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DEIMOS Camera Re-Optimization

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Introduction

I was asked to explore the possible re-optimization of the Epps 3761 DEIMOS camera assuming to alterations: assuming either 12.5-mm commercial filters rather than 6.0-mm Bessell filters, or assuming that the large Calcium Fluoride singlet replaced by Ohara FK03. Since this was a study only to show if the camera could be re-optimized, the details of the original Epps 3761 model were retained, such as catalogue materials, gap spacings, and couplants. The constraints imposed were as follows. The only free parameters were the inter-multiplet distances and those surfaces which had not yet been started in fabrication. These were the two curvatures on either side of the Calcium Fluoride singlet, the front surface of element #4, the back surface of element #6, and the spacing between elements #2 and #3, between elements #6 and #7, and between elements #8 and #9.

The major difficulty was to construct an acceptable merit criteria for the optical performance. The method used here was to construct an analytical construct which modeled the camera to arbitrary accuracy (0.25 microns at the detector was used here), and then to integrated this model over the Keck telescope aperture, with all of the appropriate imaging and grating pupils at various wavelengths in order to assess the quality of the camera performance. Using this method, each element of merit function is assured to some accuracy, and only the choice of field positions, wavelengths, grating tilts, and so on effect the optimization.

The merit function here consisted used the six wavelengths shown in the table, each sampled at the various field positions shown in the accompanying figure. All of the wavelengths were sampled for imaging and lateral color. Some wavelengths, as shown in the table, were excluded for some gratings and grating angles. Gratings considered were a 600 lines/mm 6x8 inch, an 800 lines/mm 6x8 inch grating, a 1200 lines/mm 6x8 inch grating, and a 1200 lines/mm 8x12 inch grating. The field position of the light was always assumed to come from a long-slit positioned 4.5-arcminutes from the telescope axis. The total number of merit values was 726. For the initial tests, all of the merit values were weighted equally.

Results

Table 1 shows the result of the merit function evaluated with the original Epps 3761 design. The merit values are sorted into various categories and the RMS, the variance (the RMS about the RMS), and the worst case for each category are given. The values are in units of arcseconds at the camera mouth, which corresponds to 1.847 microns. A pixel works out to be 8.12 arcseconds in these units. The RMS image diameters and lateral color seem to correspond well to the values quoted the the Epps 3761 report, except for the lateral color of 7.7 pixels at 0.39 microns and full field.

