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Instrument Science Report COS 2023-12

Cycle 27 COS FUV Detector Gain Maps

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ABSTRACT

Program 15772 used the onboard deuterium lamp to illuminate the regions of the COS FUV detector used during normal operations in Cycle 27. Data were taken two times during the year at detector positions corresponding to the three active Lifetime Positions (LPs): LP2, LP3, and LP4. The pulse height information obtained was used to create gain maps in order to monitor the detector gain sag, and thus to determine when to adjust the commanded high voltage on the detector.

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1. Introduction

Monitoring the gain (the number of electrons generated by the microchannel plate stack for each incident photon) of the COS FUV detector is crucial to ensure its optimal performance. When the modal gain (the peak of the pulse height distribution) at a particular location on the detector drops below a value of about 3, approximately 5% of the counts there fall below the lower pulse height threshold, which leads to an apparent local loss of sensitivity (Sahnow et al. 2011). The amount of gain sag is a function of the number of photon events incident on the detector, the high voltage (HV), and other factors. The largest gain drops are seen in the regions of the detector where Lyman-α airglow lines fall, since they have collected the most counts.

Cumulative Counts Image files (CCIs; Sahnow 2018) are created at each commanded HV approximately weekly by combining all of the TIME-TAG exposures obtained during that time. Gain map files are made by binning these (by 8 in X and 2 in Y) to collect the counts in a 48 μm square superpixel. A Pulse Height Distribution (PHD) is then constructed for each superpixel, and the modal gain is determined by fitting a gaussian to identify the peak of the distribution. These gain maps can be used to track the change of modal gain as a function of time at the locations where photons are detected.

However, since at least ~25 counts in a superpixel are necessary to reliably measure the peak of the PHD, the regions of the detector where the modal gain can be measured varies from week to week, depending on the grating, central wavelength, and Lifetime Position (LP) of the data collected. Even for the most commonly used cenwaves, it may be rare to ever collect enough counts for a valid measurement in any one week period in the the wings of the cross dispersion profiles.

In order to ensure more complete coverage at each LP and HV, exposures of the internal deuterium lamp (D1) are also regularly collected. The lamp illuminates a wider area in the cross-dispersion direction (y axis) of the detector than an external target so that modal gain measurements can be made everywhere that photons from science targets can fall. These gain map exposures are taken both before and after any change to the nominal detector high voltage or Lifetime Position, and at approximately six month intervals when the voltage is not changed. Because of the strongly varying intensity of the lamp as a function of wavelength, data are collected using both G130M/1309 and G160M/1600. The former is the best choice for obtaining approximately uniform coverage on Segment A, while the latter does the same for Segment B. In order to maximize the number of counts in the PHD, data from both central wavelengths is combined when creating the gain maps.

2. Observations

During Cycle 27, Program 15772 obtained deuterium data during ten one-orbit visits, which are listed in Table 1. Visits 2A, 2C, 3A, 3C, 4A, 4B, 4C, and 4D were part of the standard monitoring plan with a six month cadence. No changes to the nominal HV values were made during Cycle 27, but HV increases for LP3 and LP4 were made on

October 5, 2020, at the beginning of Cycle 28. Two additional contingency visits, 3E and 4E, were added to program 15772 to obtain deuterium spectra after this change. These are included in Table 1 for completeness, but the discussion of the data from those visits will be presented in the Cycle 28 Gain Map ISR.

All visits executed successfully; details of the configurations are shown in the table.

Exposure times were 400 seconds for the visits executed in April 2020. In subsequent visits exposure times were increased to 440 seconds to account for the decrease in count rate that has occurred due to time dependent sensitivity (TDS) changes of the instrument (Rowlands and Sankrit 2022) and a decrease in flux due to aging of the deuterium lamp.

