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Creation of the LAMPTAB reference file for use at Lifetime Position 6

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ABSTRACT

The wavelength calibration procedure employed by CalCOS at LP6 relies on measuring the separation in the dispersion direction between Pt-Ne lamp spectra that are observed immediately before and after a science exposure, and a template Pt-Ne spectrum for which the dispersion solution of the Primary Science Aperture is defined. Template spectra for each Cenwave/Segment/FP-POS combination are stored in the LAMPTAB reference file, and must be updated with each new lifetime position due to changes in the absolute focus. This document describes the creation of the LAMPTAB file for use at LP6 at the beginning of HST Cycle 30 (2022 Oct 1).

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Contents

1. Introduction

The Far Ultraviolet (FUV) detectors within the Cosmic Origins Spectrograph (COS) lose sensitivity over time, as the repeated extraction of electrons from the microchannel plate reduces the gain in places where photons are incident. To mitigate the effects of this gain sag, and to extend the operational lifetime of the COS FUV detectors, a strategy has been adopted where spectra are recorded at multiple cross-dispersion locations on the detectors. When the sensitivity to light at one cross-dispersion location decreases to the point that incoming photons are no longer properly recorded in some portions of the spectrum, the spectrum is moved to a different cross-dispersion location where the detectors have not yet suffered any gain sag. Each of these different cross-dispersion locations is referred to as a Lifetime Position (LP), and this document describes a portion of the calibration work for the sixth such position, known as LP6.

Each Lifetime Position has several reference files that are specific only to that LP. The necessity for new reference files at each LP is driven by a few different considerations, one of which is that the absolute focus position at each LP is different, resulting in slightly different dispersion solutions. Because wavelength as a function of pixel in the dispersion direction changes for each LP, any reference file relating to the dispersion solution must be updated at each LP. This includes the LAMPTAB reference file, which stores template Pt-Ne spectra that are used in the wavelength calibration procedure employed by CalCOS[1].

To facilitate science observations at LP6, a new LAMPTAB reference file has been created specifically for LP6. Note that at this time LP6 is only being used for G160M observations, so updates to the LP6 LAMPTAB file are limited to G160M entries. This document describes the observing program that was used to obtain the necessary Pt-Ne data, the custom calibration of those data, and the analysis used to generate the new LP6 LAMPTAB file from those observations.

2. Observations

Template spectra are created by observing the Pt-Ne hollow cathode lamp on the COS Calibration Platform projected through the Wavelength Calibration Aperture (WCA). Specifically, the lamp referred to as P1 or LINE1 is used, as this is the same lamp used with science observations for wavelength calibration purposes. Throughout this document, usage of the term Pt-Ne lamp is understood to refer to P1. The second Pt-Ne lamp (P2 or LINE2) is currently used only for target acquisition purposes, although it could also be employed for wavelength calibration if necessary. As no external target observations are required for our purposes, this is purely an internal observing program.

Pt-Ne lamp spectra were obtained via HST program 16909 in a single 2-orbit visit. This visit began with a long (1800 s) exposure with Target=WAVE, with the purpose of letting the position of the Optics Select Mechanism 1 (OSM1) settle and thus minimize spectral drift in the dispersion direction throughout the remainder of the visit. After the settling exposure, all G160M settings were observed at all 4 FP-POS. Each exposure was 210 s long, during which the Pt-Ne lamp was repeatedly cycled ON for 30 s and OFF for 30 s, for a total integration time of 120 s. This strategy was first employed during the acquisition of the data used to create the LP4 LAMPTAB files (HST 15369; see Frazer & Plesha 2023), and is used to ensure that the lamp does not overheat from constant use during the program, while maintaining the 120 s of lamp ON integration time used since LP1 (10$\times$ the lamp ON duration during TAGFLASH exposures; Oliveira et al. 2010). The BUFFER-TIME parameter was set to 210 s—equal to the exposure time—so that the entire data buffer is read out at the end of every exposure. This maximizes the readout time (and thus lamp cool down time) between exposures. Table 1 presents the observing strategy of program 16909 and the root names of the resulting data files. Note that the long settling exposure also utilized the lamp ON/OFF cycling strategy, although with a 30 s ON and 90 s OFF cadence. These data are not used in the creation of new template spectra, but enable characterization of OSM1 drift during the settling process if necessary.[2]

[1]For more information about this procedure, see the COS Data Handbook; Soderblom et al. (2022)
[2]Analysis of these spectra was deemed unnecessary.

Table 1. Summary of HST 16909 Observations.

