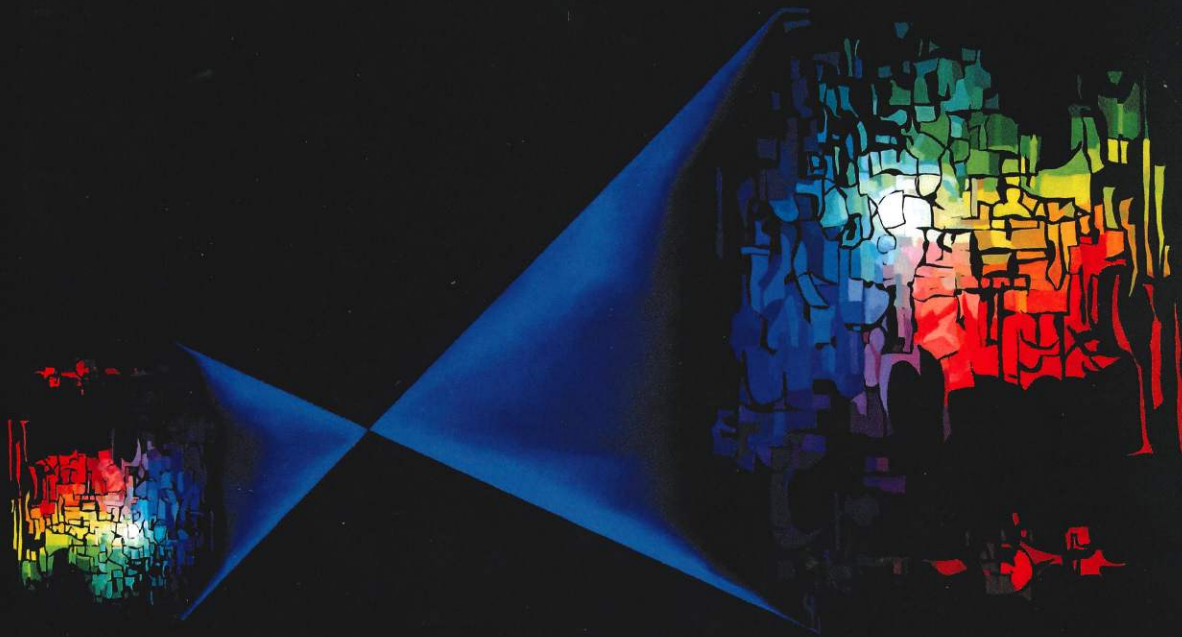


Introduction to Aberrations in Optical Imaging Systems

JOSÉ SASIÁN



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INTRODUCTION TO ABERRATIONS IN OPTICAL IMAGING SYSTEMS

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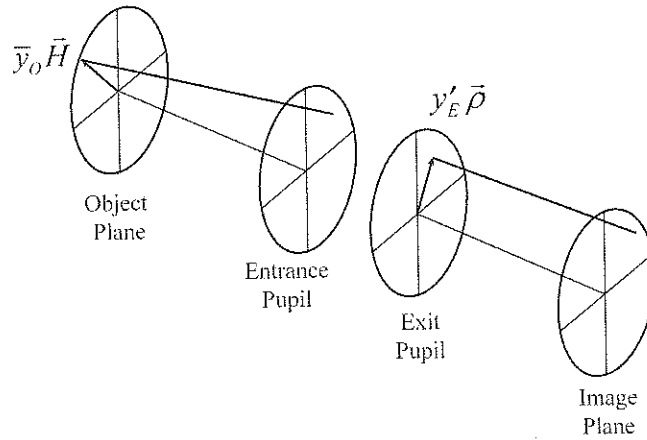


Figure 2.7 The aperture vector (scaled by the marginal ray height y'_E at the exit pupil) and the field vector (scaled by the chief ray height \bar{y}_O at the object plane).

