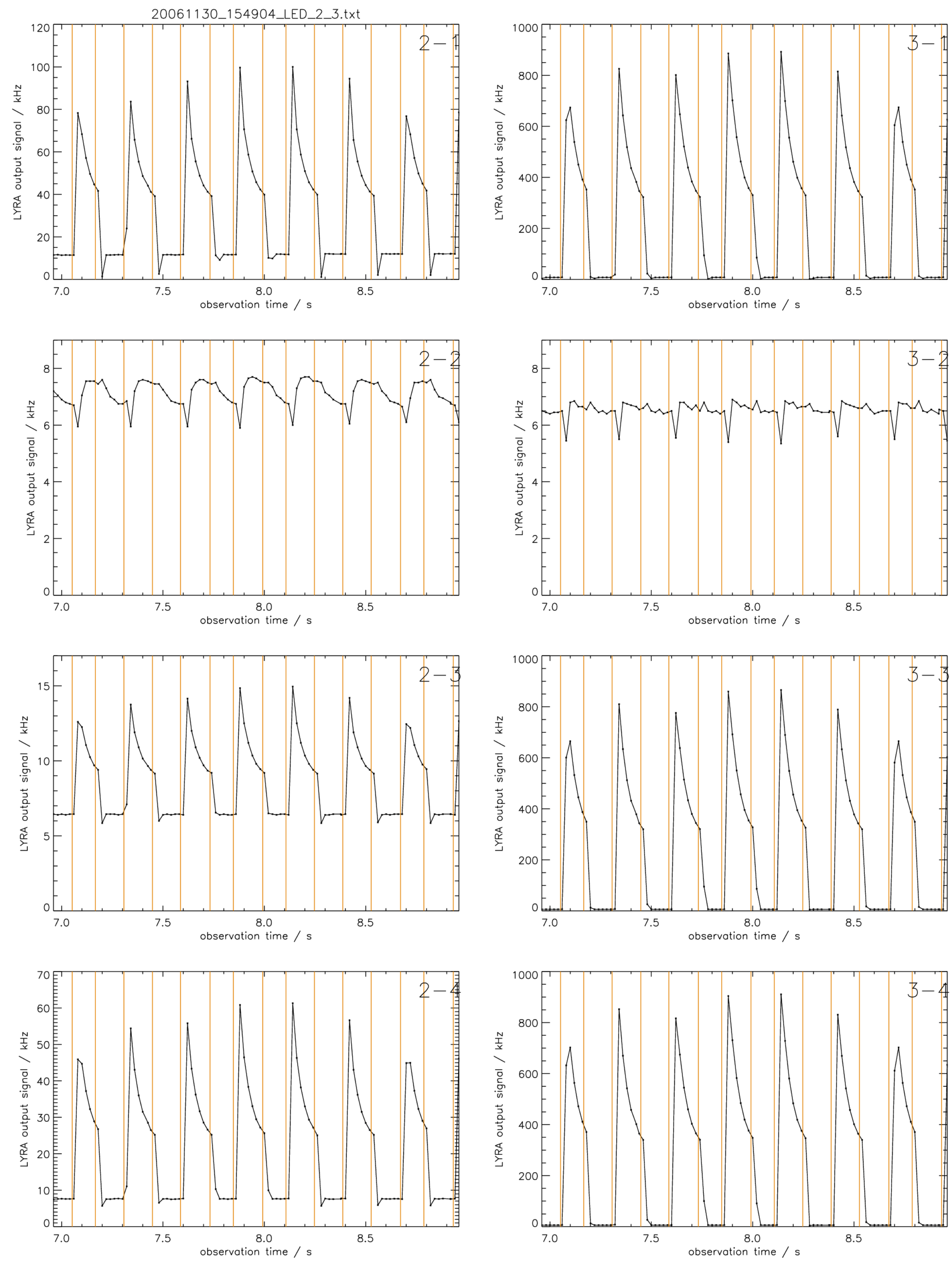

Figure 1b: Sample pulses from second test (heads 2 and 3)

Detailed Behaviour

Figures 2a and 2b show the average detailed behaviour of the pulses as recorded by the various detectors. The first (0.00 s) red line marks the time instant of the "switch on" telecommand (LED field = 1111). According to the LYRA Software User Manual, the time stamp corresponds to the instant when the packet was *put on line*. The second (0.135 s) and third (0.27 s) red line correspond to the average time instant of the "switch off" telecommand (LED field = 0000), and the following switch on of the next cycle.

