FOS Wavelength Calibration Exposures

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Abstract

Optimal use of the internal calibration lamps for FOS wavelength calibration is discussed. Revised exposure times and lamp selection rules, based on new lab calibration data and recent detector exposure limit analysis, are presented.

I. Introduction

A general strategy for using the internal Pt/Cr–Ne hollow cathode lamps to perform wavelength calibrations for all FOS disperser/aperture/detector configurations has been developed by Sirk and Bohlin (1986a,b). Exposure times and lamp selection rules (direct or cross-strapped) were proferred in CAL/FOS–028 (Bohlin and Sirk, 1986), based on the lab calibration data available at that time. Since 1986, the FOS has undergone significant hardware changes, including replacement of the red detector with a digicon having considerably greater red response, and realignment of the optical train. These changes resulted in much higher count rates in the neon lines which dominate the red spectrum of the cal lamps. This report presents a revised set of exposure times and lamp selection rules, in accord with the latest calibration data and the FOS detector exposure limit analysis given by Hartig (1988). Calibration lamp operation time and overlight protection limits are also discussed.

The exposure times for all science apertures are estimated from lab observations of the direct and cross-strapped cal lamp spectra through the A4 (0.1 arcsec pair) apertures. Relative aperture areas are taken from Lindler, Bohlin and Hartig (1985), and linearity corrections and line blending effects are included. Because the detector count rate saturates at about 70,000 cts/s/diode, the minimum exposure required to obtain the requisite 30,000 cts in the brightest line peaks is about 2 s. All spectra are to be obtained with 5 channel overscanning and 4 X-steps (the standard ACCUM mode parameters). Paired aperture exposure times include both Y-steps; special observations of only the upper or lower aperture require half the quoted time.

II. Small Aperture Template Spectra Exposures

FOS wavelength calibration will generally be performed by cross-correlating spectra obtained with the internal lamps through the aperture used for the science observations, with high quality internal lamp spectra obtained with a small aperture of the same type (lower, single, or upper). These high quality template spectra present minimal line blending and noise and can be very accurately calibrated. Lower quality spectra, requiring significantly less exposure (and cal lamp operation time), can then be used to yield accurate wavelength calibrations, with the cross-correlation technique. The template spectra will need to be obtained only infrequently during the FOS lifetime; after the initial SV observations, a complete set of these spectra should be scheduled on an approximately bimonthly basis.

The proper total exposure times in seconds are indicated in Table 1, for all standard FOS configurations. These have been selected to assure that sufficient counts will be registered in enough lines over the full spectral range covered by each disperser and that digital counter overflow does not occur for any line. In the case of the prism, two exposures are required to meet these criteria, because of the disparity in brightness of the UV lines and the very strong red neon lines combined with the rapid decrease in dispersion toward the red (line blending).

In some cases, the 0.25-PAIR apertures are used instead of the 0.1-PAIR, in order to reduce relatively long exposures to more tractable integration times. The 0.25-PAIR spectra have only slightly lower spectral resolution, so the wavelength calibration accuracy does not degrade in comparison to that for the smaller apertures.

On the red side, the cross-strapped (blue) lamp is used for the long wavelength dispersers, to reduce the neon line fluxes from the very high levels produced by the direct lamp. This results in much smaller paired-pulse corrections and a greater degree of photocathode safety (Hartig, 1988), although the exposures are somewhat lengthened.

The total lamp operation time required to perform a complete set of template spectra can be estimated from Table 1, adding approximately 10s of overhead (lamp warm-up and command execution time padding) for each exposure. The blue lamp is used for about 70 % of the exposure time, accruing 1484 s of operation time per set, while the red lamp is operated for 622 s. Several thousand sets of template spectra would be obtainable if the cal lamps perform for the same operation lifetime (1100 hrs.) of a similar lamp tested in the lab at JHU (Hartig, 1982). The actual requirement is estimated at a few hundred such sets over the FOS mission lifetime.

The maximum overlight sum required for *continuous* cal lamp operation for any of these exposures is 10^8 cts (prism/0.3 aperture/blue side). Because the exposures are short compared to the 60 s summing interval, the actual required overlight limit is considerably smaller, depending on the actual lamp operation time and the deadtime fraction (see below).

III. Standard Wavelength Calibration Exposures

Tables 2 and 3 prescribe the total exposure times for internal wavelength calibration spectra, typically obtained through the same aperture as the target, consecutive with the science observations. Shorter exposures than for the template spectra are tolerable. The

normal (direct) cal lamp may be used for all configurations on the blue side, but detector safety and calibration accuracy considerations require that the cross-strapped lamp be used on the red side for certain disperser/aperture combinations, as indicated in Table 2.

Grating G160L presents a special case, because of its efficient zero-order diffraction. The UV spectral lines of interest are relatively weak, requiring long calibration exposures, while the zero order image is dangerously bright when the direct cal lamp is used, for all but the smallest apertures. Because the small aperture exposures would be prohibitively long with the cross-strapped lamp, the direct lamp is specified (as for the template spectra) for apertures smaller than 0.5 arcsec; larger apertures require the cross-strapped lamp.

