HI-2015-03 , Day21 = BS01cfg02 testing: ANDOR iKon-M camera shift speeds
File: \data\2015\HI-2015-03\doc\Day21_camera_shift_speeds(MF).pptx
Date: 03-Sep-2015, By: MF/MLML (rev: 20Apr2016,MF)

Setup:
BS01cfg02, Lu head #Lu42, FO #3005 = short 3.75 m, splitter #1 - splitter FO#2 to BS trk#3,
splitter FO#1 to: collimator F220FC-A / Semrock BLP01-355R / FF01-720SP / F220FC-A to BS trk#12
Source = Ekspla(cfg09) laser @ 460 nm, 12" Spectralon sphere w/ 2" dia exit port

Auxiliary data collected: 3x internal BS1 thermistors = Slit, Near-camera, Under-cap;
BS1 %RH = Vdc in (~3.3 Vdc), Vdc out; ambient thermistor; thermistor at splitter

Intent:
Try to get a laser scan with clean shoulders for SL comparison versus MOS / Holospec / CP140,
by varying Andor iKon camera parameters = Horizontal & Vertical shift speeds

Data:
Collected aux file (aux2015090201.txt), Andor sig & bac & drk (s,b,d20150902xx.fits)

Day21
ANDOR Solis acquisition software (©2008, Solis ver 4.23.30002.0, SDK ver 2.95.3002.0).
For all scans set: **Detector Temperature Setting** = -40 °C, **Time to open/close Shutter** = 35 msec,
Exposure Time = 2.0 sec, **Pre-Amplifier Gain** = 4x, … with laser power @ LOW = 151 µsec.

Scans were collected while varying 2x Solis parameters:

1.) Vertical Pixel Shift Speed: "the speed with which charge is moved down the CCD-chip prior to readout. The speed is actually given as the time in microseconds taken to vertically shift one row on the CCD sensor to the next, i.e. shorter time = higher speed. Slower vertical clocks ensure better change transfer efficiency but results in a slower maximum frame rate and possibility higher well depth. To improve the transfer efficiency the clocking voltage can be increased using the **Vertical Clock Voltage Amplitude** setting. However, the higher the voltage, the higher the clock-induced charge. The user must make a measured judgement as to which setting works best for their situation. At vertical clocks of 4 µsec or longer the "Normal" voltage setting should be suitable." (ref: Solis Help)
From the ANDOR iKon-M User's Guide, 5.13 – Vertical Pixel Shift: "Speeds which appear un-bracketed in the drop-down list are guaranteed to meet all the system specifications and as a general rule we would recommend using the fastest un-bracketed speed for all measurements. In some instances, using a slightly lower vertical shift speed may result in a slight increase in the single well capacity for imaging applications."

Vertical **P**ixel **S**hift Speed options = [2.25] 4.25, 8.25, 16.25, 32.25, 64.25 µsec (i.e. "**VPS**" below).
I left **Vertical Clock Voltage Amplitude** setting = Normal.

2.) Horizontal Pixel Shift Speed: "defines the rate at which pixels are read from the shift register. The faster the Horizontal Readout Rate the higher the frame rate that can be achieved. Slower readout rates will generate less noise in the data as (they are) read out." (User's Guide, 5.14)

Horizontal **P**ixel **S**hift Speed options = 50kHz, 1MHz, 3MHz, 5MHz, all @ 16 bit (i.e. "**HPS**" below).

Day21 data were collected with Pre-Amplifier Gain setting 4x. Ref. ANDOR User's Guide, 5.14.2 – **Pre-Amplifier Gain**: "Pre-Amplifier gain determines the amount of gain applied to the video signal emerging from the CCD and allows the user to control the sensitivity of the camera system." There are three options available via drop-down menu: 1x, 2x, 4x. "These normalized gain settings will correspond to system sensitivities specified on the performance sheets (in terms of electrons per A/D count) which accompany the system. Selecting higher pre-amplifier gain values (i.e. x2 or x4) will increase the sensitivity of the camera (i.e. fewer electrons will be required to produce one A/D count) and provide the lowest readout noise performance. However this may result in the A/D converter saturating before the single pixel / register capacity of the CCD sensor is reached."