The 14 asterisks mark the average LYRA output signals within the LED cycle; the 14^{th} value occurs only in roughly half of the approx. 200 cycles. The dotted lines mark the extent of the standard deviation. The output signals are delivered in the Science Packets; according to the LYRA Software User Manual, the millisecond counter corresponds to the instant when the packet *came in* completely.

Therefore, the first averaged data point consists of observations received immediately after the switch on was commanded. Taking into account that its integration must have started 20 ms earlier, plus possible time delays for Telecommand and Science Packets, the first data point will most probably not be influenced by LEDs, and indeed shows roughly the same level as the last point of the cycle. The next 6 values are influenced by LED signals.

The next 7 values following thereafter reflect the phase of LEDs being switched off. Most detectors reach their dark current level within a decreasing phase lasting one or two steps of 20 ms integration.

Of the 14 LED cycle values, #2 and #8 – and, to a lesser extent, #3 and #9 – have a greater variance. This could be caused by the fact that in some of the cycles, #2 is partly integrated before the switch on, and #8 ist partly integrated before the switch off, depending on their temporal distance to the respective telecommand.

From their behaviour, the channels can be seperated into three groups that clearly depend on their detector type:

Channels 1-1, 1-3, 2-1, 2-3, 2-4 (MSM):
They display a relatively fast increase after switch on (all but channel 1-3 peak in value #2), with an overshoot; a negative exponential decay; a one-, two-, or three-step decrease after switch off, sometimes with an undershoot (1-1, 2-1); and an almost flat dark current in the last four or five values. The peaks usually vary between 40 and 85 kHz, channel 2-3 being an exception at 13 kHz.

Channels 1-4, 3-1, 3-3, 3-4 (AXUV):
They display a slower increase after switch on (all channels peak in value #3), also with an overshoot; a negative exponential decay; a two-step decrease after switch off; and an almost flat dark current in the last five values. The peaks vary closely around 700 kHz.

Channels 1-2, 2-2, 3-2 (PIN):
They display a *decrease* after switch on, with a minimum at value #2 or, even slower, at value #3; afterwards they rise again, channel 1-2 again being the slowest; after switch-off they slowly approach their dark current level again. All values stay closely around 5 to 8 kHz.

