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PRE-COSTAR FOS POINT SPREAD FUNCTIONS AND LINE SPREAD FUNCTIONS FROM MODELS

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Abstract

Monochromatic pre-COSTAR point spread functions for the FOS covering the wavelength range 1200–5400Å for the blue side, and 1600–8400Å for the red side, have been modeled using the TIM software. Monochromatic pre-COSTAR line spread functions for each of the non-occulting FOS apertures have been computed using the point spread function models.

I. Pre-COSTAR Point Spread Functions

Pre-COSTAR point spread functions (PSFs) were modeled using version 28.0 of the TIM software (Burrows & Hasan 1993). Twenty-two monochromatic model PSFs centered at the location of the FOS blue aperture (TIM science instrument FOS-B), and thirty-five monochromatic model PSFs centered at the location of the FOS red aperture (TIM science instrument FOS-R) were computed using the default aberrations and nominal focus for the date June 1, 1993. The values of the non-zero Zernike polynomial wavefront errors for each wavelength are given in Table 1. The monochromatic PSFs were computed for wavelengths every 200Å from 1200Å to 5400Å for the FOS blue side, and every 200Å from 1600Å to 8400Å for the FOS red side. The effects of dust and mirror microroughness were included in the PSF models, using the default TIM model parameters for each of these effects. The parameters for dust modeling (Burrows & Hasan 1993, eq. [3.22]) were $a_{min} = 15.0\,\mu\text{m}$, $a_{max} = 100.0\,\mu\text{m}$, $f = 2.5\%$, and $\xi = -4.5$. A fractal mirror defect model was used, with parameters (Burrows & Hasan 1993, eqs. [3.11, 3.12, 3.13]) $\beta = -2.50$, $\delta_e = 0.00100$, $d_2 = 0.20000\,\text{mm}$, and $d_1 = 0.02000\,\text{mm}$. Pointing jitter with an RMS value of 7 mas was included, to simulate the effects of fine lock on the telescope PSF.

The model point spread functions were sampled using a pixel size of 5.578125 mas ($\sim 0.780157\mu$m) in the FOS X-direction, and 5.5859375 mas (0.78125μm) in the FOS Y-direction. These values correspond to a sampling size of 1/64 th of a diode width in X, and 1/256 th of a diode height in Y (the latter is equal to one Y-base unit), where we have assumed that the size of a diode is exactly equal to the nominal project data base (PDB) values of 0."357 in X and 1."43 in Y (Bhattacharya & Hartig 1991, Koratkar 1993). The total sizes of the resampled model PSFs computed using TIM is 1022 × 1022 pixels (~5."70 × 5."70) for each monochromatic PSF except for the blue side PSF computed at a wavelength of 1200Å, which has a size of 946 × 946 pixels (~5."28 × 5."28). To increase the utility of the PSFs, each of the resampled PSF arrays have been symmetrically zero extended to a uniform size of 1024 × 1024 pixels. The full set of model PSFs will be made available to the community through the *HST* data archive. See Figures 1 and 2 for a sample of the PSFs.

II. Pre-COSTAR Line Spread Functions

Both blue side and red side Pre-COSTAR FOS monochromatic spectral line spread functions(LSFs) for each of the non-occulting FOS apertures have been derived from the model PSFs described above. Model LSFs were computed at the same wavelengths as the monochromatic model PSFs.

The LSFs were computed for a point source that is perfectly centered in the aperture, and have a X pixel sampling of 1/64th of a diode width, corresponding to the X pixel sampling of model PSFs. The intensity of the LSF at each X pixel position was determined by summing the individual contributions of the PSF pixels at that X pixel position, and whose Y pixel positions are included within the relevant FOS aperture. Because of the fine pixel sampling of the PSFs, no correction for the presence of fractional pixels within a given aperture was applied. The apertures were assumed to be perfectly circular in the case of the circular apertures, and perfectly rectangular with sides aligned precisely in the X and Y directions for the rectangular apertures. The aperture sizes used were obtained from the PDB (Table 2, Dressel & Harms, unpublished), except in the cases of the 4.3 and 0.25 × 2.0 apertures, where the Y extent (only) of the apertures is limited by the effective diode height and was assumed to be precisely 1″.43. It is noted here that the PDB values for the aperture areas do not agree (by up to ~40% for the blue side 0.1-PAIR and red side 0.1-PAIR-A apertures) with pre-flight measurements of Lindler, Bohlin, and Hartig (1985). Unfortunately, the latter authors provide only aperture *areas* rather than the aperture X and Y dimensions that are needed to compute LSFs.

After integrating the PSFs in the Y direction, the resulting functions were convolved with a Gaussian profile that simulates the FOS spectral instrumental profile. The FOS instrumental profile width used to construct the relevant Gaussian profile was the mean line FWHM value for the corresponding grating and detector combination obtained by Smith & Hartig (1989). These instrumental profile widths were determined by direct measurement of unblended lines from exposures of the FOS internal Pt-Cr-Ne calibration lamps. Where data for a particular grating and detector combination does not exist, the value for the same detector and the nearest (in wavelength) grating was used instead. Finally, the functions were normalized to a peak relative intensity of unity to form the LSFs. The full set of model LSFs will be made available to the community through the *HST* data archive. A subset of these LSFs are presented in Figure 3. A PostScript version of this subset is available to the community using STEIS.

References

Bhattacharya, B. & Hartig, G. 1991, FOS Instrument Science Report CAL/FOS-068
Burrows, C. & Hasan, H. 1993, Telescope Image Modelling User Manual
Dressel, L. & Harms, R. unpublished, FOS Instrument Science Report CAL/FOS-072
Koratkar, A. 1993, FOS Instrument Science Report CAL/FOS-087
Lindler, D. J., Bohlin, R. C., & Hartig, G. F. 1985, FOS Instrument Science Report CAL/FOS-019
Smith, T. E. & Hartig, G. 1989, FOS Instrument Science Report CAL/FOS-061

Table 1

Zernike Polynomial RMS Wavefront Error (Waves)

		Blue Side		
Wavelength (Å)	Z_4 (Focus)	Z_7 (X Coma)	Z_8 (Y Coma)	Z_{11} (Spherical)
1200	−5.228768	−0.101250	0.328050	−2.158650
1400	−4.481801	−0.086786	0.281186	−1.850271
1600	−3.921576	−0.075938	0.246037	−1.618987
1800	−3.485845	−0.067500	0.218700	−1.439100
2000	−3.137261	−0.060750	0.196830	−1.295190
2200	−2.852055	−0.055227	0.178936	−1.177445
2400	−2.614384	−0.050625	0.164025	−1.079325
2600	−2.413277	−0.046731	0.151408	−0.996300
2800	−2.240900	−0.043393	0.140593	−0.925136
3000	−2.091507	−0.040500	0.131220	−0.863460
3200	−1.960788	−0.037969	0.123019	−0.809494
3400	−1.845447	−0.035735	0.115782	−0.761876
3600	−1.742922	−0.033750	0.109350	−0.719550
3800	−1.651190	−0.031974	0.103595	−0.681679
4000	−1.568630	−0.030375	0.098415	−0.647595
4200	−1.493934	−0.028929	0.093729	−0.616757
4400	−1.426028	−0.027614	0.089468	−0.588723
4600	−1.364026	−0.026413	0.085578	−0.563126
4800	−1.307192	−0.025313	0.082012	−0.539662
5000	−1.254904	−0.024300	0.078732	−0.518076
5200	−1.206639	−0.023365	0.075704	−0.498150
5400	−1.161948	−0.022500	0.072900	−0.479700

Table 1 (Continued)
Zernike Polynomial RMS Wavefront Error (Waves)

	Red Side			
Wavelength (Å)	Z_4 (Focus)	Z_7 (X Coma)	Z_8 (Y Coma)	Z_{11} (Spherical)
1600	−3.921576	−0.075938	0.246037	−1.618987
1800	−3.485845	−0.067500	0.218700	−1.439100
2000	−3.137261	−0.060750	0.196830	−1.295190
2200	−2.852055	−0.055227	0.178936	−1.177445
2400	−2.614384	−0.050625	0.164025	−1.079325
2600	−2.413277	−0.046731	0.151408	−0.996300
2800	−2.240900	−0.043393	0.140593	−0.925136
3000	−2.091507	−0.040500	0.131220	−0.863460
3200	−1.960788	−0.037969	0.123019	−0.809494
3400	−1.845447	−0.035735	0.115782	−0.761876
3600	−1.742922	−0.033750	0.109350	−0.719550
3800	−1.651190	−0.031974	0.103595	−0.681679
4000	−1.568630	−0.030375	0.098415	−0.647595
4200	−1.493934	−0.028929	0.093729	−0.616757
4400	−1.426028	−0.027614	0.089468	−0.588723
4600	−1.364026	−0.026413	0.085578	−0.563126
4800	−1.307192	−0.025313	0.082012	−0.539662
5000	−1.254904	−0.024300	0.078732	−0.518076
5200	−1.206639	−0.023365	0.075704	−0.498150
5400	−1.161948	−0.022500	0.072900	−0.479700
5600	−1.120450	−0.021696	0.070296	−0.462568
5800	−1.081814	−0.020948	0.067872	−0.446617
6000	−1.045754	−0.020250	0.065610	−0.431730
6200	−1.012020	−0.019597	0.063494	−0.417803
6400	−0.980394	−0.018984	0.061509	−0.404747
6600	−0.950685	−0.018409	0.059645	−0.392482
6800	−0.922724	−0.017868	0.057891	−0.380938
7000	−0.896360	−0.017357	0.056237	−0.370054
7200	−0.871461	−0.016875	0.054675	−0.359775
7400	−0.847908	−0.016419	0.053197	−0.350051
7600	−0.825595	−0.015987	0.051797	−0.340839
7800	−0.804426	−0.015577	0.050469	−0.332100
8000	−0.784315	−0.015188	0.049207	−0.323797
8200	−0.765185	−0.014817	0.048007	−0.315900
8400	−0.746967	−0.014464	0.046864	−0.308379

Table 2

Aperture Dimensions In Arc Seconds

Aperture Designation	Blue Side		Red Side	
	X-size/Diameter	Y-size	X-size/Diameter	Y-size
4.3	4″.3053833	1″.43	4″.3056113	1″.43
1.0-PAIR	1″.0012519	1″.0012519	1″.0013050	1″.0013050
0.5-PAIR	0″.50062596	0″.50062596	0″.50065248	0″.50065248
0.25-PAIR	0″.24576184	0″.24576184	0″.24577486	0″.24577486
0.1-PAIR	0″.10012519	0″.10012519	0″.10013050	0″.10013050
0.25x2.0	0″.24576184	1″.43	0″.24577486	1″.43
1.0	1″.0012519		1″.0013050	
0.5	0″.50062596		0″.50065248	
0.3	0″.30037558		0″.30039149	

Table 3

Spectral Instrumental Profile Widths In Diodes

Grating	Blue	Red
G130H	0.916	
G190H	0.916	1.023
G270H	0.940	0.999
G400H	0.997	0.998
G570H	0.932	0.943
G780H		1.006

Figure Captions

Fig. 1 — Sample blue side monochromatic FOS PSFs. Upper left: 1400Å, upper right: 2000Å, middle left: 2800Å, middle right: 4000Å, lower left: 5000Å.