BS01cfg02 = ANDOR iKon-M, Model: DU934P-BR-DD, Serial No.: **CCD-17878**, Date: Mar 2015
Ref. ANDOR System Performance Booklet, pg. 2 of 5, Readout Noise and Base Mean Level, **Figure 1**

ANDOR | iKon-M

CCD PERFORMANCE

Summary of System Test Data

Readout Noise ♦1 and Base Mean Level

A/D Rate (MHz All 16 bit)	Preamp setting	CCD Sensitivity ♦3 eles per A/D count	Single Pixel Noise electrons	Full Vert Bin Noise electrons	Base Level ♦2 (Counts)
5	x1	6.7	34.2	33.6	976
5	x2	3.4	20.0	21.8	1579
5	x4	1.6	15.4	17.0	2949
3	x1	5.8	19.1	19.0	1068
3	x2	3.0	13.0	13.3	1998
3	x4	1.4	11.2	11.6	3670
1	x1	5.2	11.0	11.0	885
1	x2	2.7	8.0	7.8	1781
1	x4	1.2	6.4	6.2	3638
0.05	x1	5.1	5.2	5.0	540
0.05	x2	2.7	4.3	4.3	1412
0.05	x4	1.3	3.9	3.9	3219
Saturation Signal per pixel		107790	Electrons/pixel		

Note 3: Sensitivity is calculated in photoelectrons per A/D count from measurements of the Photon Transfer Curve

Figure 1, ANDOR iKon-M Performance for CCD-17878

From Fig. 1, for Saturation Signal per pixel = 107790 Electrons/pixel, and
for CCD Sensitivity (electrons per A/D count) at Preamp setting x4:

at **HPS** = 50 kHz, Saturation Signal = 107790 (eles/pix) / 1.3 (eles/ADU) = 82,915 (ADU/pix)
1 MHz, Saturation Signal = 107790 (eles/pix) / 1.2 (eles/ADU) = 89,825 (ADU/pix)
3 MHz, Saturation Signal = 107790 (eles/pix) / 1.4 (eles/ADU) = 76,993 (ADU/pix)
5 MHz, Saturation Signal = 107790 (eles/pix) / 1.6 (eles/ADU) = 67,369 (ADU/pix)

<u>R.E. signal vs back vs dark scans:</u> in the Solis software one can "Take Signal" or "Take Background". The shutter fires for a Signal, but does not fire for a Background. What I call "dark" scans are collected as "Take Signal" but with the light source shuttered/off. NOTE: we do not know how the shutter open/close timing is handled during a Background scan…

For reference, **Figure 2** below is a plot from Stephanie's webpage "pg.1.21 = Day 21 Raw Data" of a dark scan at 3MHz HPS, 4.25 µsec VPS. These have been our typical shift speed settings.

From SF's Day21 raw data summary table: Matrix Mean (ADU) = 3473.23, Matrix % std = 0.27

NOTE: the mostly **"flat"** image structure in both spectral and track dimensions (duh).