Each visit followed the same procedure:

- Adjust the HV values to the nominal levels for that LP
- Adjust the aperture block in the cross-dispersion direction so that the deuterium lamp projected through the FCA illuminates the appropriate region on Segment A when using G130M/1309
- Take a 400 or 440 second deuterium lamp exposure at FP-POS=1 using both detector segments
- Adjust the aperture block to a second cross-dispersion location to obtain additional coverage on Segment A and take a 400 or 440 second deuterium lamp exposure at FP-POS=4 using both detector segments
- Adjust the aperture block in the cross-dispersion direction so that the deuterium lamp illuminates the appropriate region on Segment B when using G160M/1600
- Take a 400 or 440 second deuterium lamp exposure using both detector segments
- Adjust the aperture block to a second cross-dispersion location to obtain additional coverage on Segment B and take another 400 or 440 second deuterium lamp exposure
- Return the aperture block to the nominal location
- Return the HV to the nominal values for the standard observing modes

The two offset positions for each grating were chosen so that when the data from the exposures are combined, the count rate is roughly uniform in the cross-dispersion direction and they overlap with the science spectra at the same LP. The aperture offset values used (LAPXSTP) are shown in Table 1; these were determined by measuring the position of spectra as a function of aperture position during previous deuterium lamp observations. In several cases, the calculated value of LAPXSTP would have moved the aperture block very close to or beyond its soft stop at -275. In those cases, a value of -267 was used.

The visits were labeled such that the first character denoted the Lifetime Position (2 for LP2, etc.). The second character in the visit label was A for the first visit at that LP in the spring, and C for the first visit in the fall. For LP4, where multiple HV values were used in each case, B was used for the second visit in the spring, and D for the fall. An E was used for the two contingency visits.

Table 1. Visits executed in Program 15772

Root Name	Vis	Date	LP	Mode	HV (A/B)	LAPXSTP (G130M)	LAPXSTP (G160M)
le5d2a*	2A	4/1/20	2	Blue	173/175	-213,-267†	-225,-267†
le5d3a*	3A	4/1/20	3	Standard	167/175	-72,-128	-84,-140
le5d4a*	4A	4/1/20	4	Standard	163/163	-32,-86	-41,-95
le5d4b*	4B	4/1/20	4	1222	163/167	-32,-86	-41,-95
le5d2c*	2C	9/28/20	2	Blue	173/175	-213,-267†	-225,-267†
le5d3c*	3C	9/28/20	3	Standard	167/175	-72,-128	-84,-140
le5d4c*	4C	9/28/20	4	Standard	163/163	-32,-86	-41,-95
le5d4d*	4D	9/28/20	4	1222	163/167	-32,-86	-41,-95
le5d3e*	3E	10/5/20	3	Standard	173/175	-72,-128	-84,-140
le5d4e*	4E	10/5/20	4	Standard & 1222	167/169	-32,-86	-41,-95

† The commanded value of LAPXSTP for these positions was set to -267 in order to avoid the soft stop at -275

3. Summary of Analysis and Results

Standard gain map creation routines were used to calculate the modal gain; they fit a gaussian to the pulse height distribution for each 2 × 8 binned pixel, and the value of the peak of that fit is taken as the modal gain. Figure 1 shows the modal gain as a function of X pixel (XCORR) near the center of the LP4 detector location for both the spring and fall visits for both segments, along with the data obtained in October 2019 (just before the start of Cycle 27) as part of Program 15534. Only the data obtained using the HV values for the Standard Modes are shown, since that FUVB HV is lower than the G130M/1222 HV, and thus the driver for when to make HV adjustments.

Figure 2 shows an expanded view for each segment. The top panel shows a region with relatively low gain on FUVA, and the bottom panel shows the region around the most heavily gain sagged region on FUVB.

The figures in this ISR show the modal gain at a constant Y superpixel for each LP, with the Y value chosen to be along the most sagged region. Although the most sagged Y superpixel can vary slightly as a function of X, this effect is not included here.

The modal gain is comfortably above 3 at all locations on both segments, except at the two locations of the Lyman-α airglow lines on FUVB. These two "gain sag holes" have been allowed since the adoption of the COS2025 rules (Oliveira et al. 2018), which were implemented to extend the life of the detector.