Fig. 2 — Sample red side monochromatic FOS PSFs. Upper left: 2000Å, upper right: 2800Å, middle left: 4000Å, middle right: 5600Å, lower left: 7400Å.

Fig. 3 — Monochromatic FOS LSFs. Each panel is identified by detector and aperture id. LSFs at five wavelengths are presented.

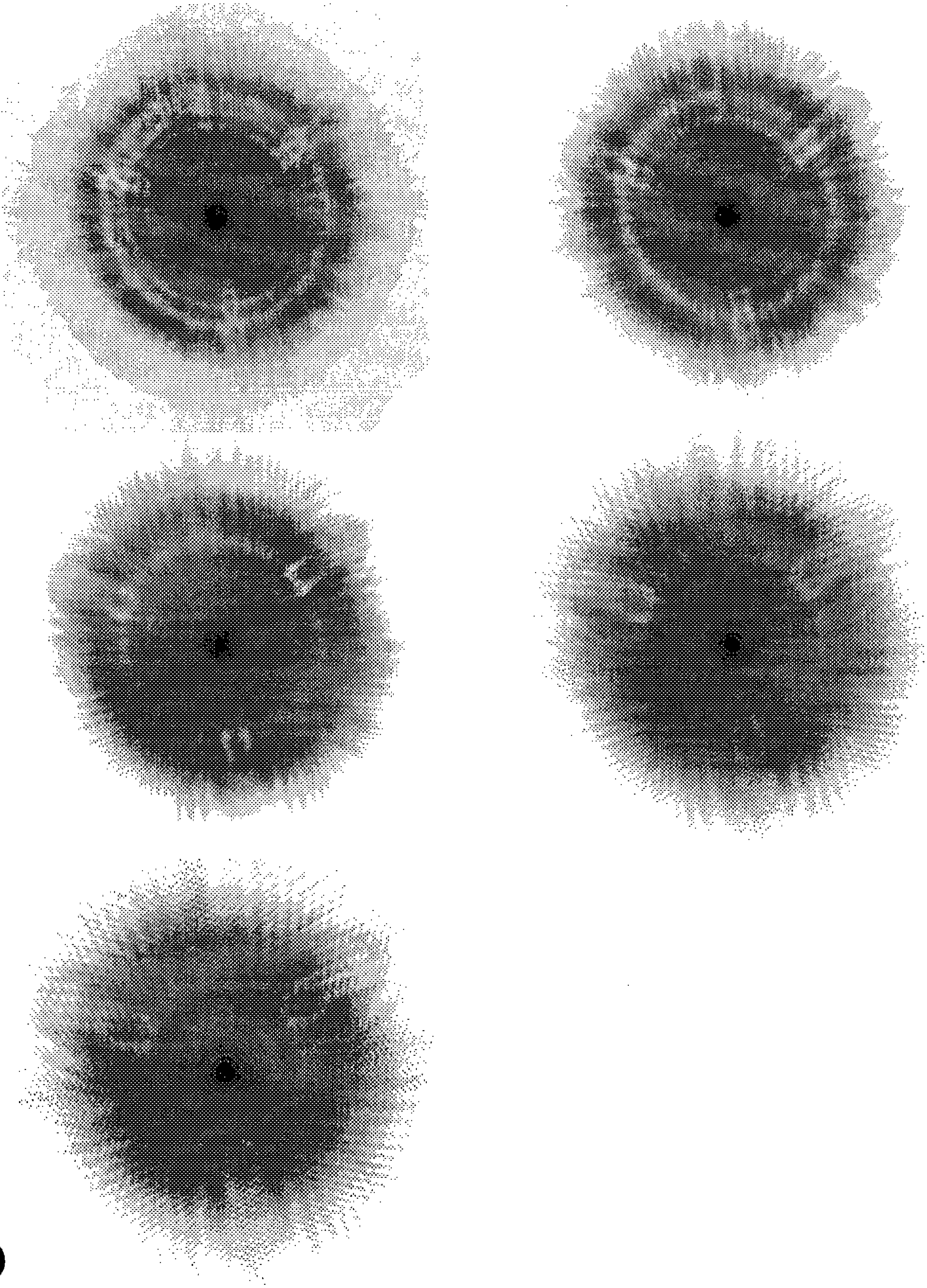


Figure 1

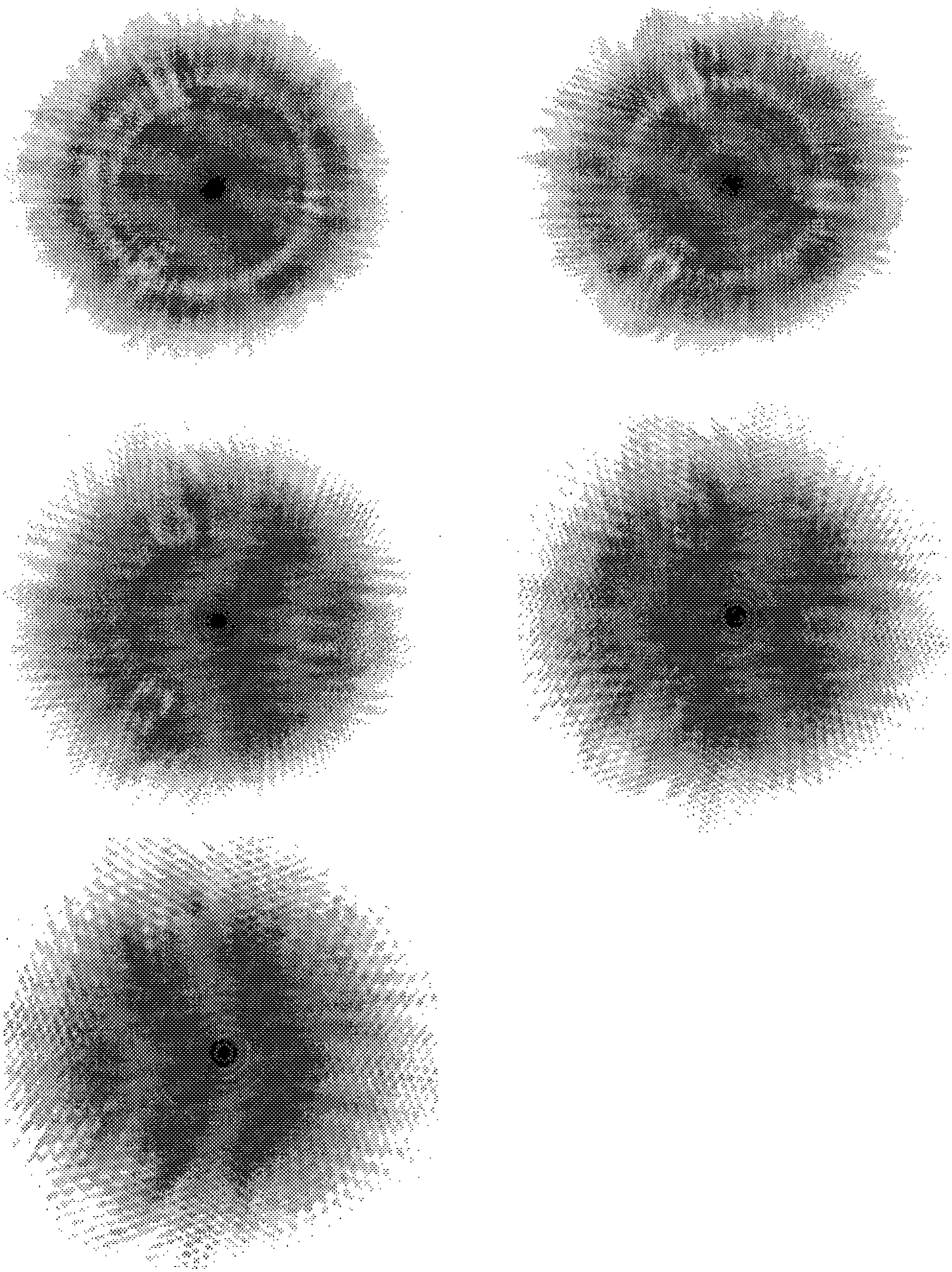
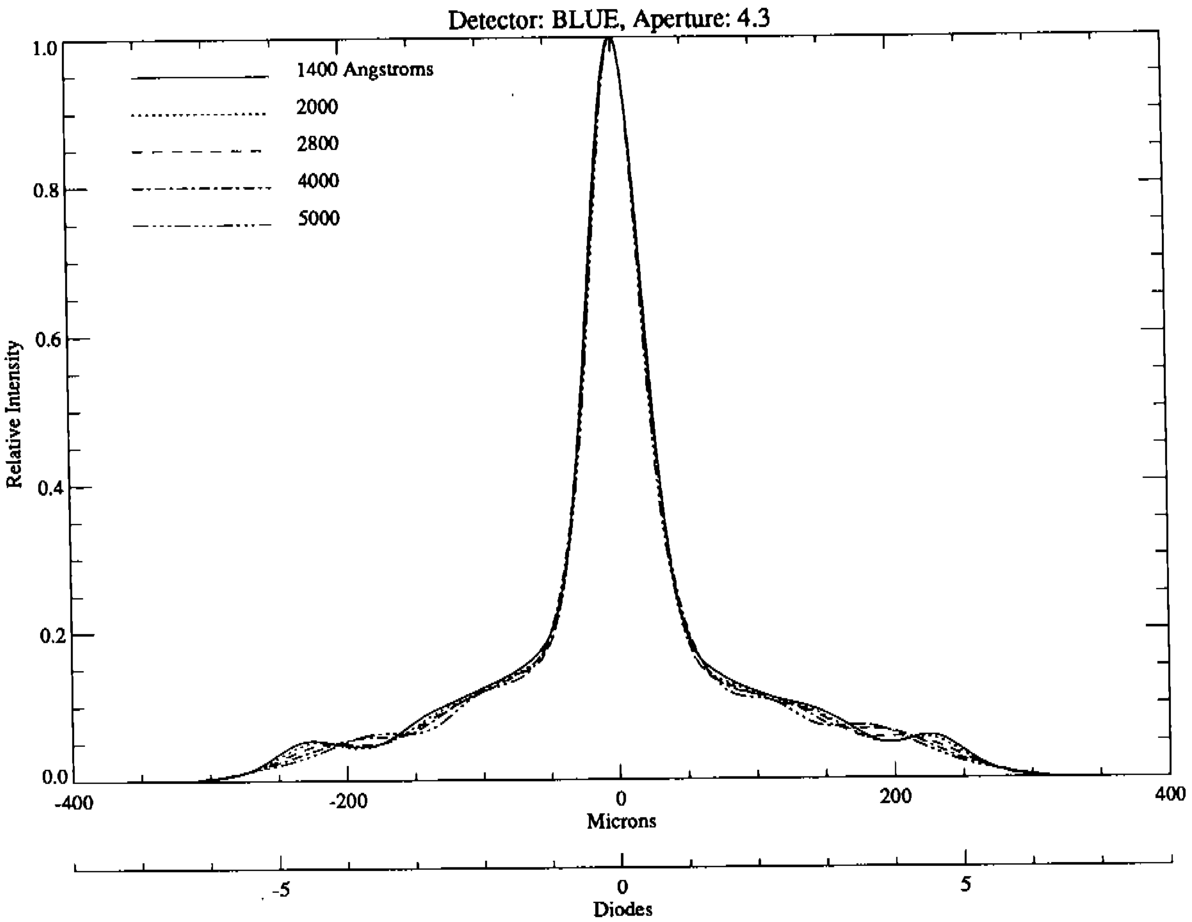