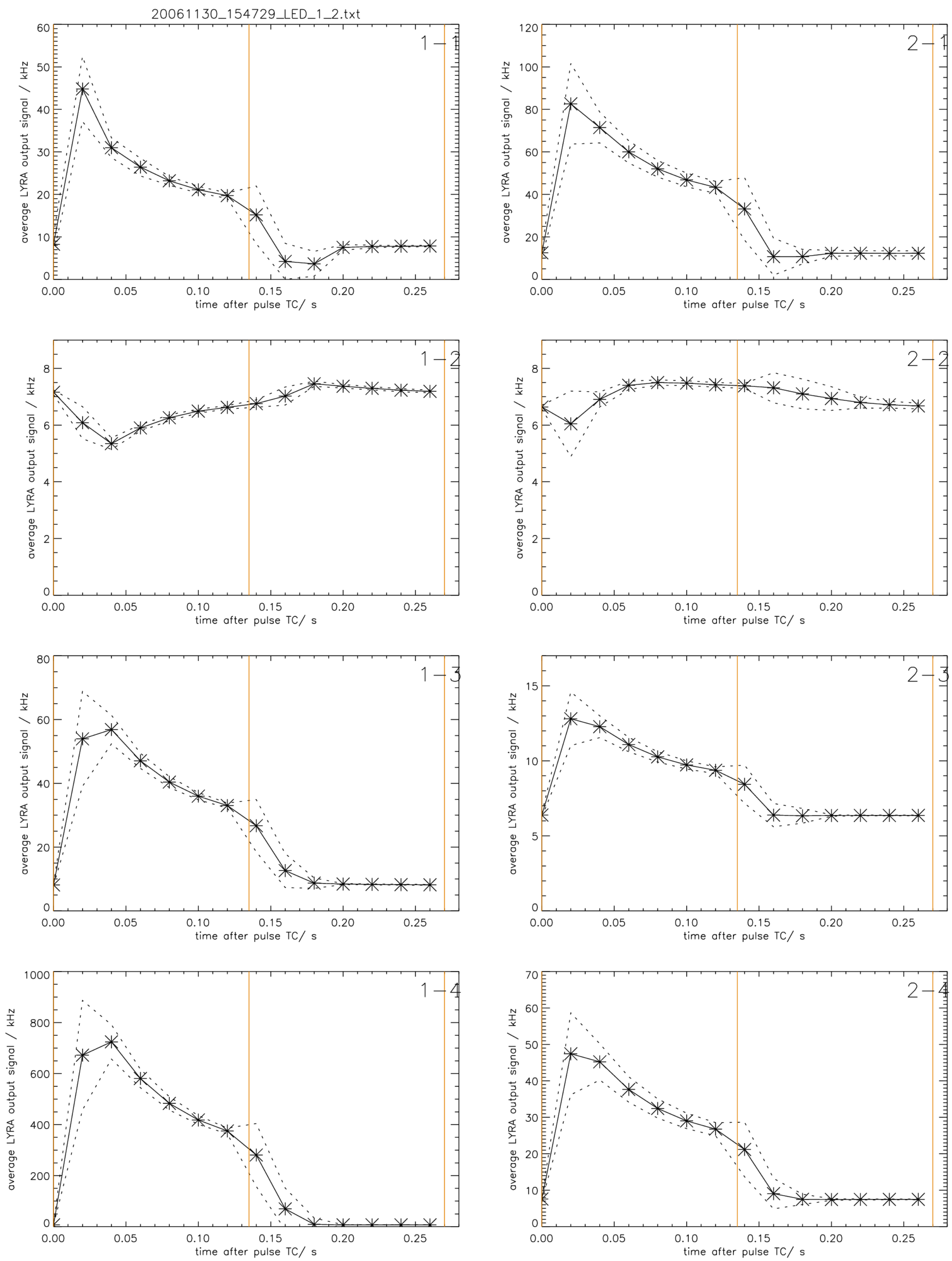

Figure 2a: Average pulses from first test (heads 1 and 2)