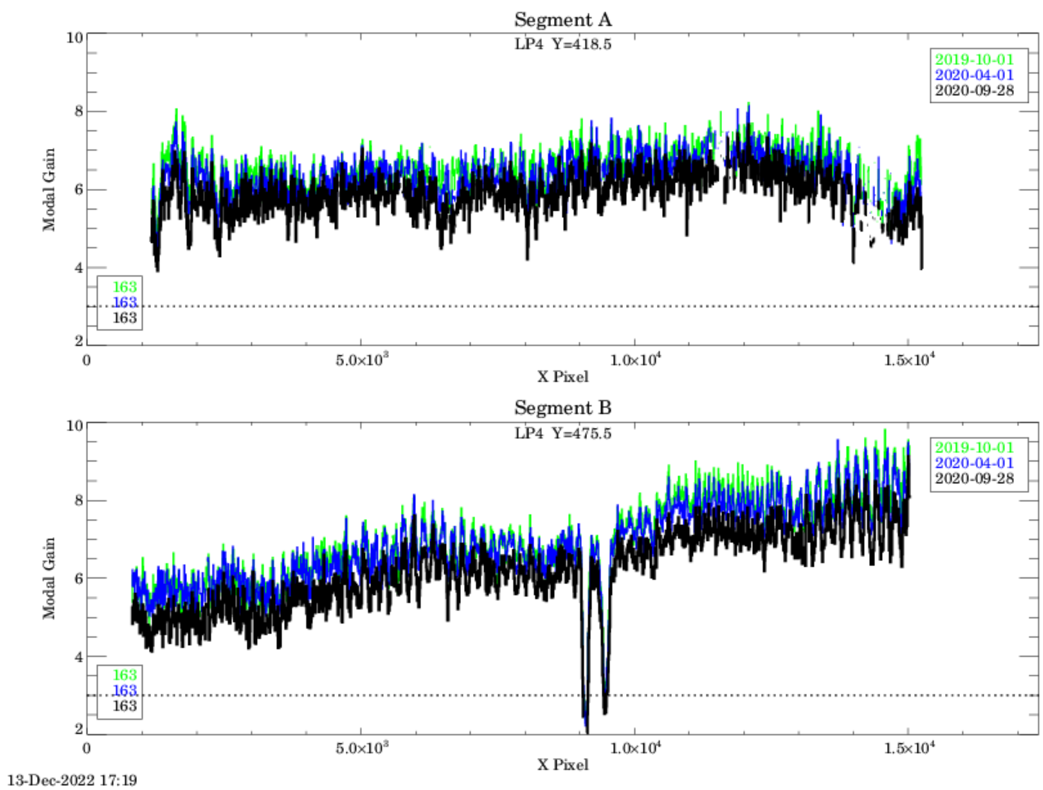

Figure 1. Modal gain as a function of unbinned X pixel at the center of the LP4 region for FUVA (top) and FUVB (bottom) at the end of Cycle 26 from Program 15534 (**green**) and at two times during Cycle 27 from Program 15772 (**blue** and **black**). As expected, there is a decrease in the overall gain as a function of time, with a variation as a function of position due to varying exposure levels.

The modal gain measured at the LP3 detector location on the same dates as in the previous figures is displayed in Figure 3, and Figure 4 shows an expanded view highlighting the deepest gain sag holes on each segment. In this case, the holes have dropped to a modal gain of 3 or below on FUVB, which is operating at the maximum allowable HV value of 175. On FUVA, the modal gain at the most sagged locations has just reached a value of 3, and the HV has not reached its maximum allowed value; as a result, the HV on that segment was increased at the beginning of Cycle 28.

Figure 5 shows the modal gain at the center of the LP2 region for the same times as the other LPs. Very little change has occurred during Cycle 27 since the number of counts that fell on this region of the detector is much smaller than at LP3 or LP4.

