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ELECTRONIC ENGINEERING

Modern Lens Design

Second Edition

- ✔ Detailed procedures for designing any major lens
- ✔ Demonstration design case studies
- ✔ Designing with lens design software

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These aberrations are related by:

$$TA = LA \cdot \tan U$$

$$AA = TA/l'$$

$$OPD = \int AA$$

The *optical path* ($OP = \Sigma n \cdot d$) is related to the time of travel of light, which is equal to $\Sigma n \cdot d/c$. Ideally the OP from the object point to a reference sphere centered on the image point (and often located at the exit pupil—or at infinity) should be constant over the full aperture. The *optical path difference*, $OPD = (OP_{ray} - OP_{ref})$, where OP_{ray} is the path along a ray and OP_{ref} is the path along the axis or along the principal ray. The *pupil function* is OPD (x, y); the *wave (front) function* is $w(x, y) = \text{OPD}\,(x, y)/\lambda$ in waves; and the *phase function* $\Phi(x, y)$ is $2\pi w\,(x, y)$ in radians.

Aberrations may be *intrinsic* or *induced*. The intrinsic aberrations are those of a surface (or element) that are unaffected by the aberrations of the other surfaces. Induced aberrations are created by the aberrations (i.e., changes in the ray heights or angles) of the other elements. Usually the lower-order aberrations of the other surfaces cause induced higher-order aberrations. For example, the third-order aberrations of preceding surfaces will induce fifth-order spherical in following surfaces. See Chap. 6, Secs. 6.3 and 6.4 for an example of how the third-order spherical and first-order chromatic aberration in the first element affect the zonal (fifth-order) spherical and spherochromatic of the lens.

5.4 Scaling a Design, Its Aberrations, and its Modulation Transfer Function

A lens prescription can be scaled to any desired focal length simply by multiplying all of its dimensions by the same constant. All of the *linear* aberration measures will then be scaled by the same factor. Note, however, that percent distortion, *chromatic difference of magnification* (CDM), the numerical aperture or *f* number, the aberrations expressed as angular aberrations, and any other *angular* characteristics remain completely unchanged by scaling.

The exact *diffraction modulation transfer function* (MTF) cannot be scaled with the lens data. The diffraction MTF, since it includes diffraction effects that depend on wavelength, will not scale because the wavelength is not ordinarily scaled with the lens. A *geometric* MTF can be scaled by dividing the spatial frequency ordinate of the MTF plot by the scaling factor. Of course, because it neglects diffraction, the geometric