Figure 2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2800
4000
5000
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1.0
-400
-200
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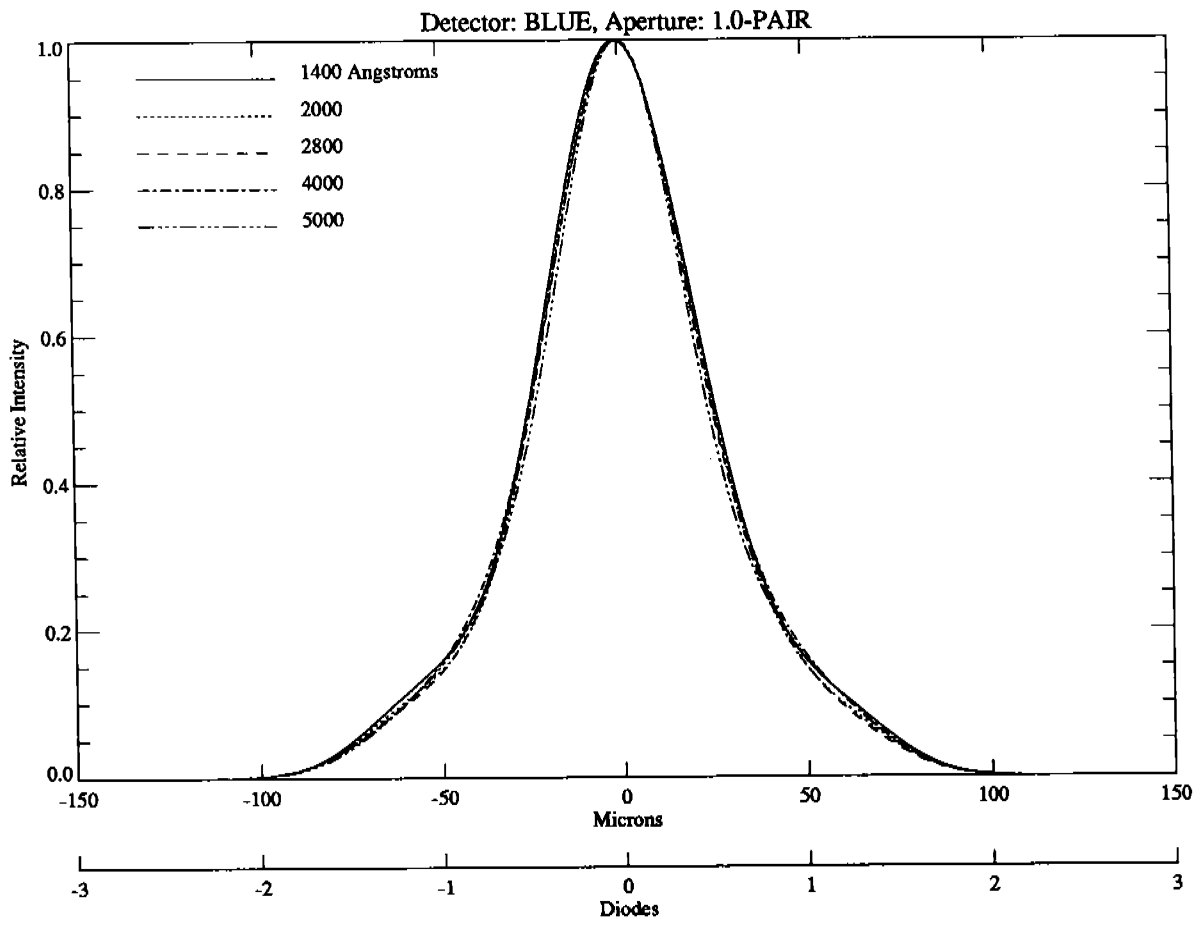
200
400
Microns
-5
0
5
Diodes


Detector: BLUE, Aperture: 1.0-PAIR
1400 Angstroms
2000
2800
4000
5000
Relative Intensity
0.0
0.2
0.4
0.6
0.8
1.0
-150
-100
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0
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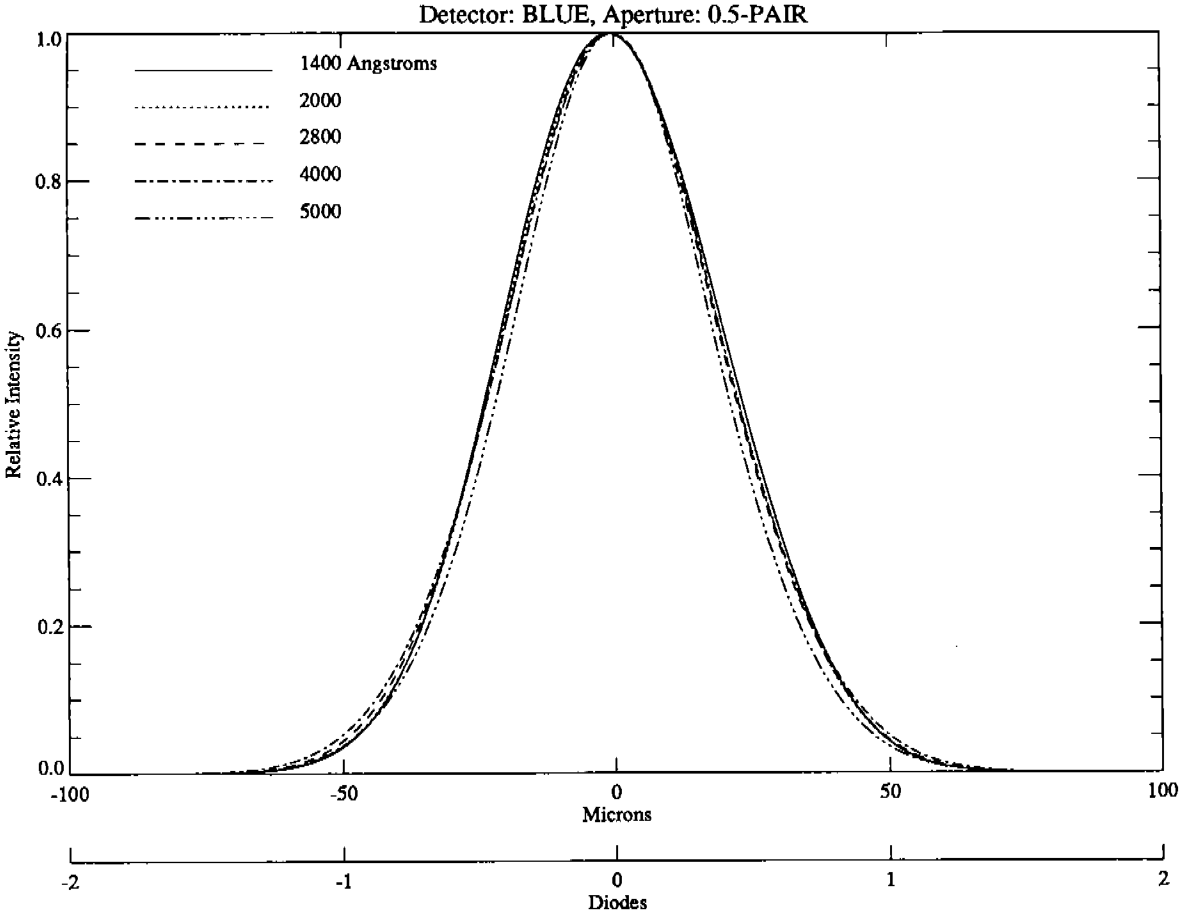
100
150
Microns
-3
-2
-1
0
1
2
3
Diodes