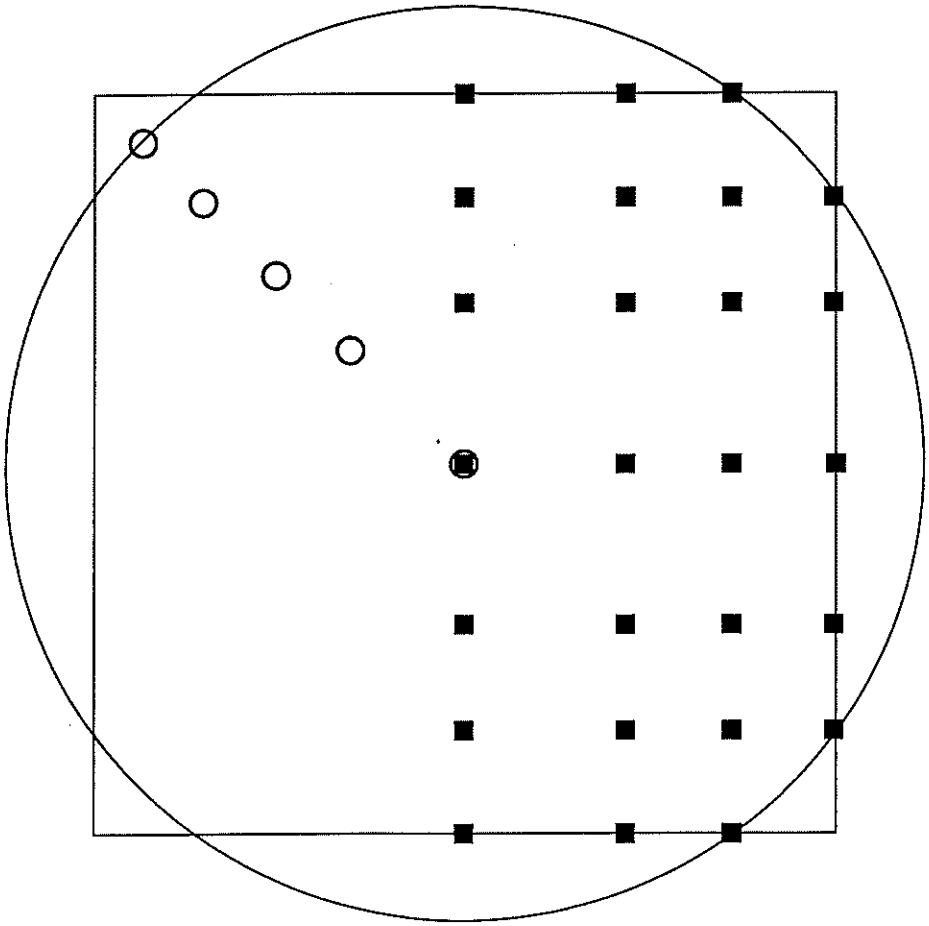
Table 2 shows the re-optimized results of the Epps 3761 design. The overall change seems to be a re-balance, with some of the larger lateral color suppressed to some extent. Table 3 is the re-optimization with the 12.5-mm filters, and Table 4 and Table 5 are the re-optimization with FK03. The first run for the FK03 version was extremely poor at 0.48 microns, and quite adequate elsewhere. For the second FK03 run, the 0.48-micron merit values were weighted more heavily. The 0.48-micron performance is still poor, but is not dramatically worse than the general performance, which have an RMS diameter of about 4.0 microns larger than the nominal camera.

Conclusions

A detailed comparison of the results of the various runs is not appropriate to an initial exploration study such as this one, and more easily conducted alone by the interested reader anyway. The main result is that re-optimization of the DEIMOS camera is quite possible. The run to include 12.5-mm filters resulted in what is probably an acceptable camera. For the FK03-singlet re-optimization, the designs here (two out of total of two runs), are not great, but do not in any sense exhaust the space of possible camera designs.

DEIMOS Merit Function Sample Locations							
Angle (deg)	Use	0.39μ	0.48μ	0.59μ	0.73μ	0.89μ	1.10μ
22.2	Imaging	X	X	X	X	X	X
35.0	600 800 1200 (6x8)	X	X	X	X	X	X
42.0	600 800 1200 (6x8)	X	X	X	X	X	X
49.0	600 800 1200 (6x8) 1200 (8x12)	-	-	X	X	X	X
56.0	600 800 1200 (6x8) 1200 (8x12)	-	-	-	X	X	X

