Optical Systems Design

Geometrical optics

$$m = -\frac{s_i}{s_0}$$

$$\frac{1}{f} = \frac{1}{s_0} + \frac{1}{s_i} \quad [1/\text{mm}]$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2} + \frac{n-1}{n}\frac{CT}{R_1 R_2}\right) \quad [1/\text{mm}]$$

$$\phi = \phi_1 + \phi_2 - \phi_1\phi_2 L = \frac{1}{\text{EFL}} \quad [1/\text{m}]$$

$$\text{NA} = \frac{1}{2(f/\#)} \approx \frac{D}{2f} \quad [\text{rad}]$$

$$\text{FOV} = 2\alpha = 2\tan^{-1}\left(\frac{d}{2f}\right) \approx \frac{d}{f} \quad [\text{rad}]$$

Aberrations

Type	f-number coeff.	Coefficient	Comments
Spherical	$\beta = \frac{K}{(f/\#)^3}$	$B_s = K\frac{D^3}{f^2}$	$K = f(n_{\text{lens}}^{-1})$
Coma	$\beta = \frac{\theta}{16(n+2)(f/\#)^2}$	$B_c = \beta_c f = \frac{\theta D^2}{16(n+2)f}$	
Astigmatism	$\beta = \frac{\theta^2}{2(f/\#)}$	$B_a = \frac{\theta^2 D}{2}$	
Field curvature	$\Delta z = \frac{y^2}{2nf}$	$\approx \frac{\theta^2 f}{2n}[\text{mm}]$	

Wavefront expansion

Series expansion for rotational symmetry

$$[\, H^2 \,,\, \rho^2 \,,\, H\cos\theta \,]$$

$$W_{IJK} \;\Rightarrow\; H^I \cdot \rho^J \cdot \cos^K\theta$$

Wavefront	Order	Expansion term.	Description
W =	1st	$W_{020}\rho^2$	Defocus
	1st	$+W_{111}H\rho\cos\theta$	Wavefront tilt
	3rd	$+W_{040}\rho^4$	SA: Spherical aberration
	3rd	$+W_{131}H\rho^3\cos\theta$	Coma
	3rd	$+W_{222}H^2\rho^2\cos^2\theta$	Astigmatism
	3rd	$+W_{220}H^2\rho^2$	Field curvature
	3rd	$+W_{311}H^3\rho\cos\theta$	Distortion
	5th	$+W_{060}\rho^6$	5th Order SA
	5th	$+W_{151}H\rho^5\cos\theta$	5th Order linear Coma
	5th	$+W_{422}H^4\rho^2\cos^2\theta$	5th Order astigmatism
	5th	$+W_{420}H^4\rho^2$	5th Order field curvature
	5th	$+W_{511}H^5\rho\cos\theta$	5th Order distortion
	5th	$+W_{240}H^2\rho^4$	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	