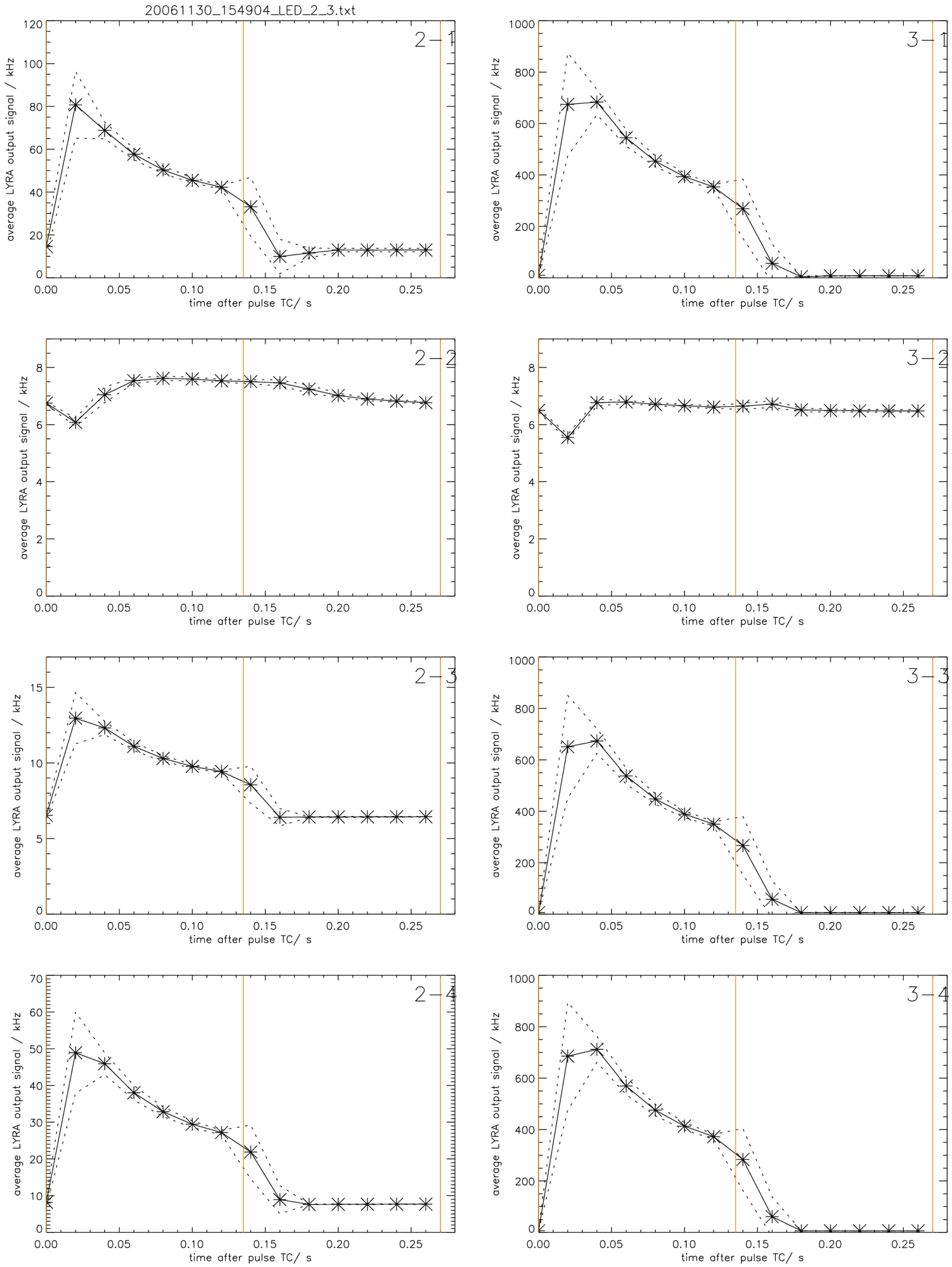

Figure 2b: Average pulses from second test (heads 2 and 3)

Pulse Fitting

In previous campaigns, other LED tests were performed: without pulses, but exposing the detectors to visual, ultraviolet, or both LEDs, constantly for 200 to 300 s instead of 0.135 s, and with an integration time of 500 ms instead of 20 ms. To make the short pulses comparable with longer LED exposures (details of those will be subject of another report, TBD), the decay phase was fitted to estimate the longer term (500 ms) expected behaviour.

Since value #1 is apparently not influenced by LEDs and value #2 may be influenced by partial exposure, values #3 to #7 were selected; these average signal values of the decay phase were fitted to a negative exponential function plus an offset value N1, since the offset obviously is not zero:

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N(t) = N1 + N0 * exp(-lambda * t) , t=1,2,3,...
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where t is the number of 20-ms-integration times that have passed since cycle start (the scale is arbitrary, though). All MSM and AXUV channels could be fitted well to this function.

When the fit is integrated from step 1 to step 25 (i.e., 25 times 20 ms), the resulting value should correspond to a value observed with 500 ms integration time; in reality, the integrated fit is mostly an over-estimation (see below). An additional problem for comparison also remains: The long-term tests do not reach their plateau value immediately, so the fitted integral should correspond to an “early” response in the rising phase. This is not yet a well-defined value (TBD). - Signal output values are in kHz. - Since the behaviour of the PIN detectors appears to be more complicated, they could not be fitted in this way.