DEIMOS Merit Function Sample Locations



Squares are for Spectrograph Mode Circles are for Imaging Mode

Merit Function Evaluation for Unmodified Epps Camera 3761

Merit Function = 2.6129e+07

Type		Count	RMS	VAR	MAX
Total Combined		726	13.13	5.37	62.55
Wavelength	0.3900	61	16.38	9.08	62.55
Wavelength	0.4800	61	13.95	2.12	18.93
Wavelength	0.5900	113	8.47	3.32	19.64
Wavelength	0.7300	165	11.99	4.26	33.11
Wavelength	0.8900	165	11.32	4.14	28.89
Wavelength	1.1000	161	16.51	4.58	26.05
Field 0.00 - 0.20		32	13.34	4.94	20.32
Field 0.20 - 0.40		89	11.05	3.66	18.43
Field 0.40 - 0.60		141	10.44	3.36	20.08
Field 0.60 - 0.80		104	10.79	3.25	18.11
Field 0.80 - 1.00		360	15.00	6.28	62.55
Imaging Combined		30	10.79	4.55	20.32
Wavelength	0.3900	5	9.30	3.48	14.87
Wavelength	0.4800	5	12.07	2.98	14.50
Wavelength	0.5900	5	5.73	1.45	7.04
Wavelength	0.7300	5	11.36	4.30	17.69
Wavelength	0.8900	5	12.59	5.80	20.32
Wavelength	1.1000	5	12.11	4.62	18.57
Field 0.00 - 0.20		6	12.58	5.66	20.32
Field 0.20 - 0.40		6	9.84	4.40	15.21
Field 0.40 - 0.60		6	8.90	2.97	13.96
Field 0.60 - 0.80		0	0.00	0.00	0.00
Field 0.80 - 1.00		12	11.14	4.34	18.57
Gratings Combined		676	12.94	4.91	33.11
Wavelength	0.3900	52	13.95	5.74	29.58
Wavelength	0.4800	52	14.15	1.81	18.93
Wavelength	0.5900	104	8.06	2.84	18.48
Wavelength	0.7300	156	12.10	4.25	33.11
Wavelength	0.8900	156	11.31	3.94	28.89
Wavelength	1.1000	156	16.64	4.49	26.05
Field 0.00 - 0.20		26	13.51	4.72	19.44
Field 0.20 - 0.40		78	11.24	3.42	18.43
Field 0.40 - 0.60		130	10.32	3.13	20.08
Field 0.60 - 0.80		104	10.79	3.25	18.11
Field 0.80 - 1.00		338	14.67	5.59	33.11
Lateral Combined		20	20.41	13.55	62.55
Wavelength	0.3900	4	38.10	21.08	62.55
Wavelength	0.4800	8	28.59	17.66	62.55
Wavelength	0.5900	8	15.50	3.29	19.64
Wavelength	0.7300	8	13.28	5.44	19.64
Wavelength	0.8900	8	8.66	4.92	17.40
Wavelength	1.1000	4	9.77	6.69	17.40
Field 0.00 - 0.20		0	0.00	0.00	0.00
Field 0.20 - 0.40		5	9.24	4.68	13.01
Field 0.40 - 0.60		5	14.50	6.33	18.55
Field 0.60 - 0.80		0	0.00	0.00	0.00
Field 0.80 - 1.00		10	26.18	16.87	62.55