Grating	Cenwave	FP-POS	Exposure Time (sec)	Lamp ON/OFF Cycle Time (sec)	Rootname
G160M	1533	3	1800	30/90	`leta01f5q`
G160M	1533	1	210	30/30	`leta01f7q`
G160M	1533	2	210	30/30	`leta01f9q`
G160M	1533	3	210	30/30	`leta01feq`
G160M	1533	4	210	30/30	`leta01fgq`
G160M	1577	1	210	30/30	`leta01fiq`
G160M	1577	2	210	30/30	`leta01fkq`
G160M	1577	3	210	30/30	`leta01fmq`
G160M	1577	4	210	30/30	`leta01foq`
G160M	1589	1	210	30/30	`leta01fqq`
G160M	1589	2	210	30/30	`leta01fuq`
G160M	1589	3	210	30/30	`leta01fwq`
G160M	1589	4	210	30/30	`leta01fyq`
G160M	1600	1	210	30/30	`leta01g0q`
G160M	1600	2	210	30/30	`leta01g2q`
G160M	1600	3	210	30/30	`leta01g5q`
G160M	1600	4	210	30/30	`leta01g8q`
G160M	1611	1	210	30/30	`leta01gaq`
G160M	1611	2	210	30/30	`leta01gdq`
G160M	1611	3	210	30/30	`leta01gfq`
G160M	1611	4	210	30/30	`leta01ghq`
G160M	1623	1	210	30/30	`leta01gjq`
G160M	1623	2	210	30/30	`leta01glq`
G160M	1623	3	210	30/30	`leta01gnq`
G160M	1623	4	210	30/30	`leta01gpq`

3. Data Processing

In creating a new LAMPTAB reference file two particular items are required for every Cenwave/FP-POS/Segment combination; these are a Pt-Ne spectrum, stored as an array of length 16384 with each element giving the lamp intensity at that *xcorr* position (the INTENSITY column), and a floating point number that gives the shift in pixels between the template spectrum at FP-POS=3 and at FP-POS=N, where N is either 1, 2, or 4 (the FP_PIXEL_SHIFT column). Producing these two items is a multi-step process. Whenever possible, CalCOS is used to perform tasks within this process since its methods are known to be robust. Outside of CalCOS, python scripts are used to edit header keywords for data processing (calibration switches and reference files), remove OSM1 drift from individual spectra within an exposure, measure shifts between spectra via cross correlation, and populate the appropriate entries in the new reference file. The overall strategy of our analysis plan is based on those used for creation of the LAMPTAB reference files at LP3 (Frazer & Plesha 2022), LP4 (Frazer & Plesha 2023), and LP5 (Hirschauer et al. 2023), and is as follows:

1. For each exposure, extract 4 separate Pt-Ne spectra; one for each of the 30 s lamp ON intervals.

2. Measure and remove the OSM1 drift between these 4 spectra.

3. Combine the drift-corrected data into 1 final spectrum for each combination of Cenwave/FP-POS/Segment.

4. Measure the separation in pixels in the along-dispersion direction between the FP-POS=3 spectrum and the FP-POS=1, 2, and 4 spectra.

For the first step, CalCOS was used with the Calibration switches set as shown in the *Run 1* column of Table 2. It is important that the WAVECORR step is set to PERFORM for this run as that step will automatically produce `lampflash` files as output. The `lampflash` files contain separate spectra for each time the lamp is flashed ON during an exposure, effectively achieving step 1 above. They also contain measurements of the shifts in the along-dispersion direction between each of these spectra and the template spectrum within the LAMPTAB reference file (see discussion below on the use of existing reference files in our analysis), stored in the SHIFT_DISP column. The differences between these measured shifts is used to determine the OSM1 drift across the entire exposure. OSM1 drift is then removed from individual photon events by subtracting appropriate values from *xcorr* locations within the `corrtag` event list. A new `corrtag` file that is identical to the original, except with the *xcorr* column modified to remove OSM1 drift is then saved, completing step 2.

At this point CalCOS is again used, but now starting from the modified `corrtag` files. Calibration switches are set as shown in the *Run 2* column of Table 2. This time, it is important that the WAVECORR step is set to OMIT so that resulting `x1d` spectra

Table 2. Calibration Switches for Data Processing.