The exposure times for most configurations are generally smaller than those specified for the template exposures; however, wavelength calibration spectra required for observations through the smallest (A4, 0.1 arcsec) aperture pair and the UV gratings can be particularly long. The recommended exposure for the G130H grating with the A4 aperture pair (blue side) is 960s, nearly half of the total exposure time for an entire set of template spectra! (Note that if only one aperture of the pair is actually used for the observation, i.e. STEP-PATT is set to SINGLE, this exposure time should be halved.) However, the need for these long exposures is limited; a large majority of FOS programs will not require that special wavelength calibration spectra be obtained with the science observations, but will rely on the standard wavelength scales determined from the previous template spectra. This scenario is likely to change only if the filter-grating wheel or aperture wheel repeatabilty degrades significantly from current performance, or other sources of unpredictable image drift appear. The expected cal lamp lifetime will probably not be approached, but care should be taken to conserve lamp operation time.

The maximum overlight sum limit required to prevent safing for *continuous* cal lamp operation is approximately 10^9 cts, for the G270H/C3 aperture/blue side/direct cal lamp configuration. Many other configurations require limits in the range of several times 10^8 (Hartig, 1988). Because these large overlight limits occur for the cases which require only very short (typically a few seconds) exposure time, the actual overlight sum reached will depend on how long the cal lamp must be operated for such short exposures. The current strategy is to permit a lamp stabilization time of 10 s prior to the start of integration, and the cal lamp is left on until after the data are dumped to the spacecraft computer, which can add nearly a minute of lamp operation time. This is wasteful of both lamp and detector lifetime (which are not unlimited), and should be changed as soon as possible. The lamp stabilization time can be shortened, since wavelength calibration is insensitive to absolute flux levels and the line spectrum appears immediately upon lamp turn-on. It should be possible to turn off the lamp shortly after the planned integration interval, rather than waiting for the data dump to finish. With these changes implemented, the minimum lamp operation time should be reduced to about 12 s.

References

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Table 1a

FOS Red Side Wavelength Calibration Template Exposures

Aperture	G190H	G270H	G400H	G570H[c]	G780H[c]	G160L	G650L[c]	PRISM[ac]
0.1-PAIR [b]	—	144	32	40	48	—	48	—
0.25-PAIR [b]	120	—	—	—	—	120	—	8/100
0.3	56	10	4	6	8	56	6	4/44

Table 1b

FOS Blue Side Wavelength Calibration Template Exposures

Aperture	G130H	G190H	G270H	G400H	G570H	G160L	G650L	PRISM[a]
0.1-PAIR [b]	—	—	60	16	—	—	28	8/80
0.25-PAIR [b]	320	56	—	—	36	56	—	—
0.3	150	24	4	4	16	24	4	2/4

[a] Two exposures are required to adequately calibrate the prism. A long exposure is used to obtain sufficient flux in the UV lines, while a short integration must be used to prevent counter overflow in the strong, blended neon lines.

[b] To keep template exposure times under 3 minutes, the 0.25-PAIR apertures are used for some dispersers, reducing exposures by a factor of .16.

[c] Use the cross-strapped (blue) calibration lamp.

Table 2

FOS Red Side Standard Wavelength Calibration Exposures

Aperture	G190H	G270H	G400H	G570H[b]	G780H[b]	G160L	G650L[b]	PRISM[b]
0.1-PAIR	256[a]	64[a]	16[a]	20[a]	24[a]	320[a]	24[a]	20
0.25-PAIR	56[a]	24	8	12	16	60[a]	12	8
0.5-PAIR	32	8	4	8	8	80[b]	4	4
1.0-PAIR	16	4	4	4	4	24[b]	4	4
0.3	24[a]	10	4	6	8	28[a]	4	4
0.5	20	5	2	4	4	48[b]	2	2
1.0	8	2	2	2	2	16[b]	2	2
0.25x2.0	10	3	2	2	2	24[b]	2	2
0.7x2.0-BAR	8	2	2	2	2	12[b]	2	2
2.0x2.0-BAR	6	2	2	2	2	10[b]	2[c]	2[c]

[a] These exposures have been reduced by up to a factor of 2.5 from optimum to avoid integration times that are unnecessarily longer than 32 s.

[b] Use the cross-strapped (blue) calibration lamp.

[c] Cross-correlation technique not recommended for optimal wavelength calibration.

Table 3

FOS Blue Side Standard Wavelength Calibration Exposures

Aperture	G130H	G190H	G270H	G400H	G570H	G160L	G650L	PRISM
0.1-PAIR	960[a]	176[a]	32[a]	16	80[a]	200[a]	28	8
0.25-PAIR	128[a]	32[a]	8	8	32	32[a]	8	4
0.5-PAIR	60	16	4	4	12	16	4	4
1.0-PAIR	16	12	4	4	8	8	4	4
0.3	60	24	4	4	16	24	4	2
0.5	30	12	2	2	8	8	2	2
1.0	12	6	2	2	4	4	2	2
0.25x2.0	24	6	2	2	4	6	2	2
0.7x2.0-BAR	12	6	2	2	4	4	2	2
2.0x2.0-BAR	10	4	2	2	4	4	2	2

[a] These exposures have been reduced by up to a factor of 2.5 from optimum to avoid integration times that are unnecessarily longer than 32 s.