Merit Function Evaluation for Re-Optimizated of Epps Camera 3761

Merit Function = 1.6986e+07

Type		Count	RMS	VAR	MAX
Total Combined		726	12.98	4.28	48.63
Wavelength	0.3900	61	11.72	7.23	48.63
Wavelength	0.4800	61	16.50	2.20	21.00
Wavelength	0.5900	113	9.31	2.92	23.70
Wavelength	0.7300	165	12.87	3.50	29.15
Wavelength	0.8900	165	12.73	3.48	25.50
Wavelength	1.1000	161	14.41	2.91	23.23
Field 0.00 -	0.20	32	14.89	5.97	22.62
Field 0.20 -	0.40	89	13.08	4.66	23.23
Field 0.40 -	0.60	141	11.45	3.91	21.29
Field 0.60 -	0.80	104	10.61	3.13	17.63
Field 0.80 -	1.00	360	13.92	4.01	48.63
Imaging Combined		30	11.54	4.93	22.62
Wavelength	0.3900	5	5.65	2.43	9.12
Wavelength	0.4800	5	14.46	3.44	17.01
Wavelength	0.5900	5	6.92	1.73	8.99
Wavelength	0.7300	5	12.84	4.14	19.27
Wavelength	0.8900	5	14.54	5.56	22.62
Wavelength	1.1000	5	11.54	3.03	15.88
Field 0.00 -	0.20	6	13.79	6.95	22.62
Field 0.20 -	0.40	6	10.99	5.40	16.95
Field 0.40 -	0.60	6	10.08	3.99	17.01
Field 0.60 -	0.80	0	0.00	0.00	0.00
Field 0.80 -	1.00	12	11.25	3.44	16.82
Gratings Combined		676	12.83	3.84	29.15
Wavelength	0.3900	52	9.73	4.59	21.29
Wavelength	0.4800	52	16.50	1.79	20.18
Wavelength	0.5900	104	8.66	1.73	15.04
Wavelength	0.7300	156	12.95	3.48	29.15
Wavelength	0.8900	156	12.77	3.14	25.50
Wavelength	1.1000	156	14.49	2.86	23.23
Field 0.00 -	0.20	26	15.13	5.65	21.60
Field 0.20 -	0.40	78	13.39	4.31	23.23
Field 0.40 -	0.60	130	11.35	3.65	19.69
Field 0.60 -	0.80	104	10.61	3.13	17.63
Field 0.80 -	1.00	338	13.64	3.33	29.15
Lateral Combined		20	18.78	10.77	48.63
Wavelength	0.3900	4	28.71	17.53	48.63
Wavelength	0.4800	8	24.23	12.69	48.63
Wavelength	0.5900	8	19.82	3.20	23.70
Wavelength	0.7300	8	16.23	6.19	23.70
Wavelength	0.8900	8	8.75	4.46	14.39
Wavelength	1.1000	4	7.89	5.51	14.39
Field 0.00 -	0.20	0	0.00	0.00	0.00
Field 0.20 -	0.40	5	10.19	5.83	15.10
Field 0.40 -	0.60	5	15.09	7.55	21.29
Field 0.60 -	0.80	0	0.00	0.00	0.00
Field 0.80 -	1.00	10	23.23	11.71	48.63

Merit Function Evaluation for Camera 3761 with 12.5mm BK7 Filter

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Merit Function = 2.0979e+07

Type		Count	RMS	VAR	MAX
Total Combined		726	13.80	4.61	47.25
Wavelength	0.3900	61	14.50	6.74	47.25
Wavelength	0.4800	61	14.08	2.93	20.77
Wavelength	0.5900	113	9.68	3.49	23.18
Wavelength	0.7300	165	13.94	4.18	32.66
Wavelength	0.8900	165	12.61	3.79	27.89
Wavelength	1.1000	161	16.60	3.36	23.14
Field 0.00 - 0.20		32	14.42	5.65	21.09
Field 0.20 - 0.40		89	12.39	4.16	23.14
Field 0.40 - 0.60		141	11.39	3.88	20.94
Field 0.60 - 0.80		104	11.26	3.68	17.98
Field 0.80 - 1.00		360	15.49	4.27	47.25
Imaging Combined		30	11.60	4.51	21.09
Wavelength	0.3900	5	9.05	2.56	12.33
Wavelength	0.4800	5	12.02	4.28	14.89
Wavelength	0.5900	5	7.64	2.31	10.69
Wavelength	0.7300	5	13.05	4.17	19.24
Wavelength	0.8900	5	13.57	5.03	21.09
Wavelength	1.1000	5	13.00	4.97	19.28
Field 0.00 - 0.20		6	13.38	6.24	21.09
Field 0.20 - 0.40		6	9.85	4.12	14.98
Field 0.40 - 0.60		6	9.24	3.10	14.29
Field 0.60 - 0.80		0	0.00	0.00	0.00
Field 0.80 - 1.00		12	12.49	3.49	19.28
Gratings Combined		676	13.73	4.28	32.66
Wavelength	0.3900	52	13.37	4.69	25.88
Wavelength	0.4800	52	13.87	2.36	18.37
Wavelength	0.5900	104	9.11	2.74	17.77
Wavelength	0.7300	156	14.07	4.16	32.66
Wavelength	0.8900	156	12.67	3.55	27.89
Wavelength	1.1000	156	16.71	3.20	23.14
Field 0.00 - 0.20		26	14.64	5.45	20.38
Field 0.20 - 0.40		78	12.70	3.83	23.14
Field 0.40 - 0.60		130	11.33	3.68	20.94
Field 0.60 - 0.80		104	11.26	3.68	17.98
Field 0.80 - 1.00		338	15.32	3.77	32.66
Lateral Combined		20	18.43	10.47	47.25
Wavelength	0.3900	4	27.97	17.00	47.25
Wavelength	0.4800	8	23.72	12.29	47.25
Wavelength	0.5900	8	19.51	3.11	23.18
Wavelength	0.7300	8	15.79	6.23	23.18
Wavelength	0.8900	8	8.79	4.51	15.45
Wavelength	1.1000	4	8.57	5.91	15.45
Field 0.00 - 0.20		0	0.00	0.00	0.00
Field 0.20 - 0.40		5	9.97	5.82	14.86
Field 0.40 - 0.60		5	14.79	7.20	20.84
Field 0.60 - 0.80		0	0.00	0.00	0.00
Field 0.80 - 1.00		10	22.81	11.28	47.25

