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TITLE: FOS Line Widths (FWHM) as a Function of Aperture Size

AUTHOR: Anne L. Kinney and Holland C. Ford

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ABSTRACT

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G. Hartig
R. Bohlin
M. Sirk
J. Wheatley

FOS Line Widths (FWHM) as a Function of Aperture Size

A.L. Kinney and H.C. Ford

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Introduction and Summary:

When observing extended sources such as galaxies and nebulae which fill the FOS entrance aperture, the line profile will be a function of the aperture size. We have characterized the line widths for the ten entrance apertures on the red and the blue sides by measuring the FWHM of emission lines in spectra of an external calibration source taken during the last FOS thermal-vacuum calibration at Martin Marietta.

The FWHM's are approximately equal to the aperture size used in the observation. The widths do not appear to vary when different gratings are used, and the asymmetry for lines on the edge of the diode array as shown by a ray trace, appear negligible. For the smallest aperture, 80% of the light in the line falls within a width of one diode.

Results:

In general the FWHM of emission lines for all apertures are approximately equal to the aperture size, for both the red and the blue tube. There are, however, several exceptions to this rule.

First, when an aperture is smaller than a diode, the FWHM is about the width of a diode, or 0.″36. This holds for the smallest circular and square apertures, as can be seen in Table 1. Second, circular apertures have smaller FWHM than their square counterparts because of the relative areas. This can be seen by comparing the circular and square apertures of comparable size. Finally, the FWHM of lines taken with the largest aperture are smaller than the aperture size of 2.″0. Instead of being flat topped, these lines are sloping, which implies that the illumination was not evenly distributed over the entrance aperture. This is the most likely cause of the relatively small FWHM for the 2.″0 aperture.

The widths of the emission lines do not appear to depend on the grating used. For the 0.″25 aperture with the blue tube, FWHM has been measured for several gratings (H13, H19, H40, H57, L15, and L65) and the prism. Two of these cases (L15 and the prism) have larger measured FWHM than expected from the 0.″25 aperture size. In each case, however, there are practically no well separated lines in the spectrum, so the larger FWHM are very likey due to the mixing of lines.

A ray trace of FOS has shown that a certain amount of asymmetry can be expected in line profiles for lines near the edge of the diode array (see *ST End to End Optical Performance Analysis*, ST/SE-24, Section F, page 7-3). On close inspection of well separated lines near the diode array edge, it appears that this asymmetry may give a small contribution to the broad, low level wings, but has a negligible affect on the FWHM.

The best present estimate of the percentage of light from the 0.″1 aperture that falls into one diode is 80%.

In order to analytically characterize the extended wings of the FOS line profiles, we have fit a pseudo Voigt function to the Hg 2537Å line profile (Blue side, aperture A4, grating H27) given by Sirk and Bohlin (1985; plot YAZ0322). The pseudo Voigt function is given by equations (1) and (2).

$$V(x,\gamma,w) = y_o \left\{ \left[1 - \frac{\gamma}{w}\right] \exp\left[-\ln 2\left(\frac{x-x_o}{w}\right)^2\right] + \left[\frac{\gamma}{w}\right] \left[\frac{1}{1+\left(\frac{x-x_o}{w}\right)^2}\right] \right\} \qquad (1)$$

$$w = \frac{\gamma}{2} + \left(\frac{\gamma^2}{4} + 2\,(\ln 2)\,\sigma^2\right)^{\frac{1}{2}} \qquad (2)$$

The quantity y_o is the amplitude of the function (height of the line), γ is a parameter which characterizes the Lorentzian wings, σ is a parameter which characterizes the Gaussian core, and $x - x_o$ is the distance from the line center in diodes. In the limit that γ goes to zero, the function becomes a pure Gaussian as given by equation 3.

$$G(x,\sigma) = y_o \exp\left(\frac{-(x-x_o)^2}{2\sigma^2}\right) \qquad (3)$$

The parameters of a good fit to the Hg 2537Å line are $\sigma = 0.30$ and $\gamma = 0.07$. These parameters give values which are within 25% of the observed line profile out to 20 diodes from the line center. The Hg 2537Å and Hg 5460Å line profiles are very similar to one another, and the profiles of the same comparison line on the red and blue sides are quite similar. Consequently, the pseudo Voigt function with the above parameters can be used as a first approximation for the (small aperture) line profile everywhere.

Table 1

FOS Line Widths (FWHM) as a Function of Aperture Size

Designation	Size (″)	H13 (Blue)	H57 (Red)
0.30 SNG	0.3 (circular)	1.00 ± .01	0.95 ± .02
0.50 SNG	0.5 (circular)	1.27 ± .04	1.20 ± .01
1.00 SNG	1.0 (circular)	2.29 ± .02	2.23 ± .01
0.10 PAIR	0.10 (square)	0.97 ± .03	0.92 ± .02
0.25 PAIR	0.25 (square)	0.98 ± .01	0.96 ± .01
0.50 PAIR	0.50 (square)	1.30 ± .04	1.34 ± .02
1.00 PAIR	1.00 (square)	2.65 ± .02	2.71 ± .02
0.25 × 2.0	0.25 × 2.0 (slit)	0.99 ± .01	0.96 ± .01
0.70 × 2.0-BAR	0.70 × 2.0	1.83 ± .02	1.90 ± .01
2.0-BAR	2.0	5.28 ± .07	5.43 ± .04

The FWHM are given in units of diodes.