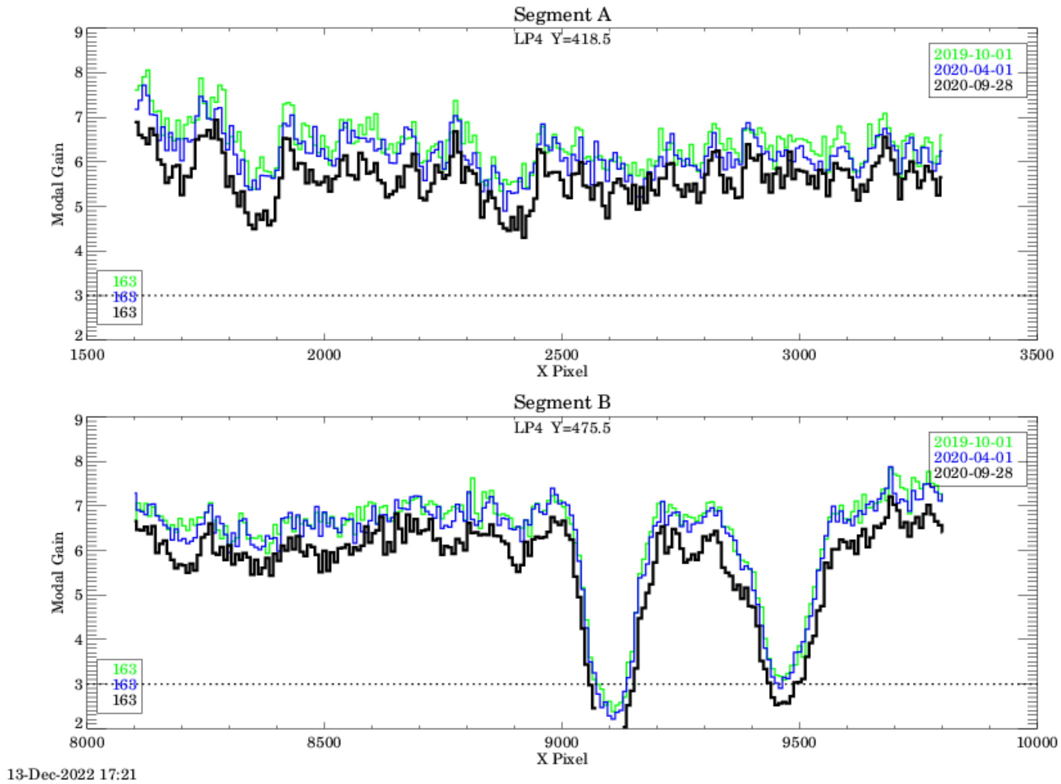

Figure 2. Zoomed in view of the data shown in Figure 1. On Segment B at the positions corresponding to the Lyman-α lines from G130M/1291, FP-POS 3 and 4, the modal gain has dropped below 3, which is allowed under the COS2025 rules. Note that the y scale is different here than in the previous figure.

The primary purpose of Program 15772 was to obtain gain maps which are used to determine the slope of the modal gain vs. extracted charge curve over the entire illuminated area of the detector at all of the nominal high voltage values used during the cycle. Making regular measurements allows a more accurate determination of these slopes, which leads to better predictions of when the gain is likely to drop to 3, and thus when a high voltage change or Lifetime Position change is needed. Examples of gain vs. extracted charge curves are shown in Sahnow et al. (2011).

Data from this program, along with data from the weekly gain measurements, is also used in the construction of the gain sag reference table (GSAGTAB), which flags the regions where the modal gain has dropped to a level which adversely affect the data.

The results described above are consistent with those from previous cycles, e.g. Sahnow (2020) for Cycle 26. Regular gain map measurements were continued in Cycle 28 in Program 16323.

