Optical Systems Design

Geometrical optics

$$m=-rac{s_i}{s_0}$$

$$rac{1}{f}=rac{1}{s_0}+rac{1}{s_i}\quad [1/ ext{mm}]$$

$$rac{1}{f}=(n-1)\left(rac{1}{R_1}-rac{1}{R_2}+rac{n-1}{n}rac{CT}{R_1R_2}
ight)\quad [1/ ext{mm}]$$

$$\phi=\phi_1+\phi_2-\phi_1\phi_2L=rac{1}{ ext{EFL}}\quad [1/ ext{m}]$$

$$ext{NA}=rac{1}{2(f/\#)}pprox rac{D}{2f}\quad [ext{rad}]$$

$$ext{FOV}=2lpha=2 an^{-1}\left(rac{d}{2f}
ight)pprox rac{d}{f}\quad [ext{rad}]$$

Aberrations

Туре	f-number coeff.	Coefficient	Comments
Spherical	$eta = rac{K}{(f/\#)^3}$	$B_s=Krac{D^3}{f^2}$	$K = f(n_{ m lens}^{-1})$
Coma	$eta=rac{ heta}{16(n+2)(f/\#)^2}$	$B_c=eta_c f=rac{ heta D^2}{16(n+2)f}$	
Astigmatism	$eta = rac{ heta^2}{2(f/\#)}$	$B_a=rac{ heta^2 D}{2}$	
Field curvature	$\Delta z = rac{y^2}{2nf}$	$pprox rac{ heta^2 f}{2n} [ext{mm}]$	

Wavefront expansion

Series expansion for rotational symmetry

$$egin{aligned} \left[\ H^2 \ , \
ho^2 \ , \ H\cos heta \
ight] \ W_{IJK} \ \Rightarrow \ H^I \cdot
ho^J \cdot \cos^K heta \end{aligned}$$

Wavefront	Order	Expansion term.	Description
W =	1st	$W_{020} ho^2$	Defocus
	1st	$+W_{111}H\rho\cos\theta$	Wavefront tilt
	3rd	+ $W_{040} ho^4$	SA: Spherical aberration
	3rd	$+W_{131}H\rho^3\cos\theta$	Coma
	3rd	$+W_{222}H^2\rho^2\cos^2\theta$	Astigmatism
	3rd	+ $W_{220}H^2 ho^2$	Field curvature
	3rd	$+W_{311}H^3\rho\cos\theta$	Distortion
	5th	+ $W_{060} ho^6$	5th Order SA
	5th	$+W_{151}H ho^5\cos heta$	5th Order linear Coma
	5th	$+W_{422}H^4\rho^2\cos^2\theta$	5th Order astigmatism
	5th	+ $W_{420}H^4 ho^2$	5th Order field curvature
	5th	$+W_{511}H^5 ho\cos heta$	5th Order distortion
	5th	+ $W_{240}H^2 ho^4$	Sagittal oblique SA
	5th	$+W_{242}H^2\rho^4\cos^2\theta$	Tangential oblique SA
	5th	$+W_{331}H^3\rho^3\cos\theta$	Cubic coma (Elliptical coma)
	5th	$+W_{333}H^3\rho^3\cos^3\theta$	Line coma (Elliptical coma)
		+ Higher order terms	