Parameters resulting for fittings of the first test (heads 1 and 2):

ch.	detect.	N1	ln(N0)	lambda	peak	integr.
1-1	MSM12	16.7	3.44047	-0.390777	37.8090	19.3102
1-2	PIN10					
1-3	MSM11	27.0	4.19763	-0.400151	71.5885	32.4080
1-4	AXUV20D	286.	6.88130	-0.399094	939.410	365.421
2-1	MSM21	35.9	4.35720	-0.392950	88.7220	42.3847
2-2	PIN11					
2-3	MSM15	8.63	2.09247	-0.399472	14.0657	9.29019
2-4	MSM19	22.1	3.94645	-0.402322	56.7096	26.2793

Parameters resulting for fittings of the second test (heads 2 and 3):

ch.	detect.	N1	ln(N0)	lambda	peak	integr.
2-1	MSM21	36.0	4.31767	-0.413608	85.6036	41.8572
2-2	PIN11					
2-3	MSM15	8.77	2.10687	-0.420774	14.1683	9.39868
2-4	MSM19	22.9	3.97593	-0.419727	57.9298	26.9877
3-1	AXUV20A	277.	6.84147	-0.417142	893.666	349.319
3-2	PIN12					
3-3	AXUV20B	275.	6.82147	-0.416800	879.662	345.958
3-4	AXUV20C	292.	6.86724	-0.413912	926.811	366.915

Figures 3a and 3b show the original data averages and the fits, calculated as described above.