Calibration Switch	Run 1 Value	Run 2 Value
FLATCORR	PERFORM	COMPLETE
DEADCORR	OMIT	OMIT
DQICORR	PERFORM	COMPLETE
STATFLAG	TRUE	TRUE
TEMPCORR	PERFORM	COMPLETE
GEOCORR	PERFORM	COMPLETE
DGEOCORR	OMIT	OMIT
IGEOCORR	PERFORM	COMPLETE
RANDCORR	PERFORM	COMPLETE
RANDSEED	12345	12345
XWLKCORR	OMIT	OMIT
YWLKCORR	PERFORM	COMPLETE
PHACORR	PERFORM	COMPLETE
TRCECORR	OMIT	OMIT
ALGNCORR	OMIT	OMIT
XTRCTALG	BOXCAR	BOXCAR
BADTCORR	OMIT	OMIT
DOPPCORR	OMIT	OMIT
HELCORR	OMIT	OMIT
X1DCORR	PERFORM	PERFORM
BACKCORR	OMIT	OMIT
WAVECORR	PERFORM	OMIT
FLUXCORR	OMIT	OMIT
BRSTCORR	OMIT	OMIT
TDSCORR	OMIT	OMIT

are **NOT** all shifted into the FP-POS=3 reference frame that defines *xfull* coordinates. The NET column (background-subtracted count rate) in the `x1d` file is multiplied by the exposure time, and this result is saved as the INTENSITY column in a new LAMPTAB file. Finally, for each Cenwave/Segment combination the shifts between the FP-POS=3 and FP-POS=1, 2, and 4 spectra are measured via cross correlation, and these values are saved to the FP_PIXEL_SHIFT column in a new LAMPTAB file. Note that for FP-POS=3 the value of FP_PIXEL_SHIFT is defined to be zero.

3.1 Iteration

In order to refine the entries in the new LAMPTAB file, the above procedure was carried out twice, with each iteration utilizing a different combination of reference files for the CalCOS processing. This is necessary because many of the new reference files being created for LP6 are interdependent. In the first iteration, the BPIXTAB and XTRACTAB files used were preliminary versions created for LP6, while the FLATFILE, LAMPTAB, and DISPTAB were the LP4 versions of those files. While these do not produce optimal data products at LP6, they are sufficient for CalCOS to perform the steps described above, enabling the creation of a preliminary LP6 LAMPTAB file. This preliminary LP6 LAMPTAB was then used as a reference file in the processing of data that were used to create the other new LP6 reference files (XTRACTAB, TRACETAB, PROFTAB, TWOZXTAB, FLUXTAB, FLATFILE, and DISPTAB). Once all relevant new preliminary LP6 reference files were ready, they were employed in the second iteration of the above procedure. That is, for the second iteration, data processing with CalCOS utilized the XTRACTAB, FLATFILE, LAMPTAB, and DISPTAB created from analyzing the observations specifically performed for generating new LP6 reference files. The result of this second iteration was the final LAMPTAB file that is now used for operation at LP6.

3.2 Special Considerations for G160M/1533 FUVB

The G160M/1533 observing mode was first introduced in Cycle 26, when science observations executed at LP4. During the initial creation of LP4 LAMPTAB entries for the G160M/1533 FUVB settings (see James et al. 2019) it was found that CalCOS could return slightly different shifts depending on whether or not the strong emission line near the right edge of the FUVB detector was included or excluded from the template spectrum. This is because the CalCOS shift finding algorithm tends to be most sensitive to the strongest line in the spectrum (White et al. 2018), and because calibration uncertainties are largest near the edge of each segment, such that the shift at the edge of the spectrum may not be representative of the average shift of the spectrum. To mitigate this effect a decision was made to truncate the 1533 FUVB template spectra so as to exclude the strong emission line near the right edge for all FP-POS. We have followed this precedent in creating the 1533 FUVB template spectra at LP6, and recommend that this practice be continued if the G160M/1533 mode is commissioned at any other LP. The point of truncation was determined by visual inspection of the spectra. Figure 1 shows the spectra prior to truncation in red, and after truncation (i.e., those that are in the LP6 LAMPTAB file) in black.