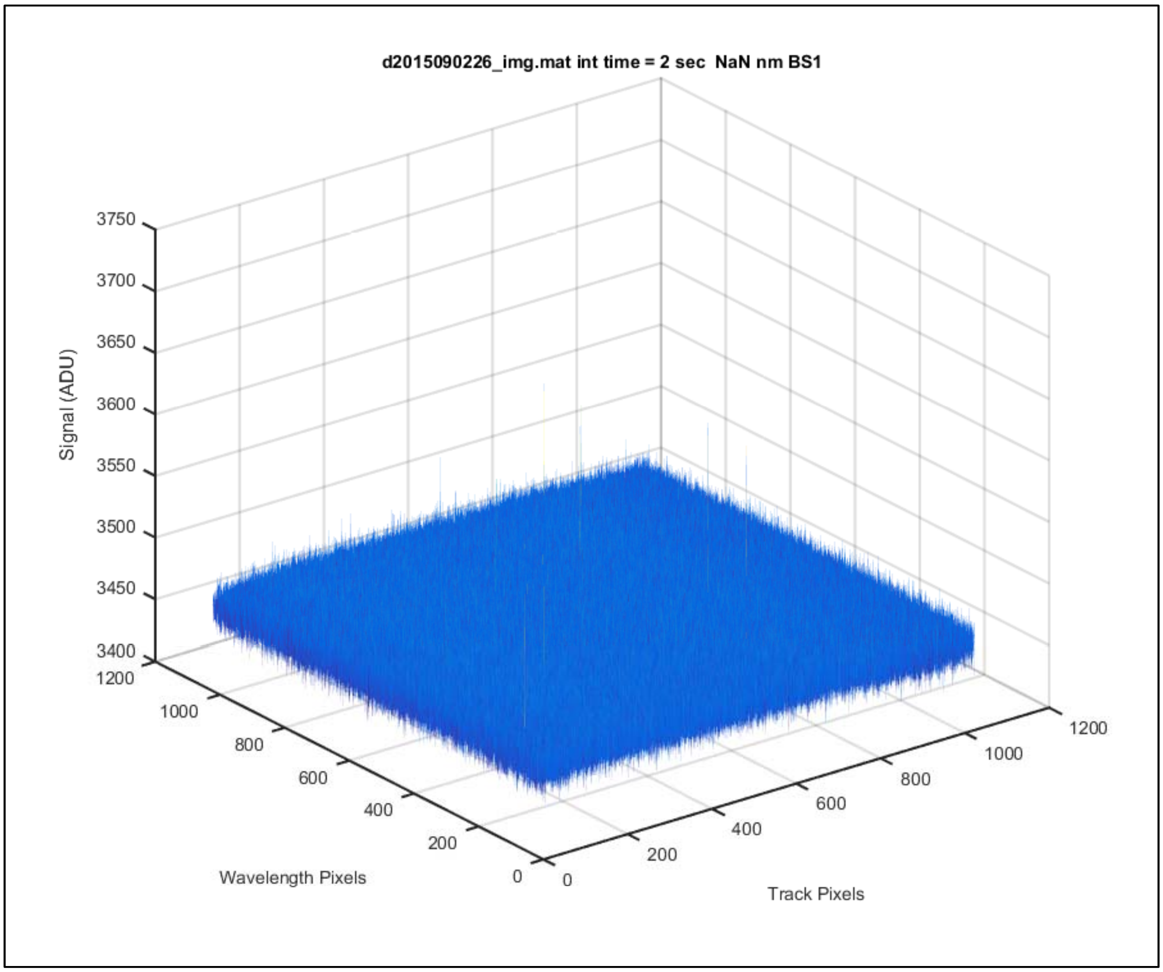

Figure 2, Dark scan at (typical) 3 MHz HPS, 4.25 µsec VPS

Next, **Figure 3** plots a dark scan at **50kHz**, 4.25 µsec, mean ADU ± std = 3330.90 ± 3.09%

Apparently the slower/longer 50 kHz Horizontal readout time allows charge to accumulate on the CCD during readout, resulting in a **"tilted"** image along the track dimension.

<u>R.E. HPS:</u> the ANDOR iKon manual notes "Slower readout rates will generate less noise in the data as it is read out." Nonetheless, I think we should avoid this tilted track effect. Why? 1.) I think this might cause us undue hassle trying to keep multiple tracks under-saturated, especially at long exposure times. 2.) ???