Figure 3



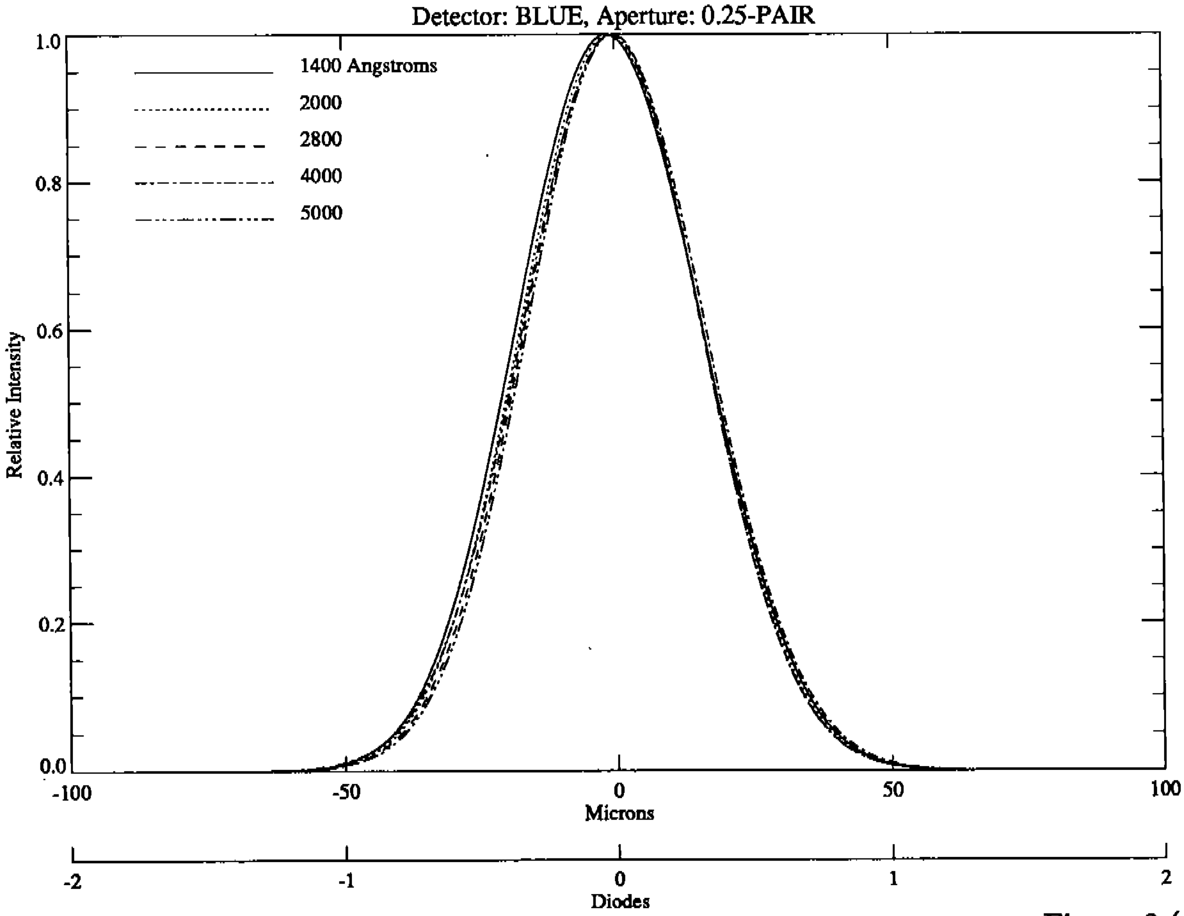
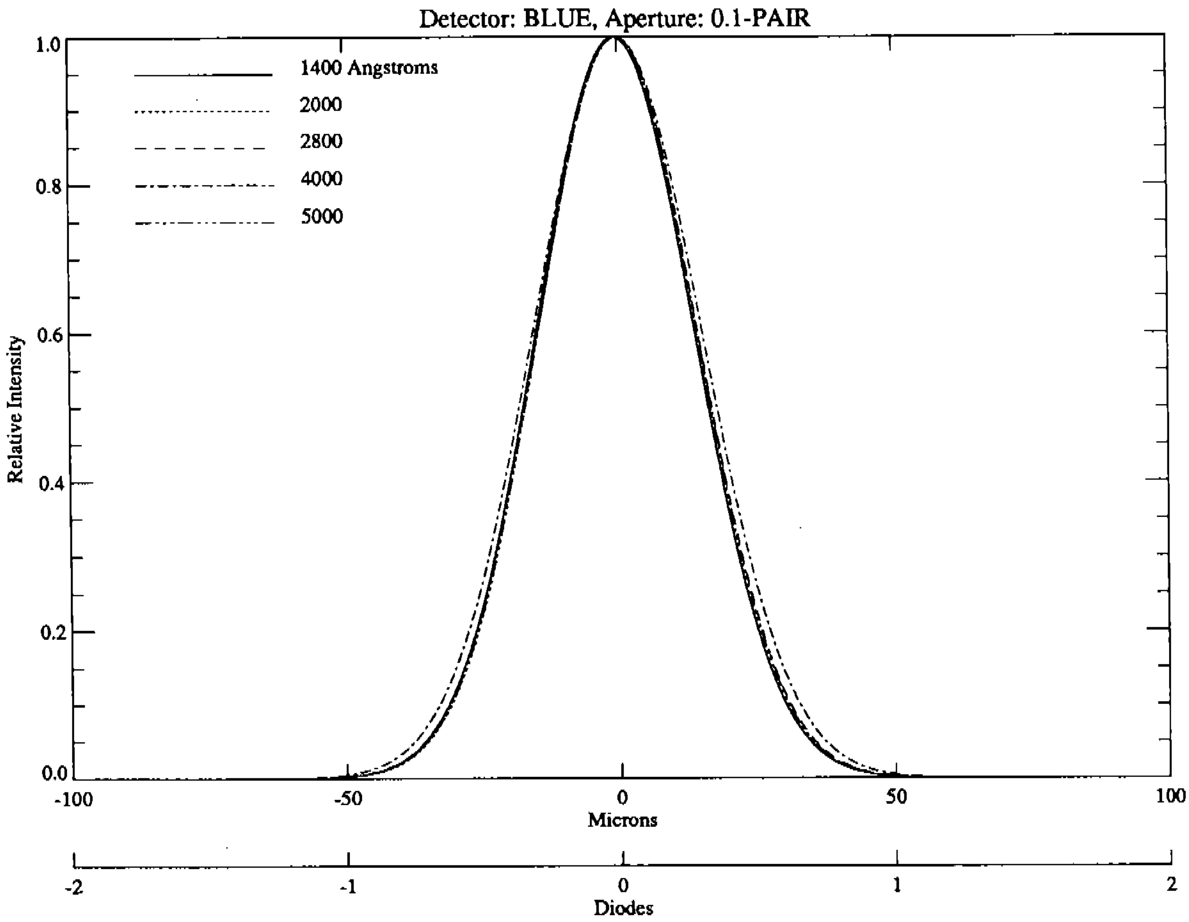
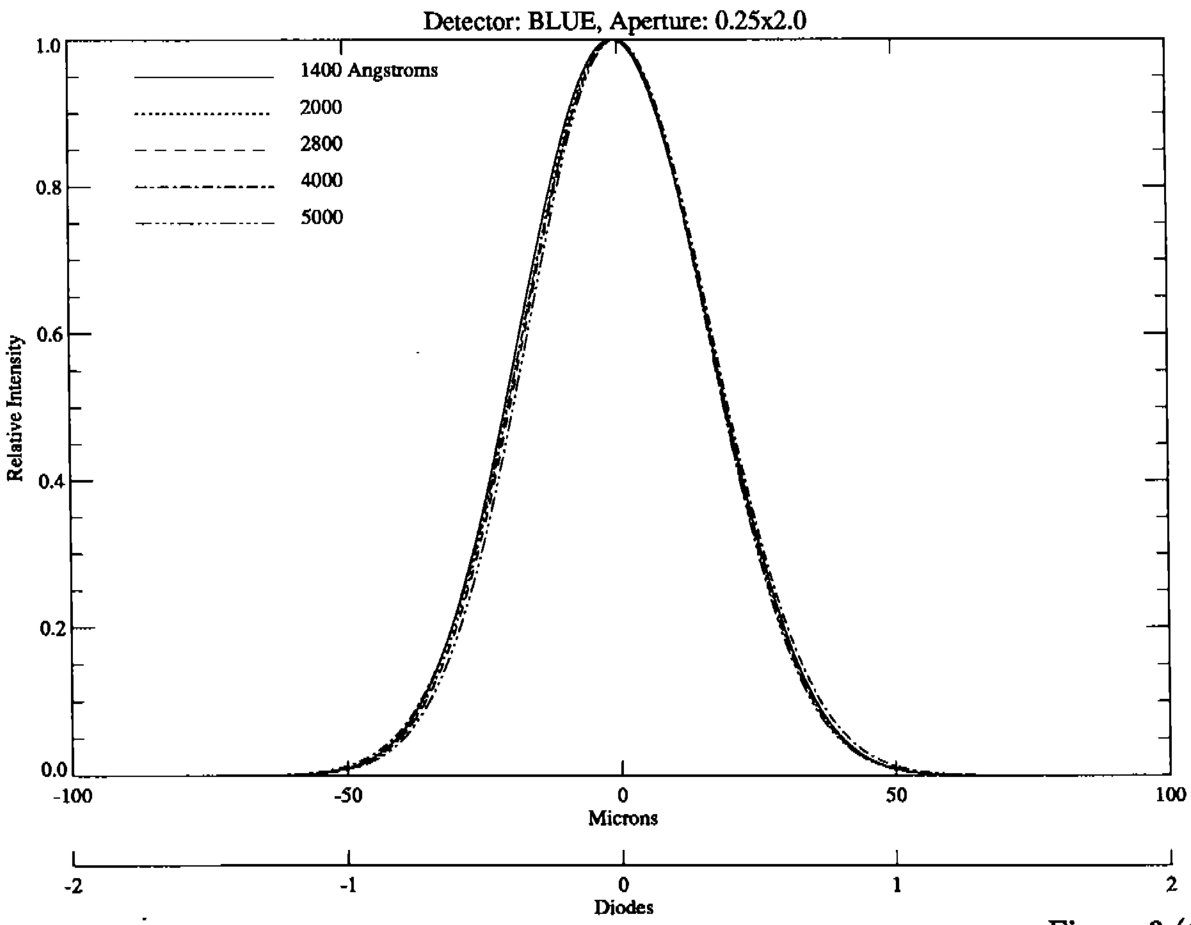


Figure 3 (Continued)