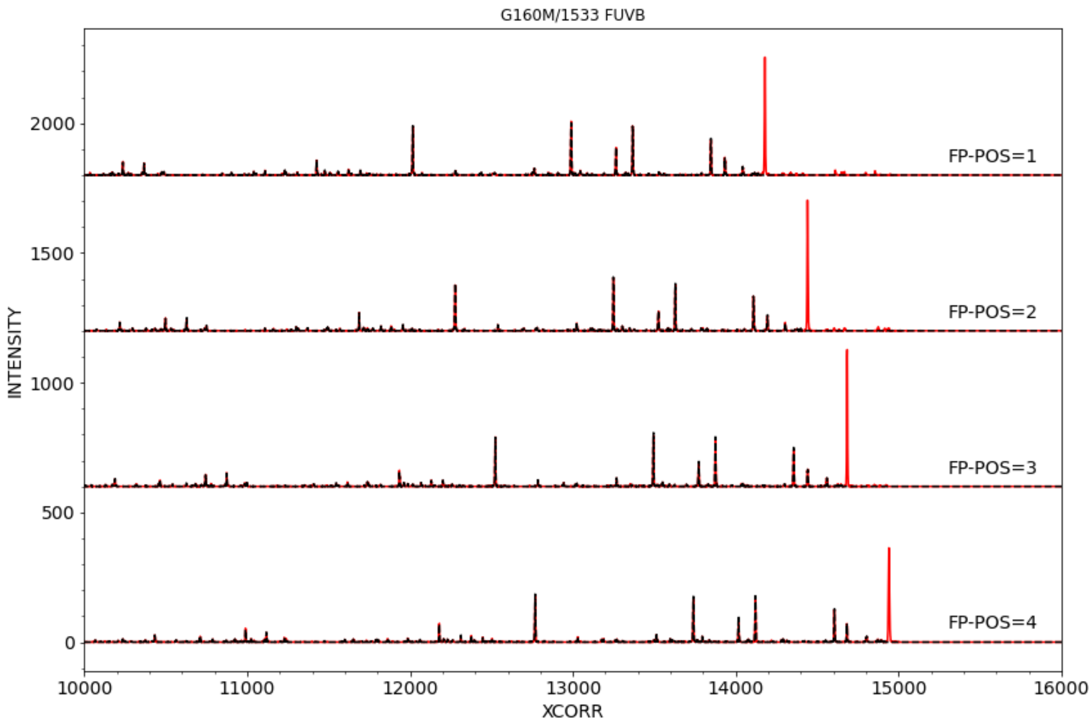

Figure 1. Shown above are the G160M/1533 FUVB LAMPTAB spectra before (red) and after (black, dashed) truncation to remove the strong emission line near the right edge. As an aside, note that the separation between a specific emission line in the FP-POS=3 spectrum and that same emission line in a different spectrum is effectively a visualization of the FP_PIXEL_SHIFT parameter.

4. Validation

4.1 OSM1 Drift Correction

The ultimate purpose of the OSM1 drift correction described above is to ensure that emission lines in the template spectra are not artificially broadened. CalCOS routinely performs a drift correction, but this correction is applied in the *xfull* frame where all spectra have been aligned at FP-POS=3. Because the LAMPTAB spectra must be defined in the *xcorr* frame, we perform an analysis outside of CalCOS to complete this task. We can check that the custom routine is comparable to the CalCOS routine by measuring the widths of emission features in spectra extracted from data that have been processed using both methods. To do so, we arbitrarily select emission lines from various spectra, perform an autocorrelation to ensure symmetric features, and fit a Gaussian function to the autocorrelation function. Figure 2 shows an example of this analysis for three emission features. The measured FWHM are comparable in all cases, demonstrating that the custom OSM1 drift correction produces lines that are indistinguishable from those output by standard CalCOS procedures.

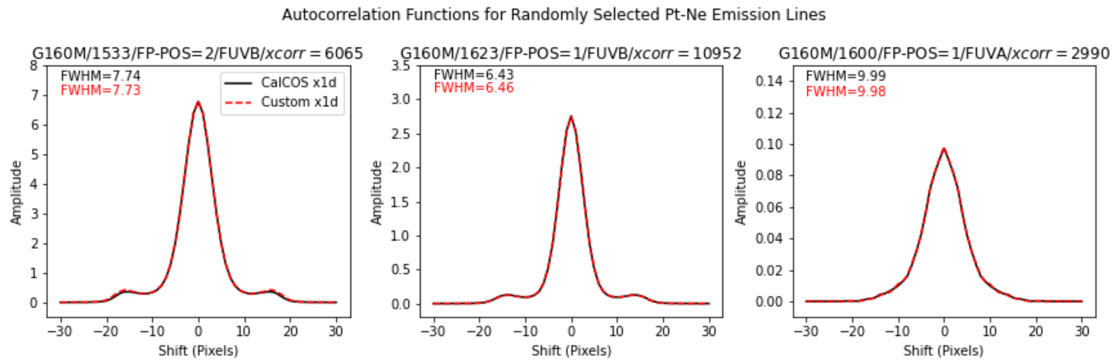

Figure 2. The autocorrelation functions for three arbitrarily selected Pt-Ne emission lines are shown for the standard CalCOS OSM drift removal (solid black) and the custom drift removal routines (dashed red). The results are indistinguishable, demonstrating the effectiveness of the custom drift removal routine.