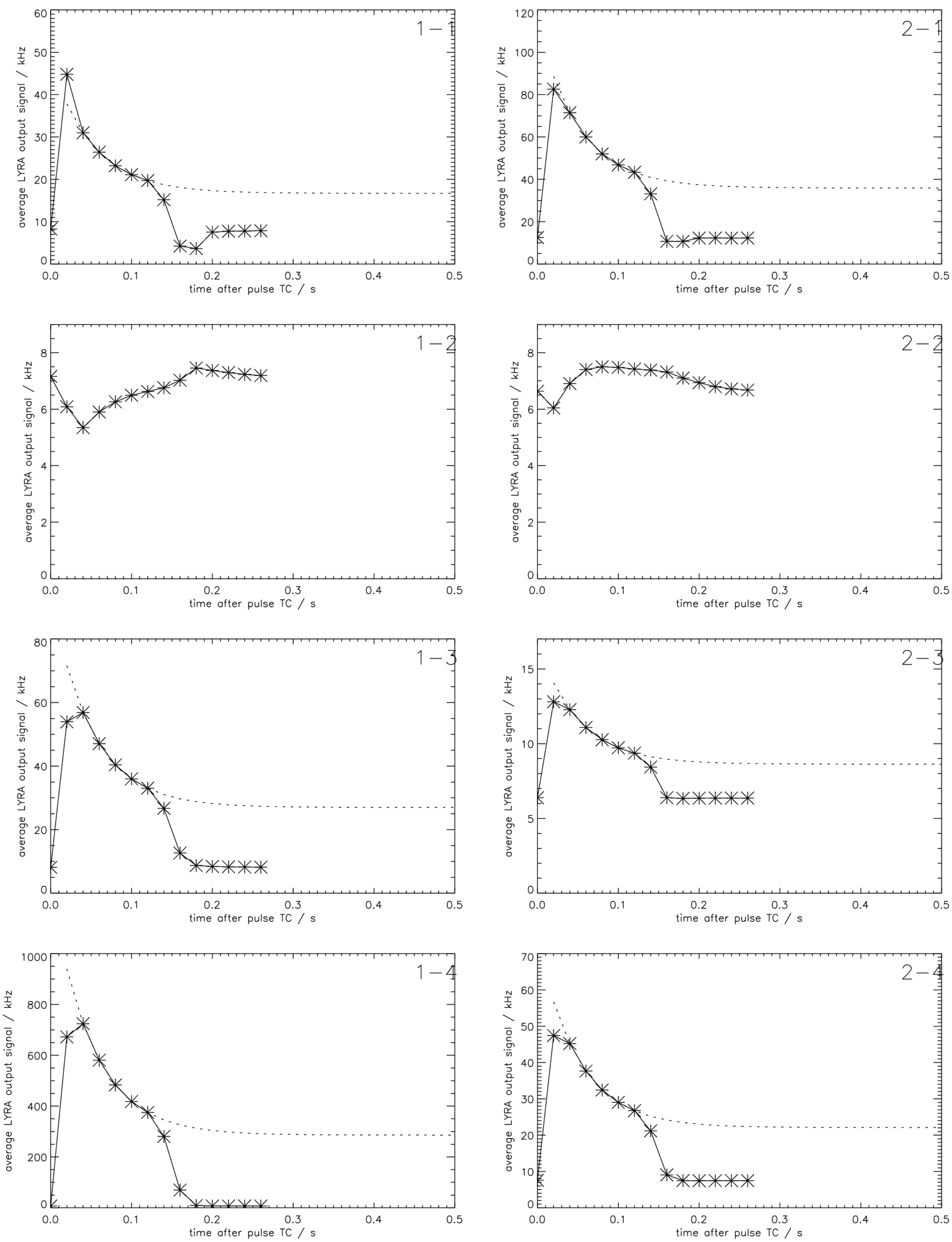

Figure 3a: Average pulses and fits of their decay phase from first test (heads 1 and 2)

