PROCEDURE FOR MONITORING RELATIVE EFFICIENCIES OF THE NUV GRATINGS DURING EXTENDED STORAGE

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1. INTRODUCTION

In early July 2003 a series of tests were conducted with the COS instrument to evaluate its basic performance metrics prior to full calibration. These tests included efficiency measurements for each of the FUV and NUV gratings. These data indicated that the G225M and G285M gratings were ~30% below modeled efficiencies, while all the other channels were performing as expected.

It was quickly pointed out that the G225M and G285M gratings were coated with bare aluminum and that perhaps the discrepancy between those gratings coated with aluminum and those coated with Al/MgF_2 was due to a degradation in the aluminum reflectivity. Witness mirror data indicates that the Al coating is stable and aging in a manner consistent with other studies published in the literature. However, we do not have a time sequence of the grating efficiencies, so we cannot say with any certainty whether or not the grating efficiencies are stable. Given the extended period of time over which COS will be stored prior to launch it is prudent to develop some means to monitor the long-term stability of the gratings. This document presents such a plan.

Fortunately the NUV wavelengths are not particularly susceptible to absorption by residual H_2O or O_2, so it is possible to test the NUV channel in an environment purged with gaseous nitrogen. COS also has internal wavelength calibration lamps, so an external light source is not required (using the internal lamps is deemed acceptable provided that their total run time on the ground constitutes <5% of the expected lamp usage in orbit (~1500 hours)).

2. DEFINITION OF REQUIREMENTS

The requirements to derive and monitor the long-term stability of the NUV gratings are as follows:

1. The relative efficiency shall be defined as the ratio of the count rates of a specific emission line or an identical band-pass as measured with two NUV gratings.
2. The relative efficiency shall be measured to ~1% accuracy. To achieve this requires that each line used to compute the relative efficiency have > 20,000 counts total.
3. The relative efficiency shall be measured for the following five combinations…
    a. G185M/G225M (Al/MgF_2 to Al)
    b. G225M/G285M (Al to Al)
    c. G185M/G230L (Al/MgF_2 to Al/MgF_2)

d. G225M/G230L (Al to Al/MgF_2)
e. G285M/G230L (Al to Al/MgF_2)

4. The relative efficiency shall be measured at ~ 6 month periods until launch.
5. The relative efficiency shall be measured with the COS instrument under a gaseous nitrogen (GN_2) purge, where the boil-off of liquid N_2 is the source of GN_2. The purge shall be implemented by feeding GN_2 into the instrument at opposite ends with a combined flow rate of ~20 scfh (standard cubic feet per hour). This requirement is based on past measurements that indicate this is a sufficient purge to provide high transmission of the NUV light.

   It is assumed that the instrument has been under continuous GN2 purge prior to this test, albeit at a lower flow rate. If this is the case then there is no need to purge the instrument for an extended period of time prior to initiating this test. If this is not the case, the instrument should be purged for ~24 hours prior to running this test.

3. MONITORING TEST PLAN

3.1 DATA ACQUISITION

The configurations and exposure times for the efficiency stability measurements are shown in the table below. These data may be acquired either through real-time command scripts or using an SMS. The PtNe lamp current for each exposure should be MEDIUM.

Table 3.1
COS Instrument Configurations for Relative Efficiency Monitoring

Channel	Central λ (Å)	Exposure Time (sec)
G185M	1986	> 2 x 300
G185M	2010	> 2 x 300
G225M	2186	> 2 x 300
G225M	2217	> 2 x 300
G225M	2390	> 2 x 300
G225M	2410	> 2 x 300
G285M	2617	> 2 x 300
G285M	2637	> 2 x 300
G230L	2635	> 2 x 300
G230L	3360	> 2 x 300

Total exposure time for the test is 6000 seconds (~1.7 hours). *The test shall conducted by acquiring a single 300 second exposure for each setting and then repeating the entire sequence, thus providing a total of 600 seconds of data*. The rationale for running two 300 second observations versus a single 600 seconds is to decouple potential variations in spectral content of the lamps with run time. There is a better chance of detecting any variation in the lamp with two non-continuous measurements, rather than a single extended exposure, should the lamp vary with time.

The exposure times are estimates based on results acquired during testing in a vacuum enviroment. These exposure times should be reviewed after the procedure is run for the first time with COS in a GN2 environment and updated if required.

It should be noted that this test will result in an additional 6.8 hours of run time for the PtNe wavelength calibration lamps onboard COS. At this time we do not believe that this represents a significant risk, as this represents ~1% of the expected on-orbit usage of the lamps.

3.2 DATA ANALYSIS AND MONITORING

The data described above must be reduced to compute the relative efficiency. Each NUV data set contains three spectral stripes that are not contiguous in wavelength. The table below and Figure 1 show the Channel, central wavelength, spectral stripe to be extracted, bandpass of the extracted stripe, and the band-pass of the spectra to be used to monitor the relative efficiencies.