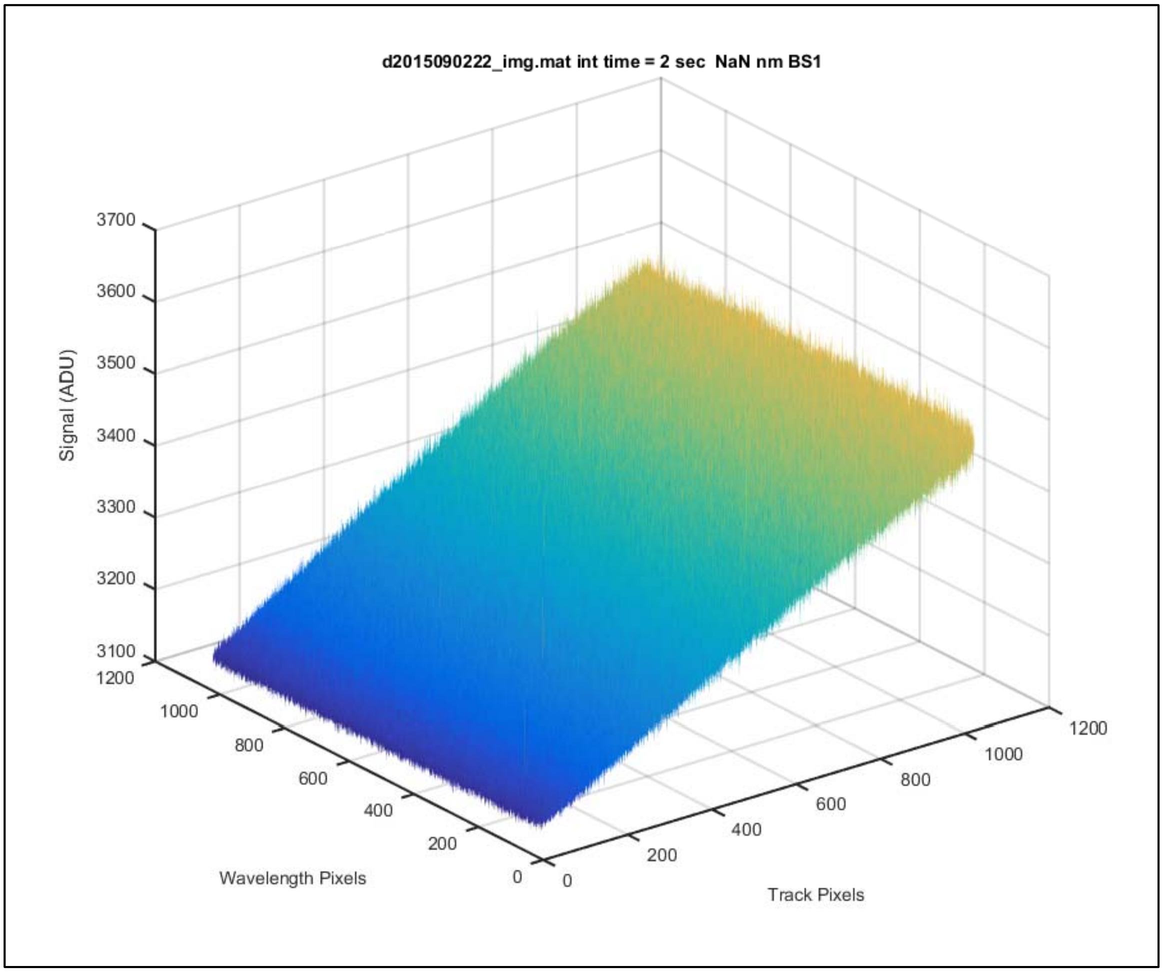

Figure 3, Dark scan at 50 kHz HPS, 4.25 µsec VPS

Figure 4 plots binned dark scans for Trk#3 (blue) and Trk#12 (green) at **Δ HPS**, 4.25 µsec VPS. The tilted track effect is seen via higher ADU/pix for Trk#12 vs lower Trk#3 in the top plot, collected at 50 kHz, and less-so in the 2nd plot at 1 MHz. I don't know why Trk#3 is slightly higher than #12 in the 3rd plot? It may be that the 4th / 5 MHz data are noisier than 3rd / 3 MHz (see Table 1 below).