4.2 FP_PIXEL_SHIFT Entries

Once the new LAMPTAB file was created the combination of INTENSITY arrays and FP_PIXEL_SHIFT entries was checked for correctness. INTENSITY arrays from FP-POS=1, 2, and 4 were cross-correlated with that from FP-POS=3, and the shifts were compared to the corresponding FP_PIXEL_SHIFT entries. Results were identical, demonstrating that the pairs are correct.

4.3 Comparison to LP4 LAMPTAB

The Pt-Ne template spectra at LP4 and LP6 should be very similar, (i.e., the same emission lines at about the same locations in *xcorr* with roughly the same relative intensities for each Cenwave/FP-POS/Segment), since they are produced by the same lamp projected at different cross-dispersion locations on the detector. Differences in the response of the detector at each location mean that the spectra will not be identical though. Note that a comparison is done to LP4 rather than LP5 since only G130M settings were updated in the LP5 LAMPTAB. Visual inspection of all LP6 INTENSITY arrays and their LP4 counterparts shows this to be predominantly true (e.g., see Figure 3), although for a few settings one or two emission lines may have significantly different intensities between the two spectra. This can be the result of a line falling in a gain-sag hole or a low response region on the detector, and so is not considered problematic.

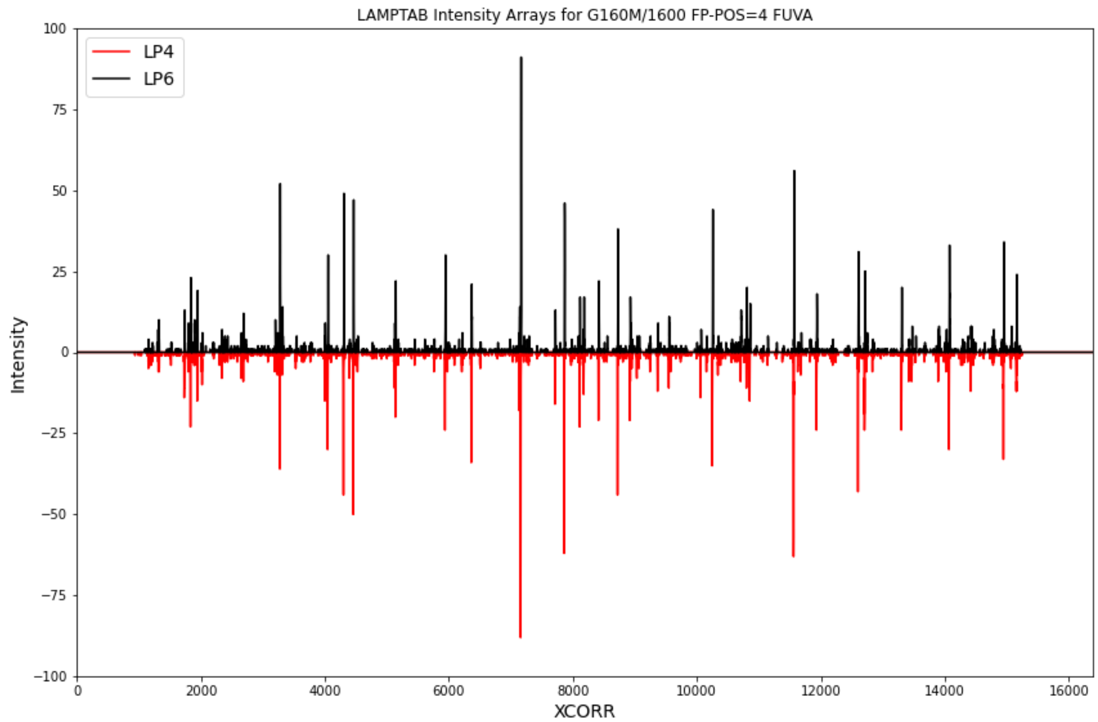

Figure 3. The LP4 (red) and LP6 (black) LAMPTAB Intensity arrays for G160M/1600, FUVA, FP-POS=4 are shown here. The LP4 spectrum has been multiplied by -1 for ease of comparison. Both spectra are broadly consistent, with only minor differences in the intensities of various features.

5. Summary

Pt-Ne emission line spectra were obtained through the WCA at LP6 for all G160M Cenwave/FP-POS/Segment combinations. The data were processed and analyzed so as to generate new entries for the INTENSITY and FP_PIXEL_SHIFT columns within the LAMPTAB reference file. These results were incorporated into a new LAMPTAB reference file that has been created for use in the calibration of all G160M data taken at LP6. The file (69d21093l_lamp.fits) was delivered to the HST Calibration Reference Data System on 2022 Sep 14, in advance of the start of HST cycle 30.

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Change History for COS ISR 2023-09

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