Change History for COS ISR 2023-12

Version 1: 26 May 2023

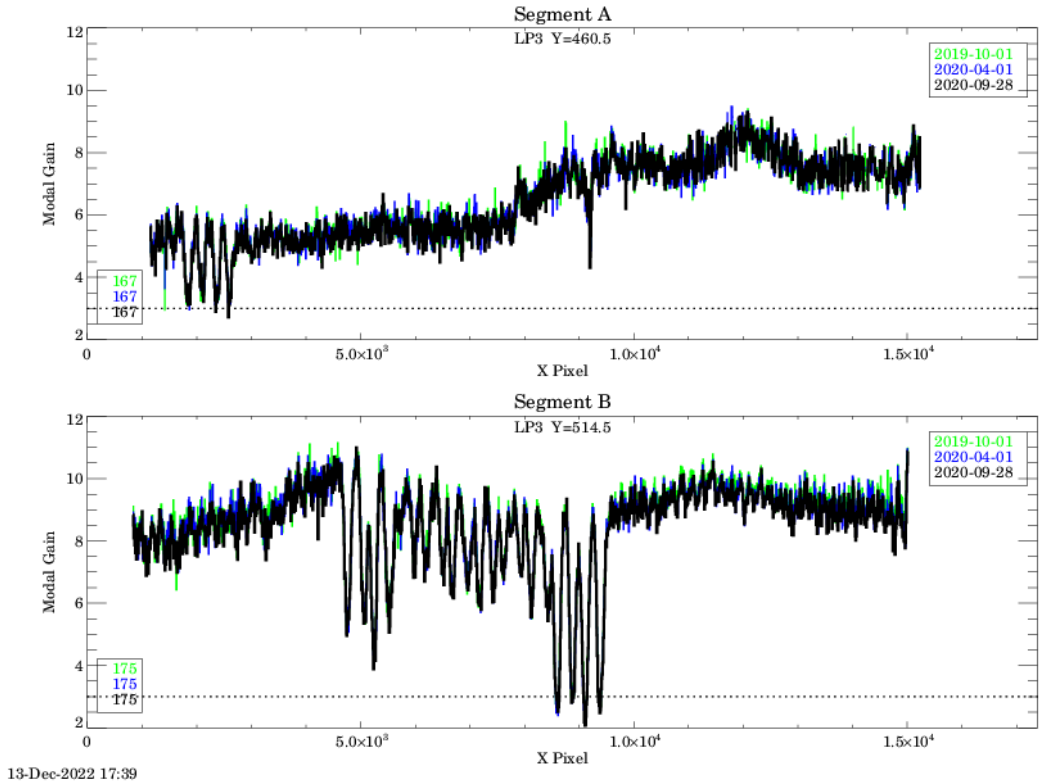

Figure 3. Modal gain as a function of X pixel at the center of the LP3 region of the detector using the LP3 G130M/1222 HV values of 167/175. The low gain feature near the center of FUVA has been present since launch.