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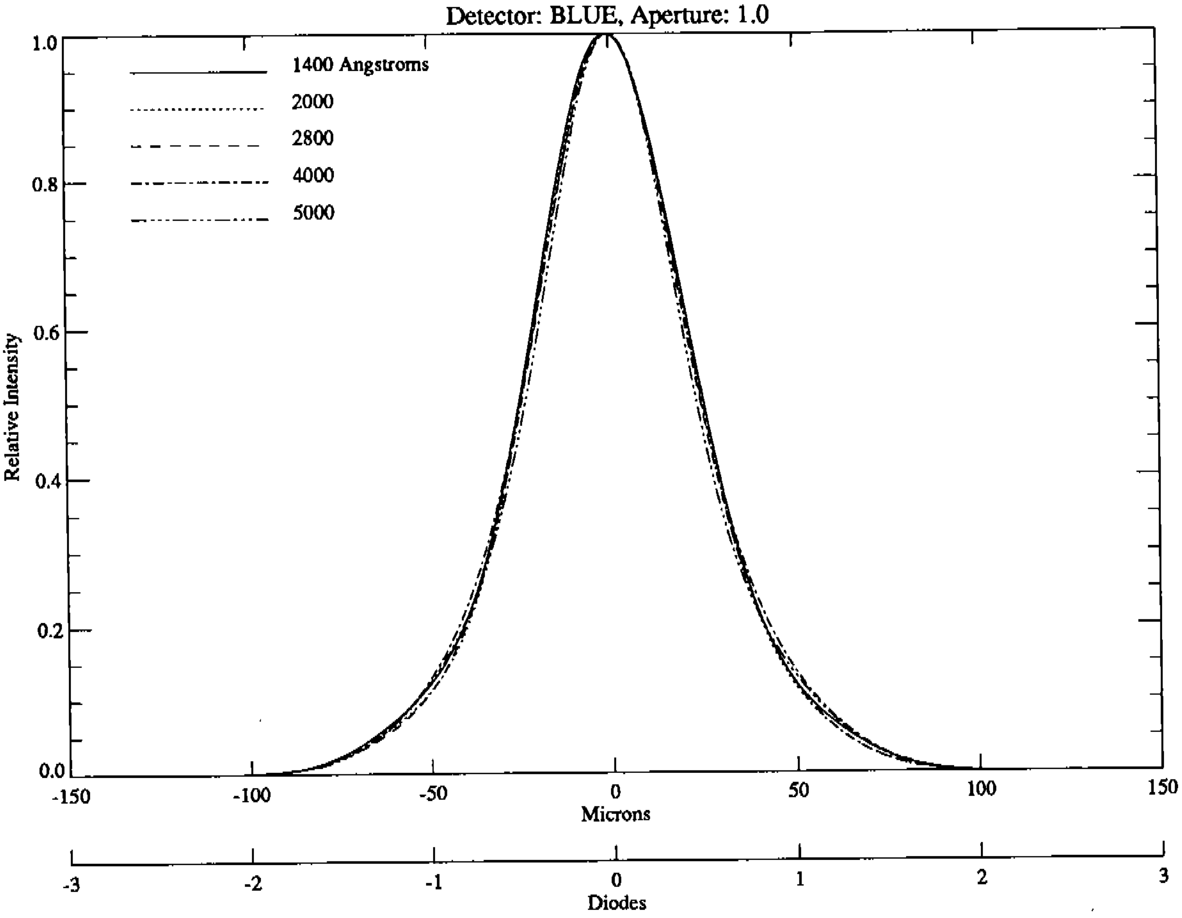

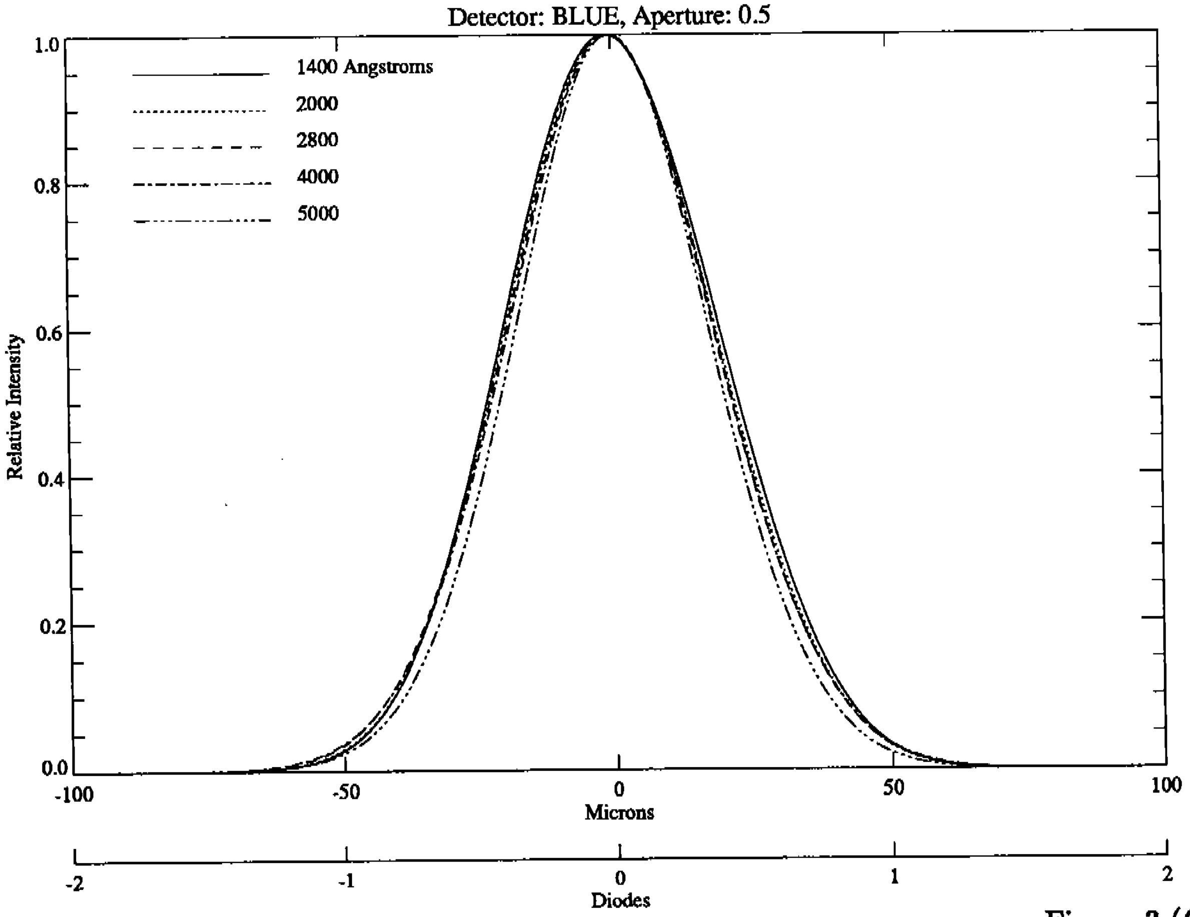

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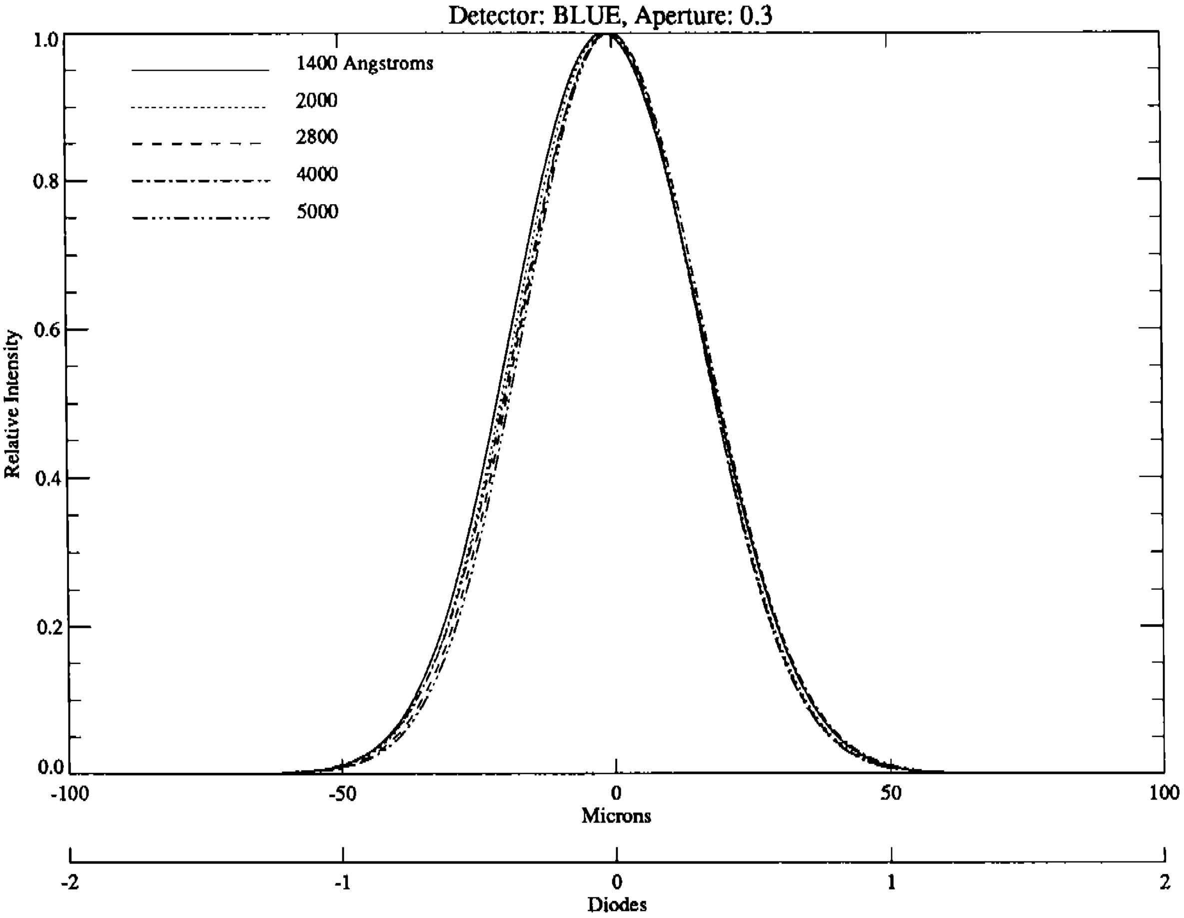