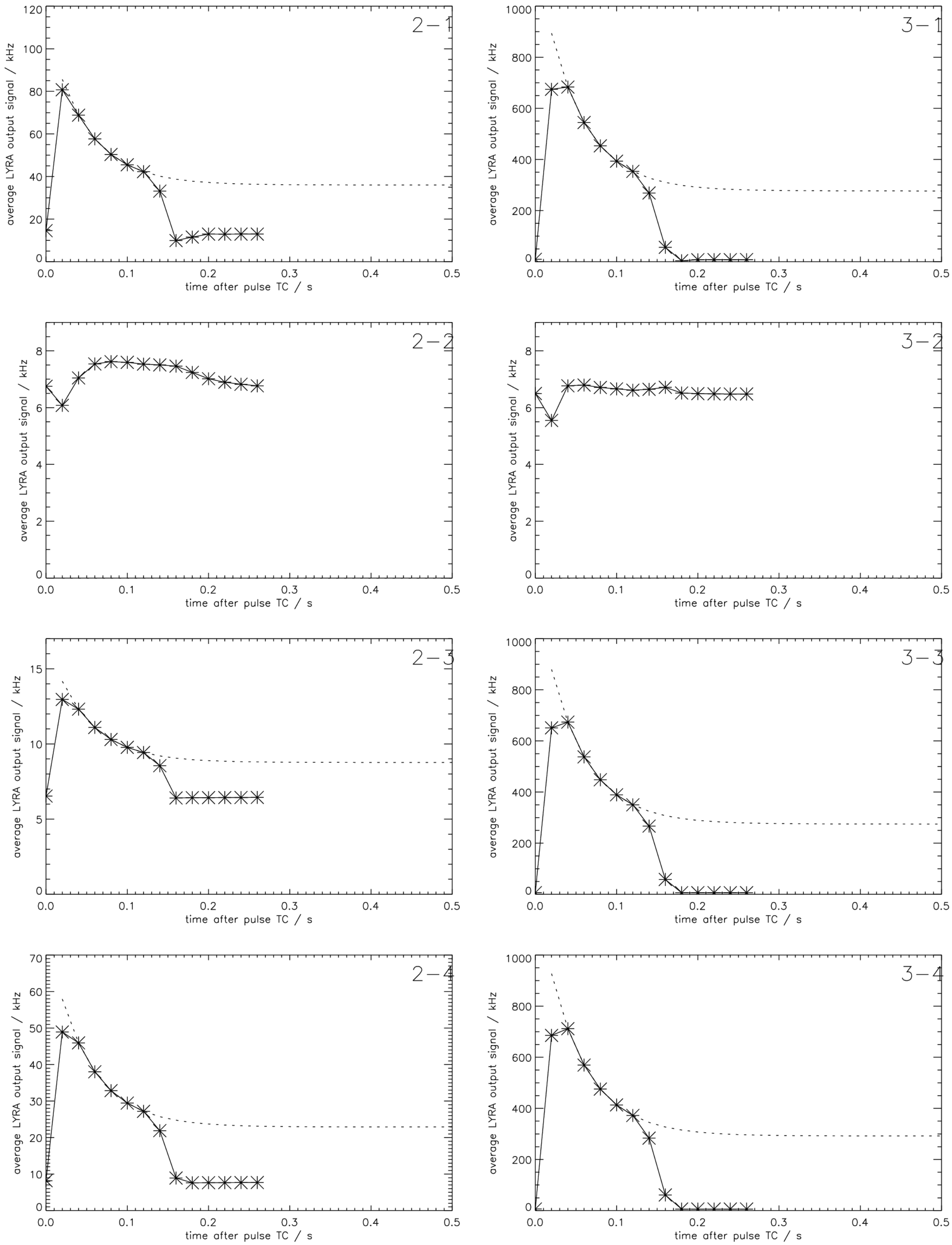

Figure 3b: Average pulses and fits of their decay phase from second test (heads 2 and 3)

The curve fits quantitatively confirm the qualitative descriptions of the MSM and AXUV detectors as stated in the preceding section. AXUV channels are more sensitive than the rest, they are more similar within their group, and their fitted peaks are always higher than their observed ones. But while they differ significantly concerning their response level, all fitted detectors show a similar decay-time constant *lambda* between 0.39 and 0.42, which leads to a half-life period *ln(2)/lambda* that corresponds to 0.035 and 0.033 s. Apparently, *lambda* is also influenced by the test situation, since in the first test all values are between 0.39 and 0.40, and in the second test between 0.41 and 0.42.

Dark current values generally show quite similar values around 7 kHz, except for channel 2-1 which starts at the same level but then displays an upward drift.

In the following tables, the observed dark currents as well as the fitted integrals and plateau values (N1) shall be compared to previous tests that, similarly, involved observations with visual LEDs being switched on/off simultaneously. - In the case of PIN detectors, there are no fits to be compared. - Signal output values again are in kHz.

ch.	detect.	other d.curr. observations	pulsLED d.curr.	other visLED observations	pulsLED integr.	pulsLED N1
1-1	MSM12	11.1658,9.22659	7.86285	23.3795,22.8930	19.3102	16.7
		10.6844,10.6269		19.1523,18.5131		
		10.3702,10.4285		19.1358,18.7857		
1-2	PIN10	6.44996,6.59550	7.18899	6.67447,6.86322		
		6.63115,6.66208		6.84703,6.85157		
		6.65890,6.65697		6.92472,6.92376		
1-3	MSM11	6.78523,6.72557	8.18120	26.5878,26.3113	32.4080	27.0
		6.80128,6.85230		26.3990,26.2870		
		6.80939,6.81642		26.4411,26.3905		
1-4	AXUV20D	7.39418,7.35195	6.96560	273.841,274.501	365.421	286.
		7.42589,7.45969		273.682,273.114		
		7.43740,7.44233		273.601,273.439		
2-1	MSM21	9.23316,11.1333	12.6185	40.3351,42.8437	41.1210	36.0
		15.0305,15.2642		40.0283,40.4900		
2-2	PIN11	6.48632,6.28414	6.72115	7.20643,6.99099		
		7.26520,7.25548		7.94379,7.96931		
2-3	MSM15	6.53941,6.60026	6.40228	8.72980,8.58040	9.34444	8.70
		5.50406,7.32362		9.31379,9.94156		
2-4	MSM19	9.81032,10.1347	7.58307	23.9713,23.4299	26.6335	22.5
		14.7513,15.1552		32.7083,30.7159		
3-1	AXUV20A	12.9890,13.0470	8.23991	262.668,263.144	349.319	277.
		19.8355		265.986		
3-2	PIN12	6.21992,6.22710	6.48114	6.78283,6.55599		
		7.07478		7.41072		
3-3	AXUV20B	6.28770,6.28072	6.35307	253.398,253.004	345.958	275.
		4.94285		248.342		
3-4	AXUV20C	5.94563,5.93051	6.31553	274.385,274.090	366.915	292.
		6.13887		272.047		