Merit Function Evaluation for Camera 3761 with FK03 3rd Element (1)

Merit Function = 2.1331e+07

Type		Count	RMS	VAR	MAX
Total Combined		726	12.80	4.71	59.81
Wavelength	0.3900	61	13.08	8.78	59.81
Wavelength	0.4800	61	20.13	2.38	23.89
Wavelength	0.5900	113	12.96	2.79	24.74
Wavelength	0.7300	165	10.54	2.99	26.45
Wavelength	0.8900	165	13.61	3.07	27.87
Wavelength	1.1000	161	9.93	2.61	19.81
Field 0.00 -	0.20	32	14.45	5.11	20.01
Field 0.20 -	0.40	89	13.35	4.06	23.47
Field 0.40 -	0.60	141	11.93	4.43	23.82
Field 0.60 -	0.80	104	10.99	3.95	21.79
Field 0.80 -	1.00	360	13.31	4.95	59.81
Imaging Combined		30	11.96	5.27	20.91
Wavelength	0.3900	5	5.47	2.59	9.24
Wavelength	0.4800	5	18.45	2.45	20.91
Wavelength	0.5900	5	9.68	3.04	11.72
Wavelength	0.7300	5	9.07	2.48	13.13
Wavelength	0.8900	5	13.79	4.22	20.01
Wavelength	1.1000	5	11.04	4.04	17.01
Field 0.00 -	0.20	6	13.37	6.63	20.01
Field 0.20 -	0.40	6	12.16	4.99	17.72
Field 0.40 -	0.60	6	11.92	5.15	20.91
Field 0.60 -	0.80	0	0.00	0.00	0.00
Field 0.80 -	1.00	12	11.10	4.57	19.93
Gratings Combined		676	12.49	4.13	27.87
Wavelength	0.3900	52	9.82	4.73	22.20
Wavelength	0.4800	52	20.58	1.90	23.89
Wavelength	0.5900	104	12.64	1.96	17.96
Wavelength	0.7300	156	10.45	2.92	26.45
Wavelength	0.8900	156	13.74	2.83	27.87
Wavelength	1.1000	156	9.89	2.55	19.81
Field 0.00 -	0.20	26	14.69	4.57	19.36
Field 0.20 -	0.40	78	13.57	3.93	23.47
Field 0.40 -	0.60	130	11.69	4.27	23.82
Field 0.60 -	0.80	104	10.99	3.95	21.79
Field 0.80 -	1.00	338	12.76	3.92	27.87
Lateral Combined		20	21.51	12.26	59.81
Wavelength	0.3900	4	36.34	20.31	59.81
Wavelength	0.4800	8	28.01	16.19	59.81
Wavelength	0.5900	8	19.01	4.32	24.74
Wavelength	0.7300	8	18.68	4.62	24.74
Wavelength	0.8900	8	11.60	4.73	17.08
Wavelength	1.1000	4	6.74	2.05	8.65
Field 0.00 -	0.20	0	0.00	0.00	0.00
Field 0.20 -	0.40	5	11.07	3.53	15.08
Field 0.40 -	0.60	5	16.96	4.41	21.99
Field 0.60 -	0.80	0	0.00	0.00	0.00
Field 0.80 -	1.00	10	26.83	15.50	59.81

