Fast scopes and mechanical precision

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Depth of focus (diffraction limited case)

Depth of focus

The depth of focus is the tolerance on the axial position of the detector relative to the best optical focus. In the case of diffraction-limited optics, the light beam near the focus has a tunnel shape due to diffraction effects, as shown in Fig. 4.14, and the wavefront error at the distance Δz from the geometrical focus is given to the first order by $\Delta z / 8N^2$, where N is the focal ratio at the corresponding focus. The depth of focus is generally defined using the Rayleigh $\lambda/4$ rule and is then given by [14]

$$\text{Depth of focus} = \pm 2\lambda N^2 . \tag{4.16}$$

The above formula is only valid for diffraction-limited optics. For seeing-limited optics, the depth of focus is usually defined as the focus range within which the signal does not degrade by more than 2%.

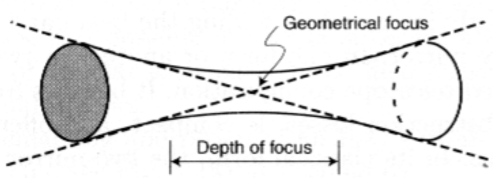
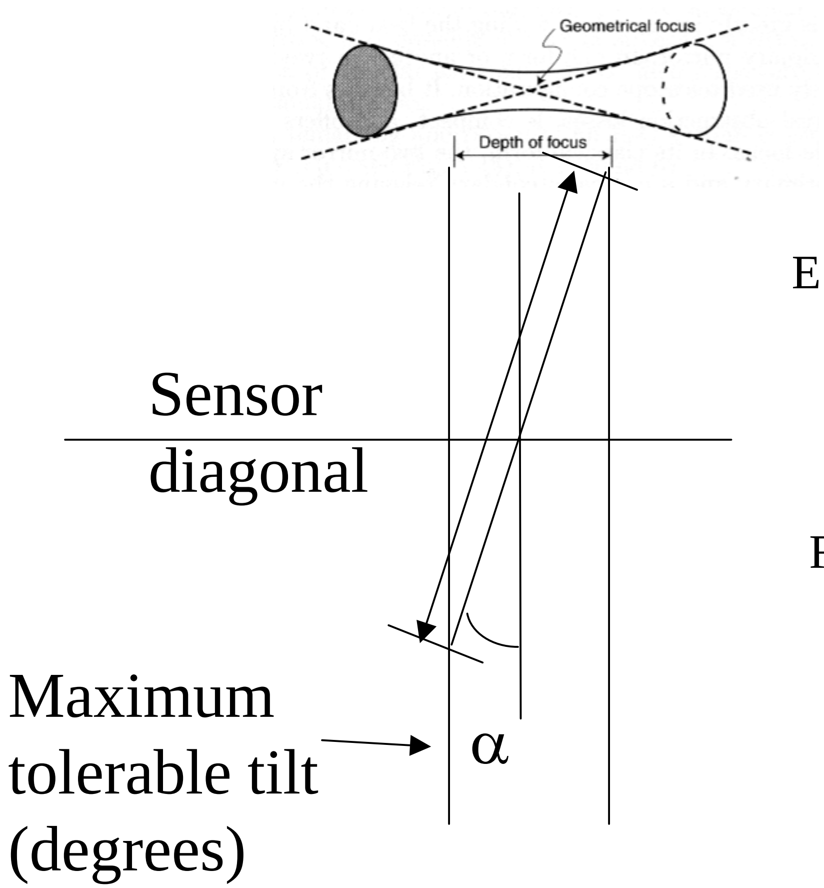


Fig. 4.14. Shape of the light beam near the focus of a diffraction-limited system. The depth of focus is the region where the rms wavefront error due to defocus is negligible compared to diffraction effects.

f/# (N)	lambda (microns)	Depth of Focus (microns)
1	0.55	1.1
1.2	0.55	1.584
1.5	0.55	2.475
1.75	0.55	3.36875
2	0.55	4.4
2.5	0.55	6.875
2.8	0.55	8.624
3	0.55	9.9
3.2	0.55	11.264
3.5	0.55	13.475
3.8	0.55	15.884
4	0.55	17.6
4.2	0.55	19.404
4.5	0.55	22.275
4.8	0.55	25.344
5	0.55	27.5
5.6	0.55	34.496
6.4	0.55	45.056
7.2	0.55	57.024
8	0.55	70.4