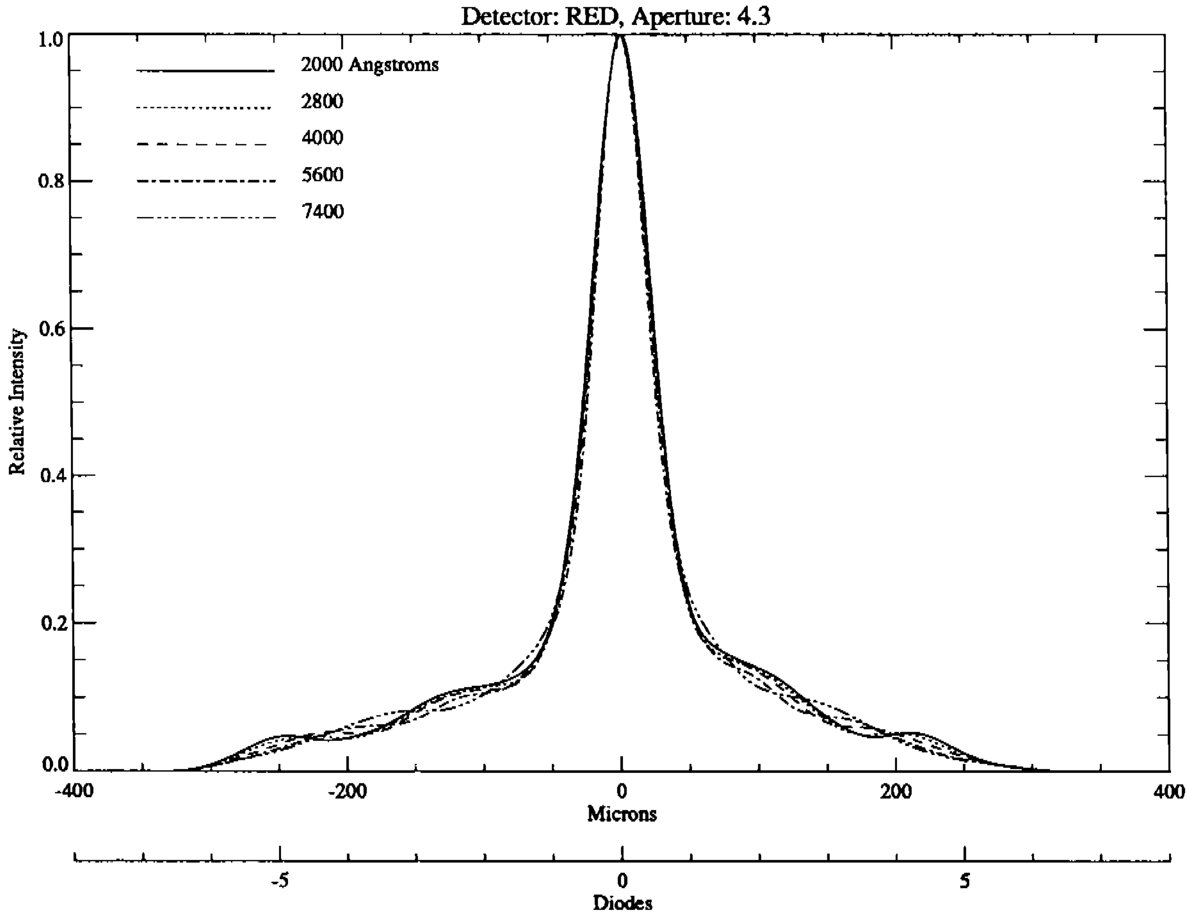
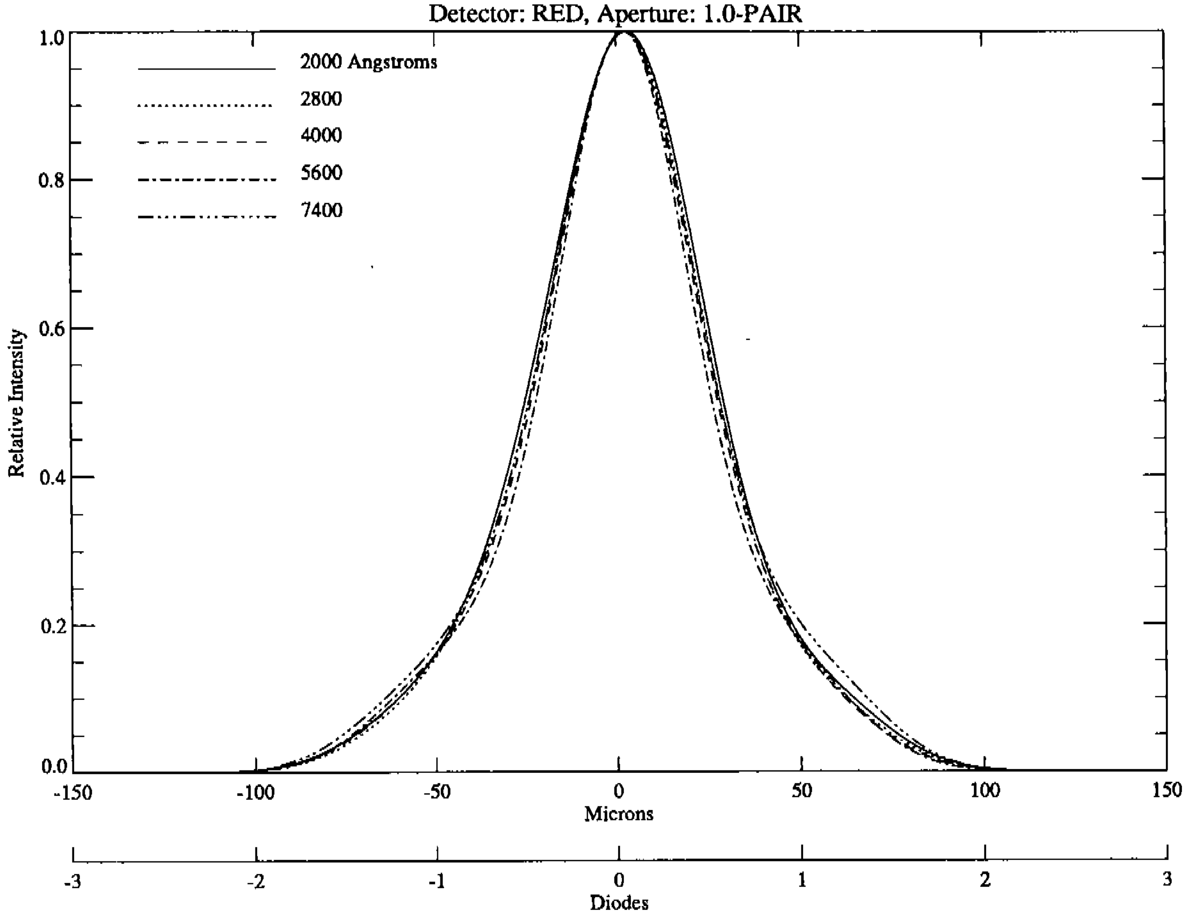


Figure 3 (Continued)

Detector: RED, Aperture: 1.0-PAIR



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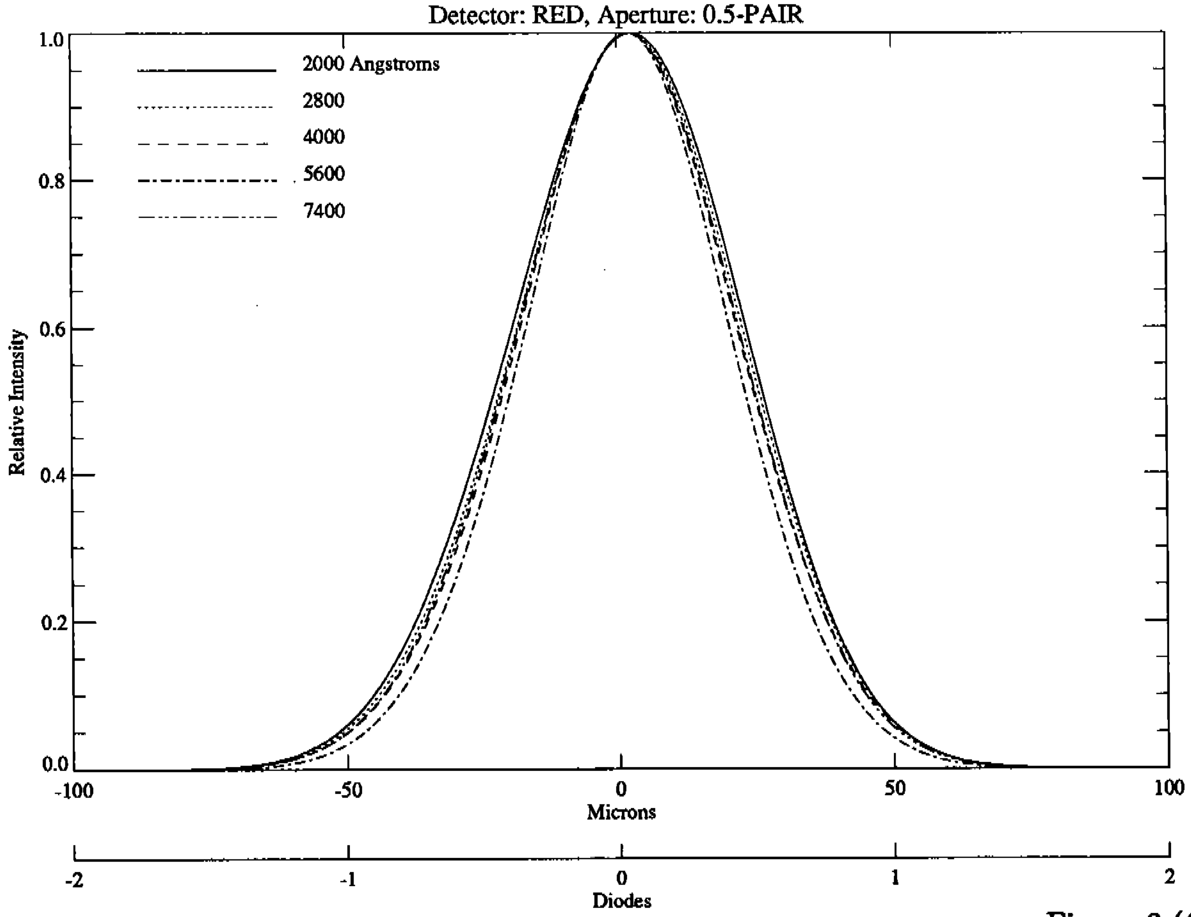