Parameters observed or fitted in the pulsed-LED tests are averages of approx. 200 cycles of 20 ms integration time. Parameters are taken from the first test for head 1, from the second test for head 3, and averaged from both tests for head 2. They are compared to 500 ms observations of dark currents and LED levels as recorded on 17 and 29 Mar 2006 during BESSY campaigns. Appropriate intervals were selected for comparison: visual LEDs switched on, but no beam signal; approx. 200 values averaged from plateau phase, if possible.

Several of these previous observations are listed to demonstrate the variability, or - in some cases - the reliability of the tests.

For the table above, the final values (#14) of the LED-test averages are taken as estimates for the dark current. In the case of PIN detector 1-2, this is probably an over-estimate, because this channel has not finished its decline phase yet. Other cases are more complicated and involve drifts or possible temperature effects. This can be analyzed further, if necessary.

In most cases, the plateau values (N1) of the fits – rather than the integrals - correspond better with the LED values from the other tests and are therefore used for comparison in the following table. To compare the net effect of LEDs quantitatively, the various dark current levels have been subtracted ("diff" columns). For simplicity reasons, values were averaged and rounded to one decimal digit. - Values are in kHz:

ch.	detect.	d.c. obs.	d.c. fit.	LED obs.	LED fit.	diff obs.	diff fit.
1-1	MSM12	10.4	7.9	20.3	16.7	9.9	8.8
1-2	PIN10	6.6	7.2	6.9		0.3	
1-3	MSM11	6.8	8.2	26.4	27.0	19.6	18.8
1-4	AXUV20D	7.4	7.0	273.7	286.0	266.3	279.0
2-1	MSM21	12.7	12.6	40.9	36.0	28.2	23.4
2-2	PIN11	6.9	6.7	7.5		0.6	
2-3	MSM15	6.5	6.4	9.1	8.7	2.6	2.3
2-4	MSM19	12.5	7.6	27.7	22.9	15.2	15.3
3-1	AXUV20A	15.3	8.2	263.9	277.0	248.6	268.8
3-2	PIN12	6.5	6.5	6.9		0.4	
3-3	AXUV20B	5.8	6.4	251.6	275.0	245.8	268.6
3-4	AXUV20C	6.0	6.3	273.5	292.0	267.5	285.7

As a result, it can be observed that the fits of the pulsed tests...

- usually estimate the dark current levels well, around 7 kHz
- follow the trend of the dark current level and estimate it correctly in the case of channel 2-1
- do not follow the trend and thus underestimate it in the case of channels 1-1, 2-4, and 3-1
- tend to underestimate the net LED effect (dark current subtracted) in the case of the MSM detectors: -11%, -4%, -17%, -12%, 0%
- tend to overestimate the net LED effect in the case of the AXUV detectors: +5%, +8%, +9%, +7%, relative to the long-term observations.

For PIN detectors, LED pulsing apparently cannot be used to estimate exact values of decay time constants, or LED output signals, but this kind of test can nevertheless be used to estimate the overall reaction level (e.g., to measure degradation or temperature effects).

Documents used:
BRUSAG: LYRA Software Manual (SUM), Version 1.04 of 15 Mar 2005

Files used:
20061130_154729_LED_1_3.txt
20061130_154904_LED_2_3.txt