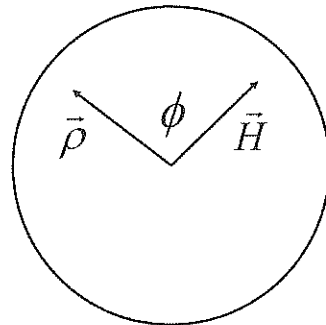


Figure 2.8 The angle ϕ between the field and aperture vectors looking down the optical axis.

The chief ray height in the object plane is \bar{y}_O and the marginal ray height at the exit pupil is y'_E . The magnitude of the aperture vector is ρ , and the magnitude of the field vector is H .

Using the field and aperture vectors we can define fans of rays in a meridional plane by setting the field vector \vec{H} and the aperture vector $\vec{\rho}$ parallel to each other ($\phi = 0$). We can define sagittal rays by setting the vectors perpendicularly to each other ($\phi = 90^\circ$).

2.7 Real, first-order, and paraxial rays

Rays of light are traced through an optical system in an iterative manner. The initial data are the spatial coordinates of a point and the direction of the ray. The ray is traced by finding its intersection coordinates with the next surface. Then

Figure 2.9 In ob...
 u , the normal lin...
 $\vec{r}\vec{y}$ represents th...

the direction of th...
For spherical surfa...
closed-form equat...
intersection point i...
repeated until the i...
By real rays we...
of refraction and th...

where I and I' are...
indices of refractio...
line to the surface,
real ray tracing the...

By first-order ra...
path of a real ray. F...
law,

The optical surf...
optical power prop...
transfer respectivel...

² See, for exam...

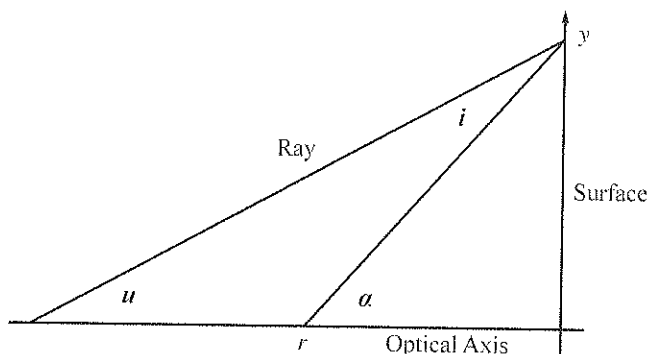


Figure 2.9 In object space there are three first-order slopes, the incident ray slope u , the normal line slope α , and the slope of incidence i (not an angle). The segment \overline{ry} represents the normal line to the surface of radius r and curvature $c = 1/r$.

the direction of the ray after refraction is determined by applying Snell's law. For spherical surfaces or conic surfaces the ray intersection is determined using closed-form equations. For other surfaces an iterative algorithm is used until the intersection point is found to a high degree of accuracy. This ray-tracing process is repeated until the image plane is reached.

By real rays we mean rays of light that are traced accurately using Snell's law of refraction and that may not be close to the optical axis. Snell's law is

$$n' \sin(I') = n \sin(I), \quad (2.3)$$

where I and I' are the angles of ray incidence and refraction, and n and n' are the indices of refraction of the media surrounding the refracting surface. The normal line to the surface, the incident ray, and the refracted ray are coplanar. In accurate, real ray tracing the actual shape of the refracting surface is used.

By first-order rays we mean rays of light that are a first approximation to the path of a real ray. First-order rays are traced using a linear approximation to Snell's law,

$$n'i' = ni. \quad (2.4)$$

The optical surfaces are considered planar as shown in Figure 2.9, but with optical power properties. The first-order ray-tracing equations, for refraction and transfer respectively, are²

$$n'u' = nu - \frac{n' - n}{r}y, \quad (2.5)$$

$$y' = y + u't, \quad (2.6)$$

² See, for example, J. Greivenkamp, *Field Guide to Geometrical Optics*, SPIE Press, 2004.

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