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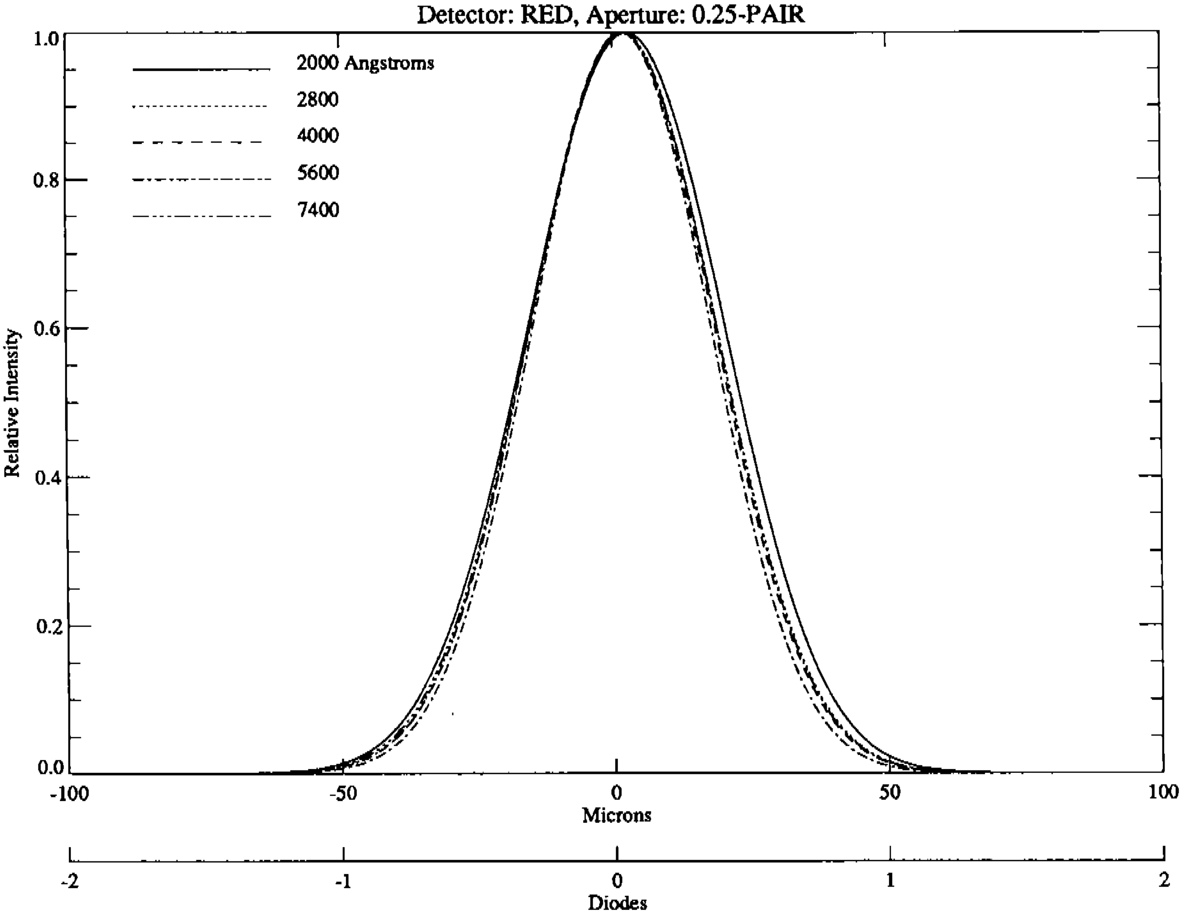

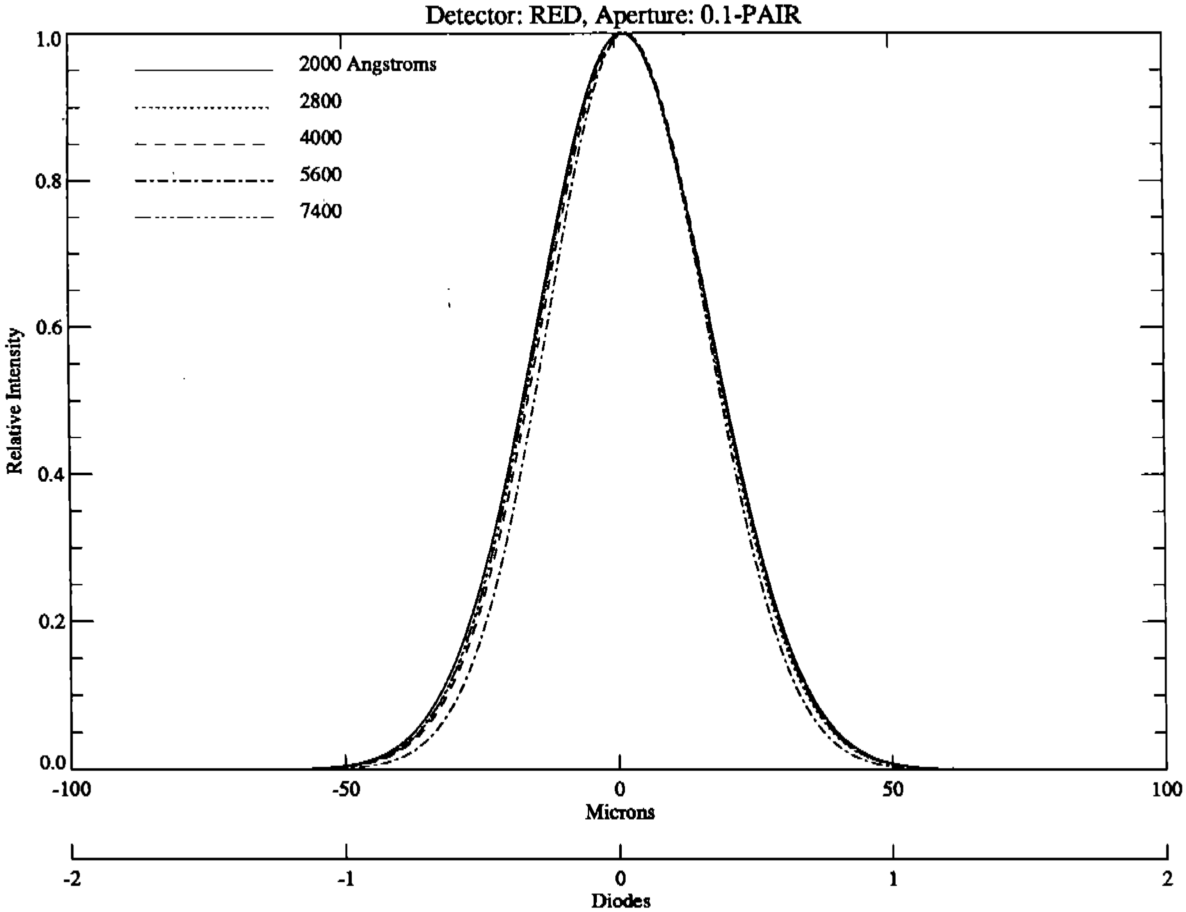

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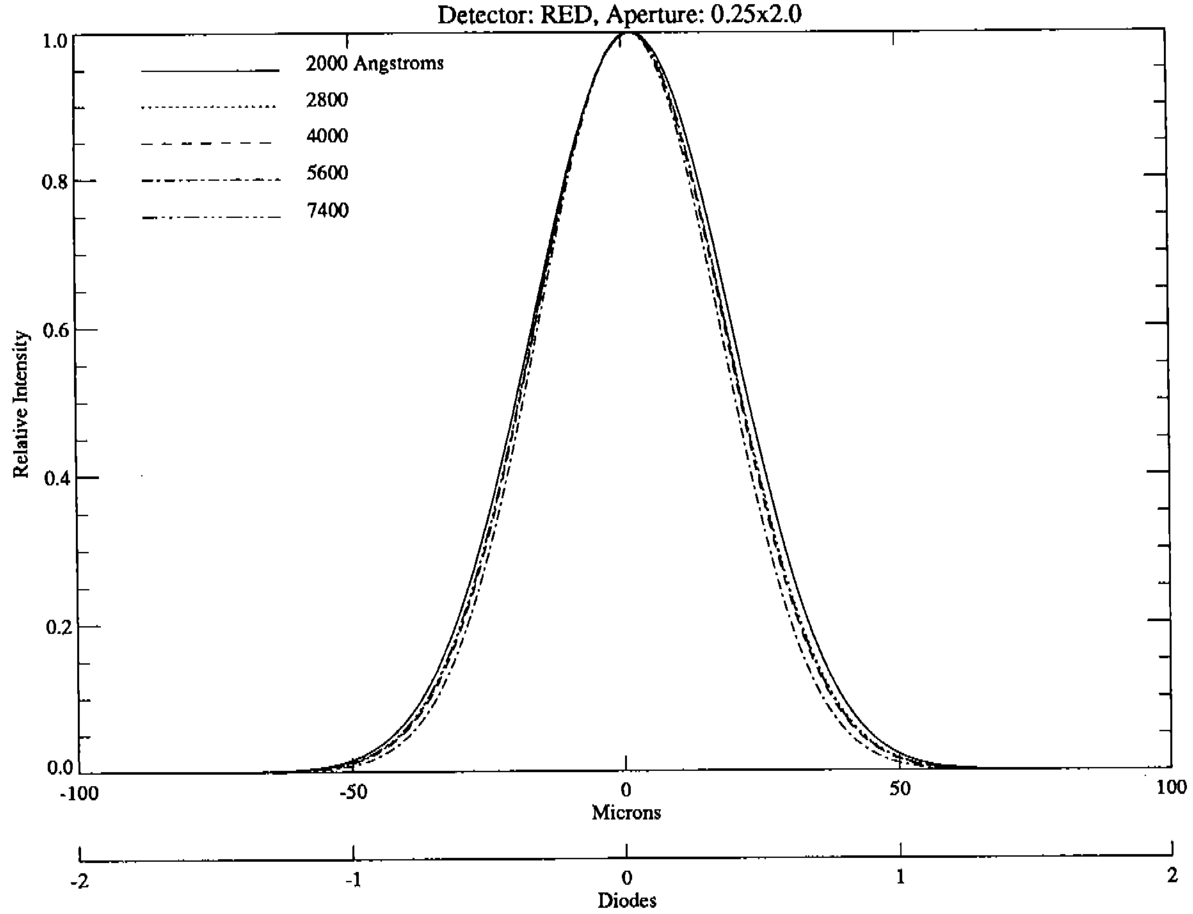