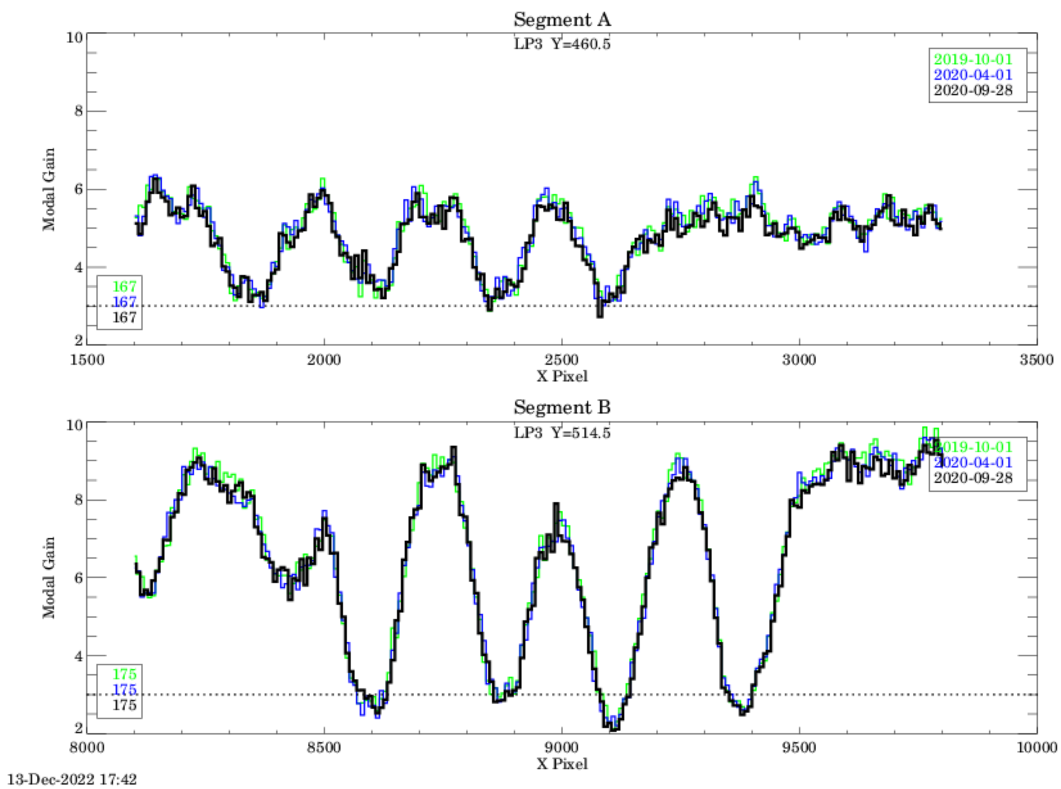

Figure 4. An expanded view of a portion of the modal gain plot shown in Figure 3. All four Lyman-α lines due to G130M/1291 at LP3 on FUVB have dropped to a modal gain below 3 at HV=175. On FUVA, the four Lyman-α impacted regions from G140L/1105 have just reached this value. Note that the y scale is different than in the previous figure.

References

Oliveira, C., et al., 2018, "COS2025: A New Strategy to Prolong the Lifetime of the COS/FUV Detector to 2025"

Rowlands, K. and Sankrit, R. COS ISR 2022-08, "Cycle 28 COS/FUV Spectroscopic Sensitivity Monitor"

Sahnow, D., et al. 2011, "Gain sag in the FUV detector of the Cosmic Origins Spectrograph", Proc. SPIE 8145, 8145Q

Sahnow, D. 2018, COS TIR 2018-02, "Requirements for COS Cumulative Images"

Sahnow, D. 2020, COS ISR 2020-07, "Cycle 26 COS FUV Detector Gain Maps"

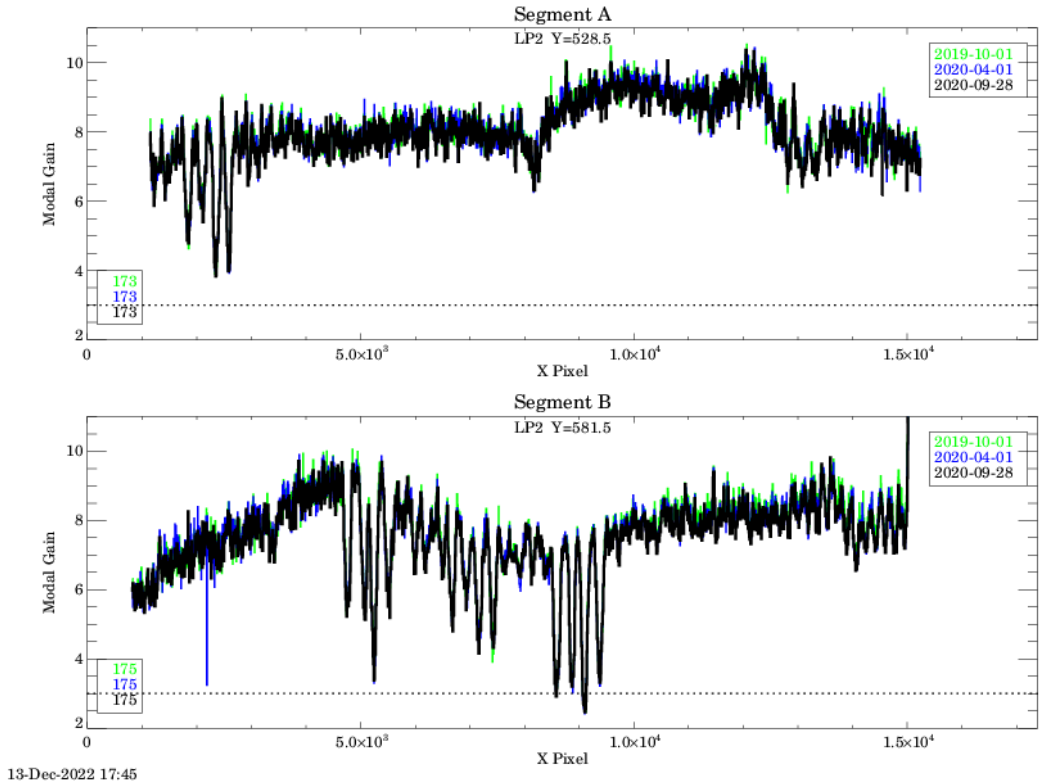

Figure 5. Modal gain as a function of X pixel at the center of the LP2 (Blue Mode) region of the detector using the Blue Modes HV values of 173/175. There was very little change during this cycle since these modes are not used extensively.