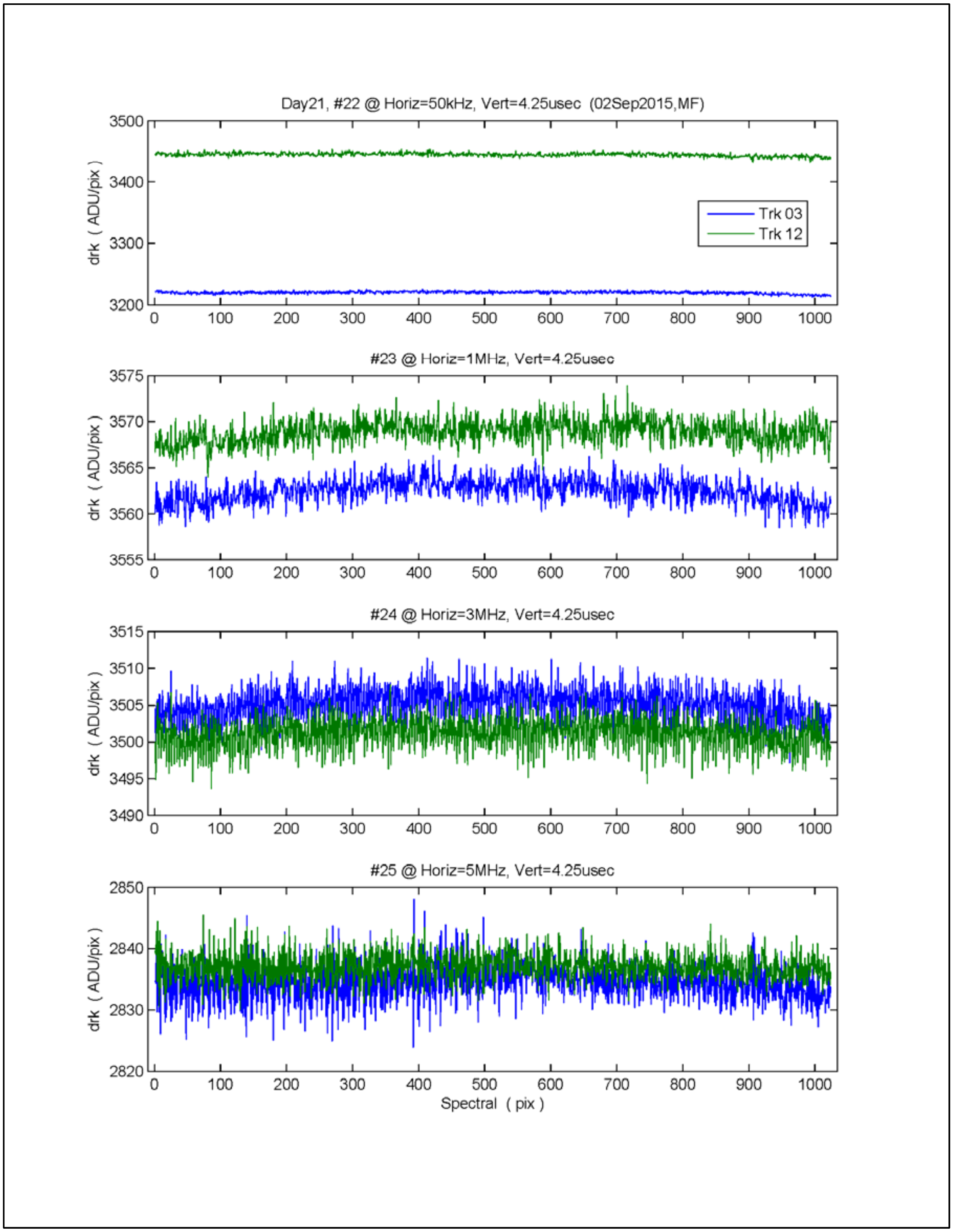

Figure 4, Binned Dark scans at Δ Hz HPS, 4.25 µsec VPS

Figure 5 plots a dark scan at 50 kHz HPS, **64.25 µsec VPS**, mean ADU ± std = 3325.30 ± 2.97%

The tilted image effect - along the track dimension - is evident here, due to slow 50 kHz HPS, but also (less obvious) is a **"bowed"** image structure along the spectral dimension. This is more easily seen in Fig.6.

R.E. VPS: the Andor iKon manual notes "as a general rule we would recommend using the fastest un-bracketed speed for all measurements. In some instances, using a slightly lower vertical shift speed may result in a slight increase in the single well capacity for imaging applications." (where "bracketed" speed [2.25] µsec does require adjusting the Vertical Clock Voltage Amplitude). I think we should avoid this bowed spectral effect. Why? 1.) I just don't like the idea of having this additional structure induced in the spectral dimension!
2.) ???