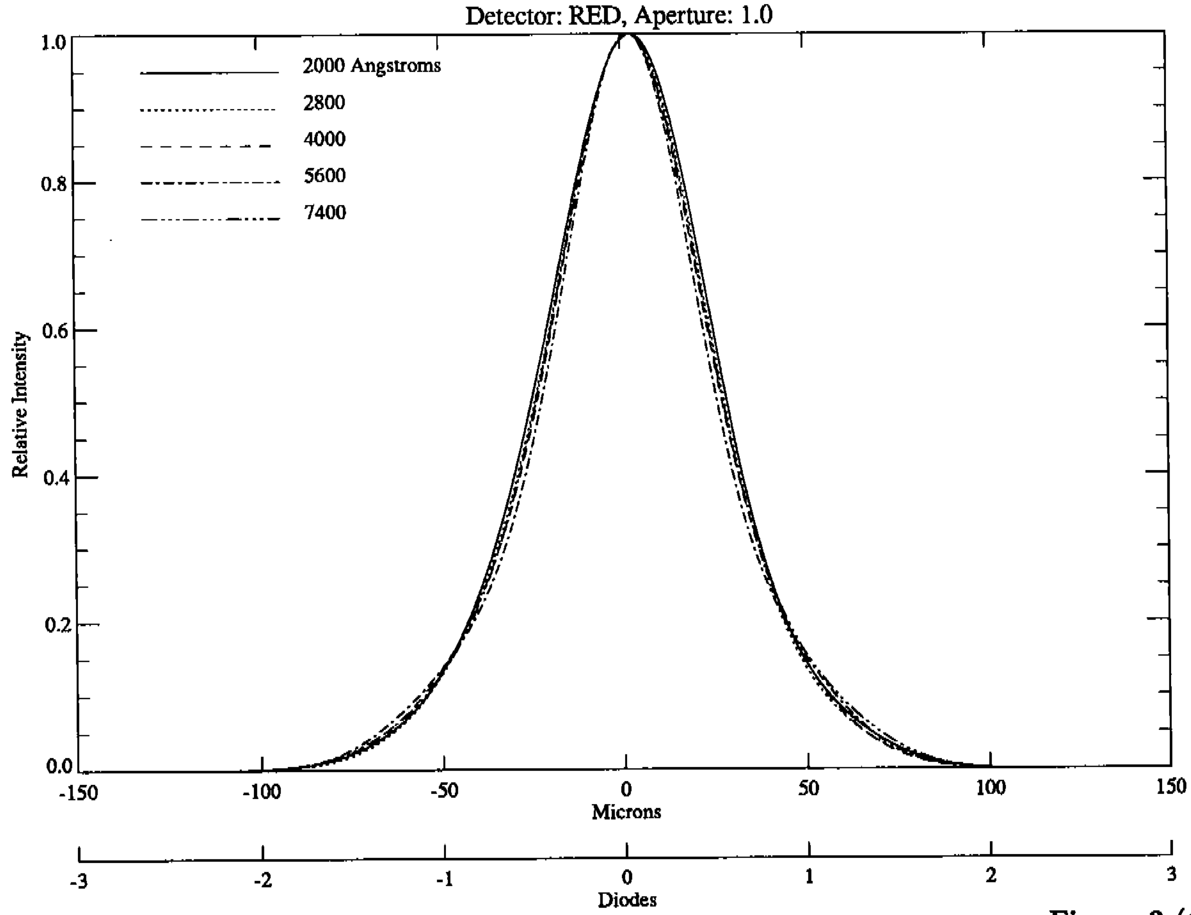

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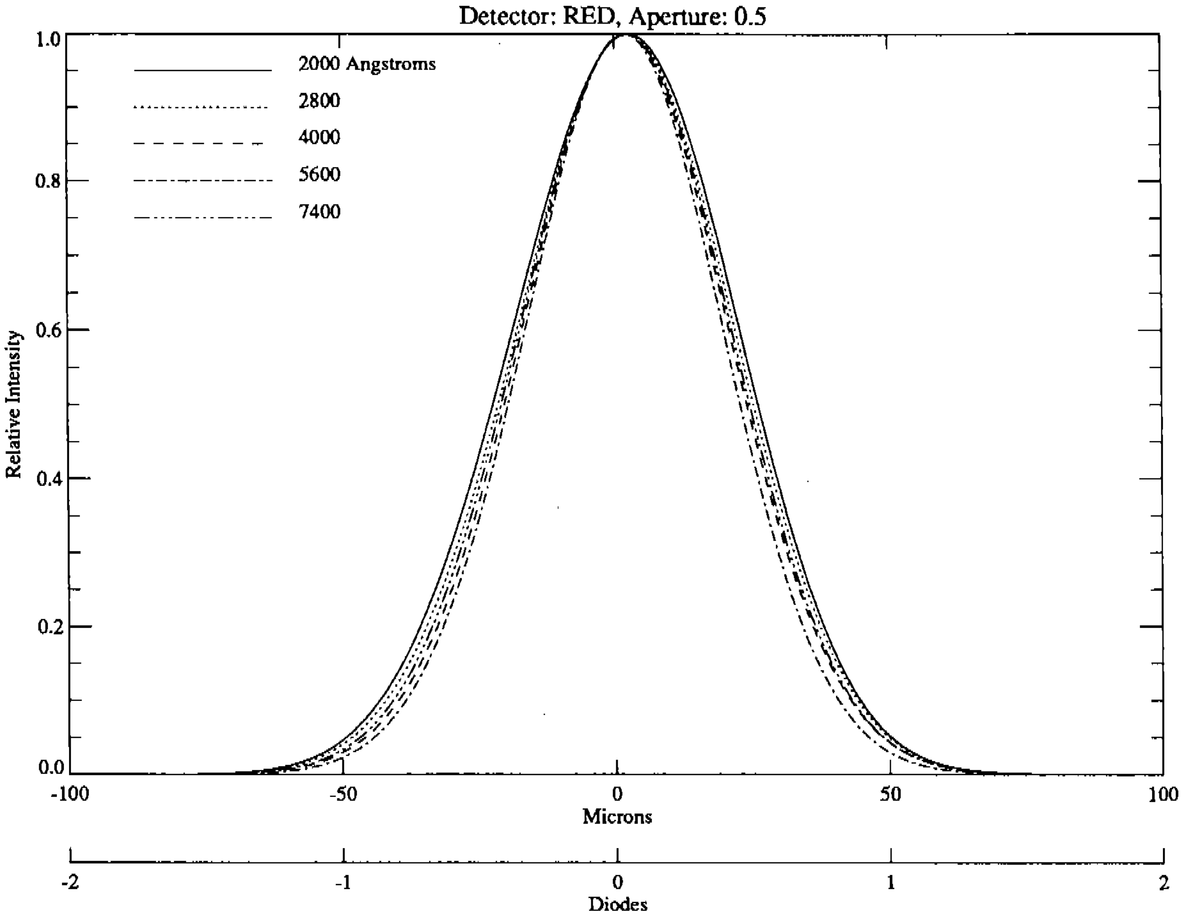

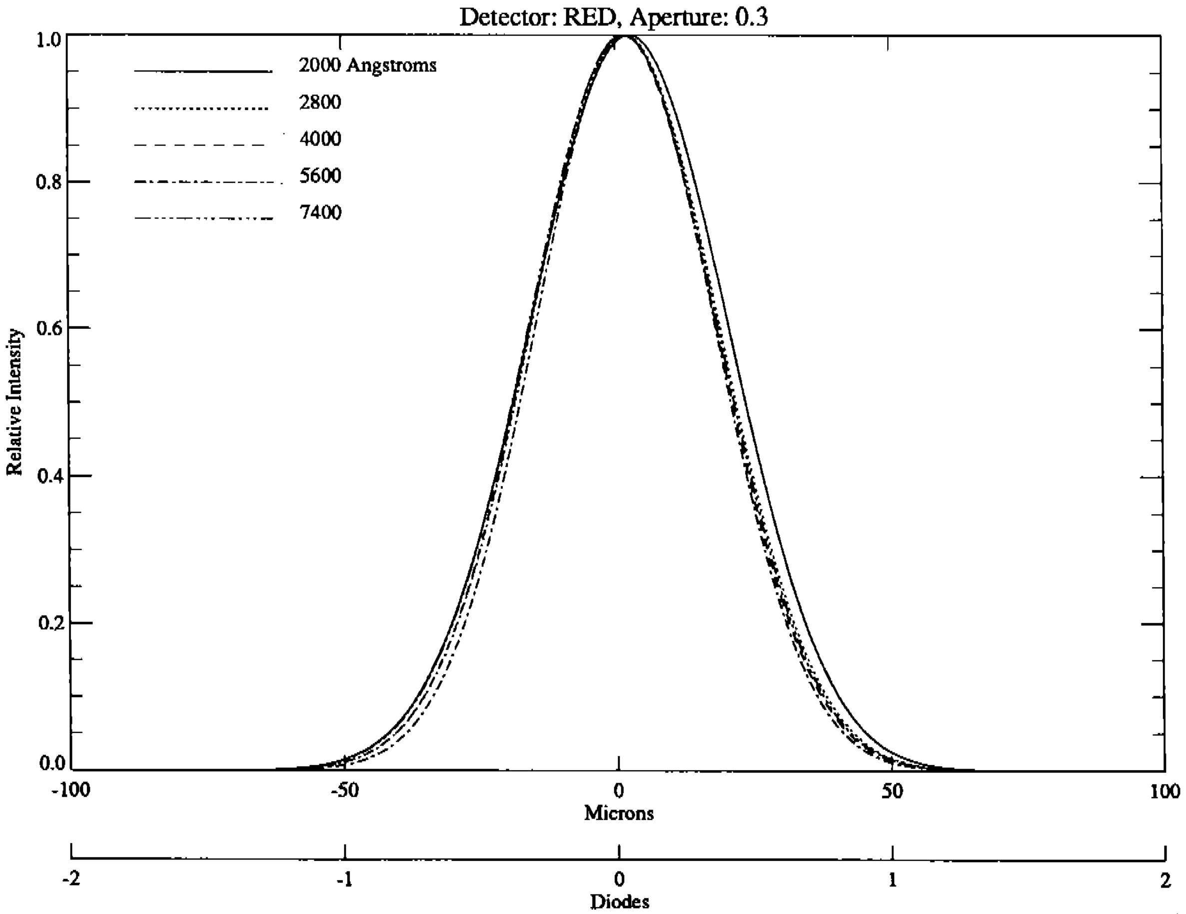

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