Merit Function Evaluation for Camera 3761 with FK03 3rd Element (2)

Merit Function = 5.05326e+07

Type		Count	RMS	VAR	MAX
Total Combined		726	14.51	4.59	53.37
Wavelength	0.3900	61	12.79	7.72	53.37
Wavelength	0.4800	61	18.36	2.36	24.15
Wavelength	0.5900	113	11.57	3.15	26.61
Wavelength	0.7300	165	13.50	3.15	27.83
Wavelength	0.8900	165	17.60	3.50	29.73
Wavelength	1.1000	161	12.70	2.93	21.64
Field 0.00 - 0.20		32	16.83	6.26	24.55
Field 0.20 - 0.40		89	15.01	4.26	21.18
Field 0.40 - 0.60		141	13.17	3.68	23.32
Field 0.60 - 0.80		104	12.64	3.37	19.37
Field 0.80 - 1.00		360	15.15	4.90	53.37
Imaging Combined		30	13.07	5.59	24.55
Wavelength	0.3900	5	5.86	2.15	9.08
Wavelength	0.4800	5	16.44	2.96	18.73
Wavelength	0.5900	5	8.22	2.32	10.22
Wavelength	0.7300	5	12.10	3.49	17.34
Wavelength	0.8900	5	17.44	5.04	24.55
Wavelength	1.1000	5	14.22	5.55	21.64
Field 0.00 - 0.20		6	15.91	8.15	24.55
Field 0.20 - 0.40		6	13.85	5.90	20.09
Field 0.40 - 0.60		6	12.51	4.38	18.56
Field 0.60 - 0.80		0	0.00	0.00	0.00
Field 0.80 - 1.00		12	11.24	3.80	18.73
Gratings Combined		676	14.33	4.13	29.73
Wavelength	0.3900	52	10.50	4.58	21.57
Wavelength	0.4800	52	18.54	2.18	24.15
Wavelength	0.5900	104	11.01	1.93	16.16
Wavelength	0.7300	156	13.48	3.11	27.83
Wavelength	0.8900	156	17.79	3.06	29.73
Wavelength	1.1000	156	12.65	2.81	20.96
Field 0.00 - 0.20		26	17.04	5.64	23.29
Field 0.20 - 0.40		78	15.29	3.93	21.18
Field 0.40 - 0.60		130	13.01	3.49	21.46
Field 0.60 - 0.80		104	12.64	3.37	19.37
Field 0.80 - 1.00		338	14.84	4.20	29.73
Lateral Combined		20	21.03	10.91	53.37
Wavelength	0.3900	4	31.90	18.74	53.37
Wavelength	0.4800	8	26.00	13.91	53.37
Wavelength	0.5900	8	21.02	4.30	26.61
Wavelength	0.7300	8	20.06	5.13	26.61
Wavelength	0.8900	8	12.46	4.88	18.22
Wavelength	1.1000	4	7.42	1.89	9.28
Field 0.00 - 0.20		0	0.00	0.00	0.00
Field 0.20 - 0.40		5	11.55	4.46	15.89
Field 0.40 - 0.60		5	17.35	4.94	23.32
Field 0.60 - 0.80		0	0.00	0.00	0.00
Field 0.80 - 1.00		10	25.83	13.02	53.37