Table 3.2
Spectral Information for Monitoring Relative Efficiency

Channel	Central λ (Å)	Spectral Stipe/Bandpass	Test Band-pass (Å)
G185M	1986	C / 2074.9 – 2110.3 Å	2093-2105
G185M	2010	C / 2092 – 2127 Å	2125-2130
G225M	2186	A / 2070 – 2105 Å	2093-2105
G225M	2217	A / 2098.3 – 2134.9 Å	2125-2130
G225M	2390	C / 2468.3 – 2501.1 Å	2485-2500
G225M	2410	C / 2494 – 2527 Å	2497-2516
G285M	2617	A / 2480 – 2521 Å	2485-2500
G285M	2637	A / 2488.4 – 2532.5 Å	2497-2516
G230L	2635	B / 2435 - 2834 Å	2478-2533
G230L	3360	A / 2059 – 2458 Å	2089-2135

The analysis of the data is straightforward. The relative efficiency is computed by dividing the total counts in a given line acquired with one grating by the counts for the same line measured with a different grating. The relative efficiency and associated statistical error are computed as shown below.

$$\varepsilon_\lambda = \frac{R_{grating1,\lambda}}{R_{grating2,\lambda}}$$

$$\sigma_\varepsilon = \varepsilon_\lambda \sqrt{1/C_{grating1,\lambda} + 1/C_{grating2,\lambda}}$$

where $R_{grating1,\lambda}$ and $R_{grating2,\lambda}$ correspond to the count rates within a line of wavelength λ or fixed bandpass as measured with grating1 or grating2 respectively. $C_{grating1,\lambda}$ and $C_{grating2,\lambda}$ are the total counts in the lines used to calculate the relative efficiency. The count rates and counts in the line are background subtracted values. It is anticipated that the background rates will be sufficiently low that their contribution to the error is insignificant and can be ignored. This assumption should be verified for each test.

Seven relative efficiencies shall be computed for each data set. Those relative efficiencies are shown below. The subscript on the channel shows the stripe to be used. The value within the parenthesis is the wavelength setting for the channel.

ε_1 = G185M_C(1986Å) / G225M_A(2186Å)
ε_2 = G185M_C(2010Å) / G225M_A(2217Å)
ε_3 = G225M_A(2390Å) /G285M_C(2617Å)
ε_4 = G225M_A(2410Å) / G285M_C(2637Å)
ε_5 = G185M_C(2010Å) / G230L_A(3360Å)
ε_6 = G225M_A(2217Å) / G230L_A(3360Å)
ε_7 = G285M_A(2637Å) /G230L_B(2635Å)

These relative efficiencies will monitor the relative performance of Al vs Al/MgF_2, Al vs Al, and Al/MgF_2 vs Al/MgF_2.

The relative efficiencies computed using G230L data require a note of clarification. The disparity in resolution between the M and L gratings makes it difficult to uniquely identify specific wavelengths for comparison. Therefore, for ε_5, ε_6, and ε_7 were computed by comparing the total number of counts in the spectral stripe for the M gratings against a similar, but not exact, bandpass in the L grating. This is evident in the bandpasses listed for ε_5, ε_6, and ε_7, which are somewhat larger than the spectral stripes used.

4. BASELINE MEASUREMENTS

Table 4.1
Baseline Relative Efficiencies

Ratio	Band-pass (Å)	ε	σ_ε
ε_1	2093-2105	1.443	0.012
ε_2	2125-2130	1.195	0.012
ε_3	2485-2500	1.420	0.012
ε_4	2497-2516	1.250	0.012
ε_5	2089-2135	4.625	0.048
ε_6	2089-2135	3.262	0.035
ε_7	2478-2533	4.588	0.046

For reference, the baseline measurements listed above were computed from the following data sets acquired during final calibration. In six cases two data sets were acquired to get sufficient counts to meet the accuracy goal of ~1%. For those cases the spectra were cross-correlated prior to adding the spectra to eliminate potential variations in the wavelength scale due to OSM1 or OSM2 errors. The relative efficiency numbers based on G230L data have a larger error due a shorter net exposure time and thus fewer counts.

Table 4.2
Baseline Relative Efficiency Data

File	Grating/central λ	Exposure Time (s)
CSIL03266023423_1_rawtag.fits	G185M/1986	120
CSIL03266044935_1_rawtag.fits	G185M/2010	120
CSIL03266121900_1_rawtag.fits	G225M/2186	120
CSIL03266103736_1_rawtag.fits	G225M/2217	120
CSIL03266120206_1_rawtag.fits	G225M/2390	120
CSIL03266132636_1_rawtag.fits	G225M/2410	120
CSIL03266212736_1_rawtag.fits	G285M/2617	120
CSIL03266194612_1_rawtag.fits	G285M/2637	120
CSIL03291125625_1_rawtag.fits	G185M/1986	480
CSIL03291130525_1_rawtag.fits	G185M/2010	480
CSIL03291131453_1_rawtag.fits	G225M/2186	480
CSIL03291132354_1_rawtag.fits	G225M/2217	480
CSIL03291133254_1_rawtag.fits	G225M/2410	480
CSIL03291134154_1_rawtag.fits	G285M/2637	480
CSIL03267064458_1_rawtag.fits	G230L/2635	60
CSIL03267084734_1_rawtag.fits	G230L/3360	60

5. CURRENT STATUS

The above data can be considered the baseline measurements for relative efficiency between the Al and Al/MgF_2 coated gratings. Subsequent measurements will be made in a GN2 environment during extended storage at GSFC. Prior to the beginning of long-term storage these measurements should be made again and followed approximately every 6 months.