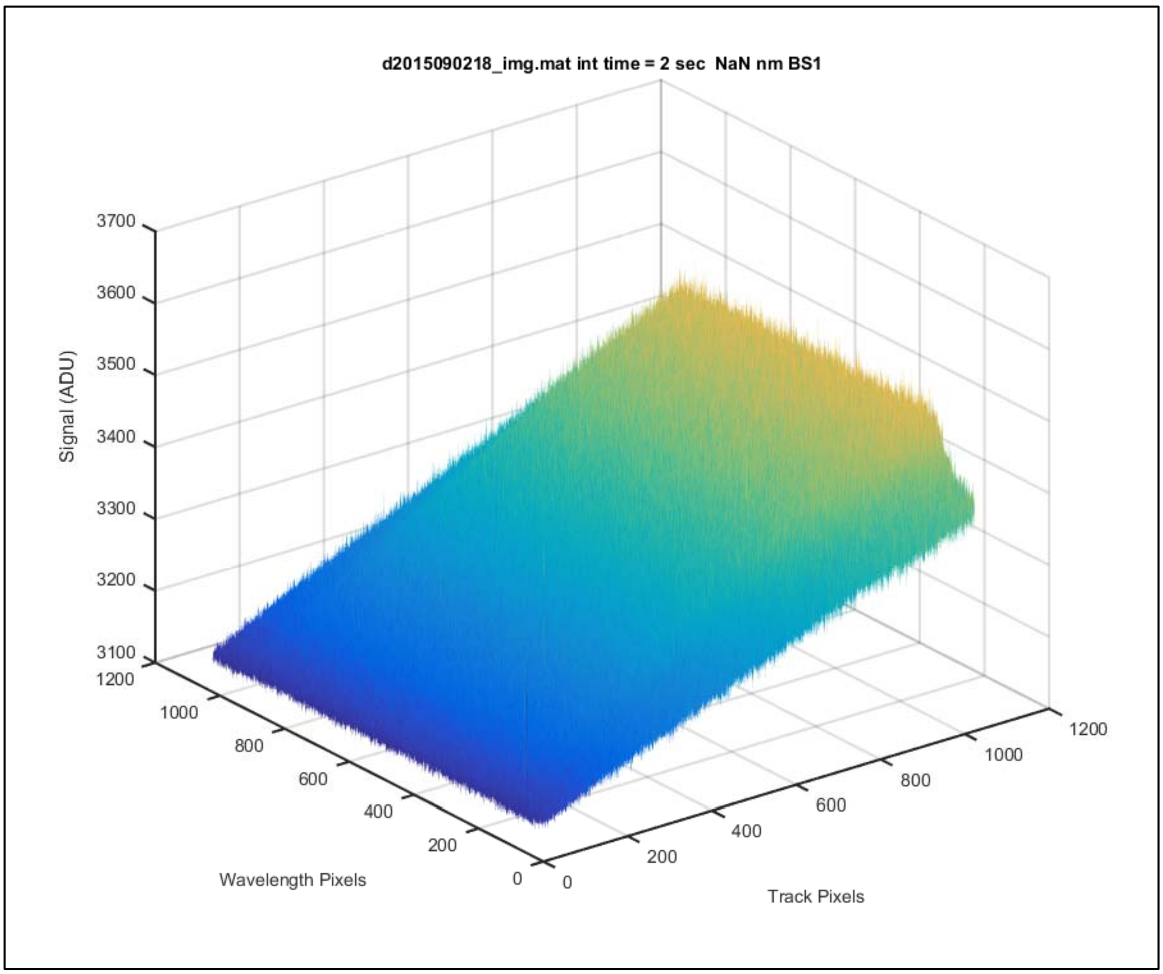

Figure 5, Dark scan at 50 kHz HPS, 64.25 µsec VPS

Figure 6 plots binned background scans for Trk#3 (blue) and Trk#12 (green): **Δ HPS**, 64.25 µsec VPS. The tilted track effect is seen via higher ADU/pix for Trk#12 vs lower Trk#3 in the top 2 plots, and also evident is the bowed spectral effect at longer/slower 64.25 µsec HPS. Here again the 5MHz data seem to be noisier than at 3 MHz (Table 1).