Maximum tolerable tilt before defocus (diffraction limited case) for 36.8 x 36.8 mm sensor



f/# (N)	lambda (microns)	Depth of Focus (+/-microns)	Sensor diagonal (mm)	Maximum tilt (degrees)
1	0.55	1.1	52	0.002424052
1.2	0.55	1.584	52	0.003490635
1.5	0.55	2.475	52	0.005454117
1.75	0.55	3.36875	52	0.007423660
2	0.55	4.4	52	0.009696209
2.5	0.55	6.875	52	0.015150326
2.8	0.55	8.624	52	0.019004569
3	0.55	9.9	52	0.021816470
3.2	0.55	11.264	52	0.024822295
3.5	0.55	13.475	52	0.029694640
3.8	0.55	15.884	52	0.035003314
4	0.55	17.6	52	0.038784835
4.2	0.55	19.404	52	0.042760281
4.5	0.55	22.275	52	0.049087057
4.8	0.55	25.344	52	0.055850163
5	0.55	27.5	52	0.060601305
5.6	0.55	34.496	52	0.076018277
6.4	0.55	45.056	52	0.099289179
7.2	0.55	57.024	52	0.125662867
8	0.55	70.4	52	0.155139341

E180ED (f/2.8)

FSQ (f/5)

3:1 (f/2.8 to f/5)

10:1 (f/2.5 to f/8)

KAF6303

f/# (N)	lambda (microns)	Depth of Focus (+/-microns)	Sensor diagonal (mm)	alpha degrees
1	0.55	1.1	33.39296	0.003774769
1.2	0.55	1.584	33.39296	0.005435667
1.5	0.55	2.475	33.39296	0.008493230
1.75	0.55	3.36875	33.39296	0.011560229
2	0.55	4.4	33.39296	0.015099075
2.5	0.55	6.875	33.39296	0.023592305
2.8	0.55	8.624	33.39296	0.029594187
3	0.55	9.9	33.39296	0.033972919
3.2	0.55	11.264	33.39296	0.038653632
3.5	0.55	13.475	33.39296	0.046240917
3.8	0.55	15.884	33.39296	0.054507661
4	0.55	17.6	33.39296	0.060396300
4.2	0.55	19.404	33.39296	0.066586921
4.5	0.55	22.275	33.39296	0.076439067
4.8	0.55	25.344	33.39296	0.086970672
5	0.55	27.5	33.39296	0.094369219
5.6	0.55	34.496	33.39296	0.118376748
6.4	0.55	45.056	33.39296	0.154614529
7.2	0.55	57.024	33.39296	0.195684013
8	0.55	70.4	33.39296	0.241585201

5:1

KAF09000/KAF16803

f/# (N)	lambda (microns)	Depth of Focus (+/-microns)	Sensor diagonal (mm)	alpha degrees
1	0.55	1.1	52	0.002424052
1.2	0.55	1.584	52	0.003490635
1.5	0.55	2.475	52	0.005454117
1.75	0.55	3.36875	52	0.007423660
2	0.55	4.4	52	0.009696209
2.5	0.55	6.875	52	0.015150326
2.8	0.55	8.624	52	0.019004569
3	0.55	9.9	52	0.021816470
3.2	0.55	11.264	52	0.024822295
3.5	0.55	13.475	52	0.029694640
3.8	0.55	15.884	52	0.035003314
4	0.55	17.6	52	0.038784835
4.2	0.55	19.404	52	0.042760281
4.5	0.55	22.275	52	0.049087057
4.8	0.55	25.344	52	0.055850163
5	0.55	27.5	52	0.060601305
5.6	0.55	34.496	52	0.076018277
6.4	0.55	45.056	52	0.099289179
7.2	0.55	57.024	52	0.125662867
8	0.55	70.4	52	0.155139341

The required degree of precision of the adaptors/focusers etc moving from a 6303 on an FSQ (f/5) to a 16803 on an f/2.8 system is about 5:1. The faster system with the larger sensor needs a much tighter tolerance than the slower FSQ with the smaller 6303