All data collected specifically to track long-term degradation of the NUV gratings shall be delivered to the Principal Investigator, Prof. James C. Green at University of Colorado for analysis and interpretation.

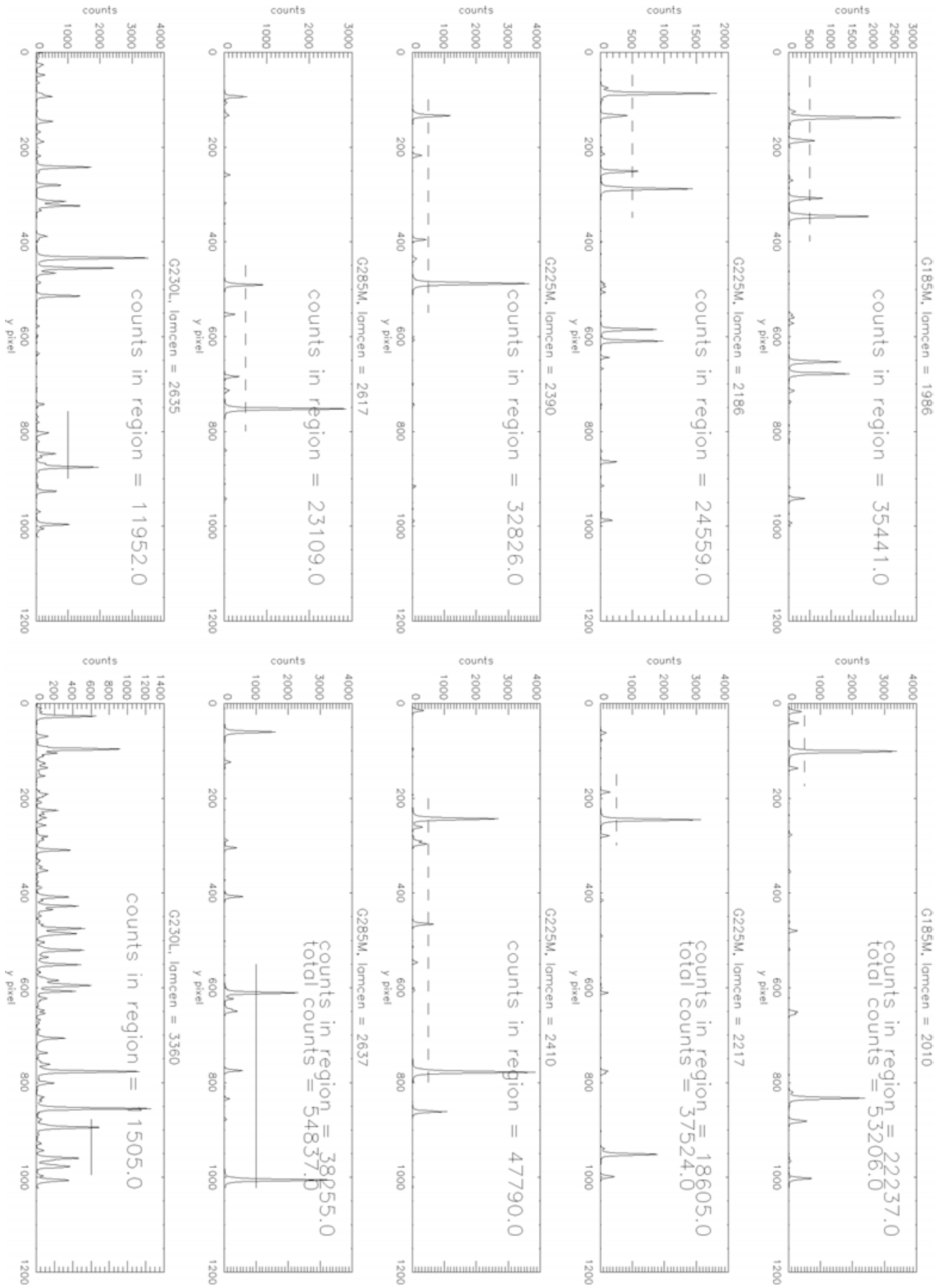

Figure 1: Spectra used to calculate the relative efficiencies. The dashed line indicates the band-passes used to compute the relative efficiencies. The "counts in the region" denotes the number of events with the highlighted bandpasses.