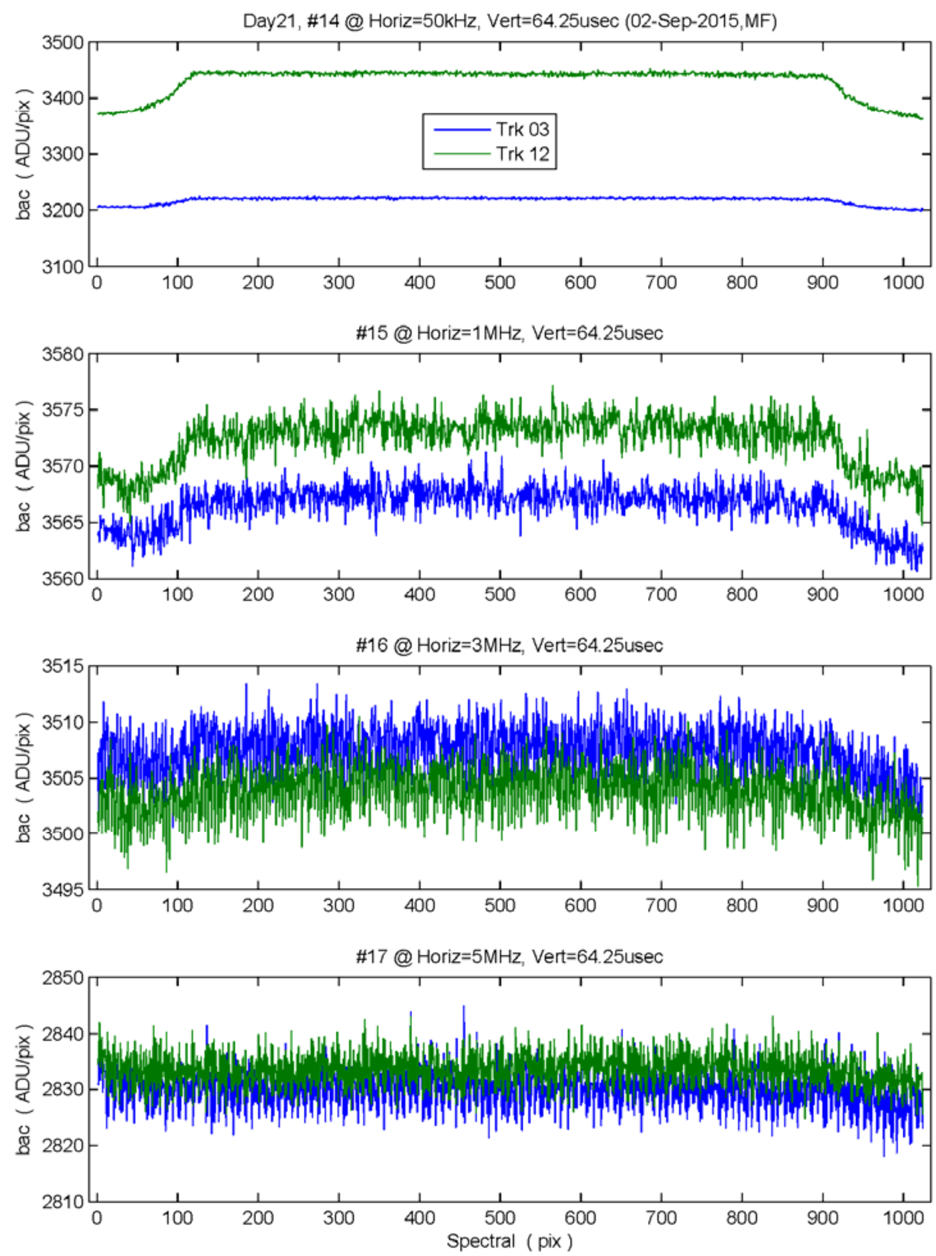

Figure 6, Binned Background scans at Δ Hz HPS, 64.25 µsec VPS

For reference, **Figure 7** shows binned dark scans for at 3 MHz HPS, and **different** µsec VPS.
3 MHz, 4.25 µsec (top plot) was our typical setup, and I think we should continue to use it.

<u>Note:</u> in the bottom 2 panels, the fall-off in ADU for red pixels at slowest Vertical Shift speeds!

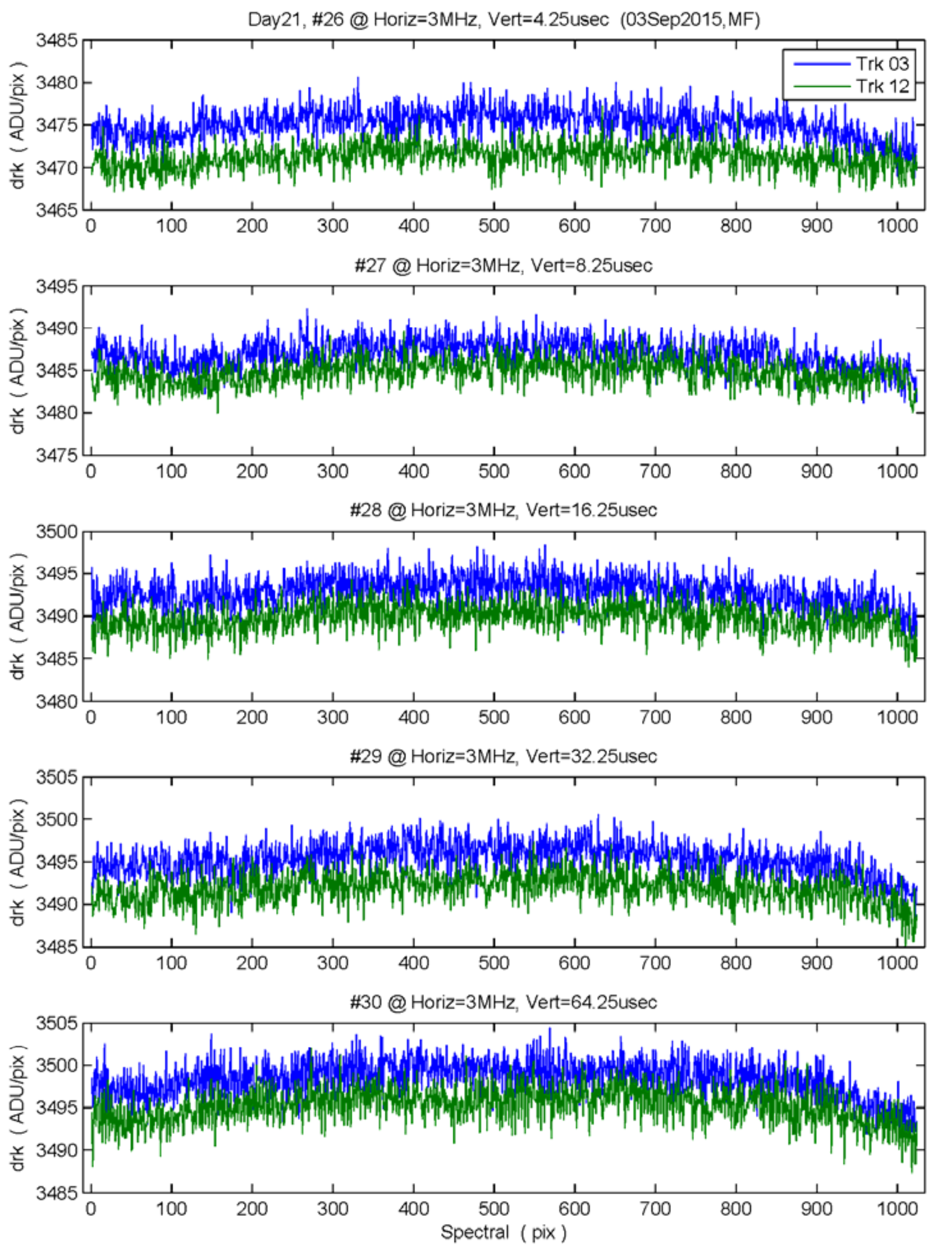

Figure 7, Binned Dark scans at 3 MHz HPS, Δ µsec VPS

Last, I looked at SF's Raw Data summary table to compare full Matrix Mean (ADU) & %std at different shift settings. **Table 1** was r.e. the question: "Is 5 MHz readout noisier than 3 MHz ?" It looks like the answer is "Yes".

VPS		scn#	HPS	%bac		scn#	HPS	%bac
4.25		01	3MHz	0.28		12	5MHz	0.41
64.25		05	3MHz	0.28		13	5MHz	0.39
64.25		16	3MHz	0.29		17	5MHz	0.41
VPS		scn#	HPS	%drk		scn#	HPS	%drk
4.25		24	3MHz	0.29		25	5MHz	0.51
64.25		20	3MHz	0.29		21	5MHz	0.52

Table 1, Full matrix %std for bac & drk: 3 MHz vs 5 MHz HPS

From: Kenneth Voss voss@physics.miami.edu, Date: 03-Sep-2015 23:22
reading on Andor's website they indicate that the tradeoff for vertical shift is that fast is good because you get lower noise, but too fast and the charge transfer efficiency goes down (charge left behind).

From: Kenneth Voss voss@physics.miami.edu, Date: 04-Sep-2015 01:49
Was looking through the Andor site. In the specifications sheet for the camera (IKON-M) it says: "5 MHz is for focusing/visualization mode only. " so we probably shouldn't be considering that readout rate….

Conclusions: We will continue to **use the 4x Pre-Amplifier Gain** (keeps the single pixel saturation level greater than the 16 bit A/D converter's 65k ADU maximum). We will not use the slowest 50 kHz HPS (tilted readout Fig.3), nor the fastest 5 MHz (focusing/visualization only) – this leaves us to **choose between 1 & 3 MHz Horizontal Speeds** (3MHz may be slightly noisier than 1MHz, Fig.4). We will not use the 2 slowest VPS, 32.25 & 64.25 µsec (bowed readout Fig.5/6, red pix ADU falloff Fig.7), nor will we use the fastest "bracketed" [2.25] µsec (change Vertical Clock Voltage Amplitude) – **choose from 4.25, 8.25, 16.25 µsec Vertical Speeds** (slower = better charge transfer efficiency & maybe deeper single well capacity, faster = lower noise).