

**OPTICAL AND ELECTRO-OPTICAL
ENGINEERING SERIES**

MODERN LENS DESIGN

A Resource Manual

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GENESEE OPTICS SOFTWARE, INC.

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Modern Lens Design

A Resource Manual

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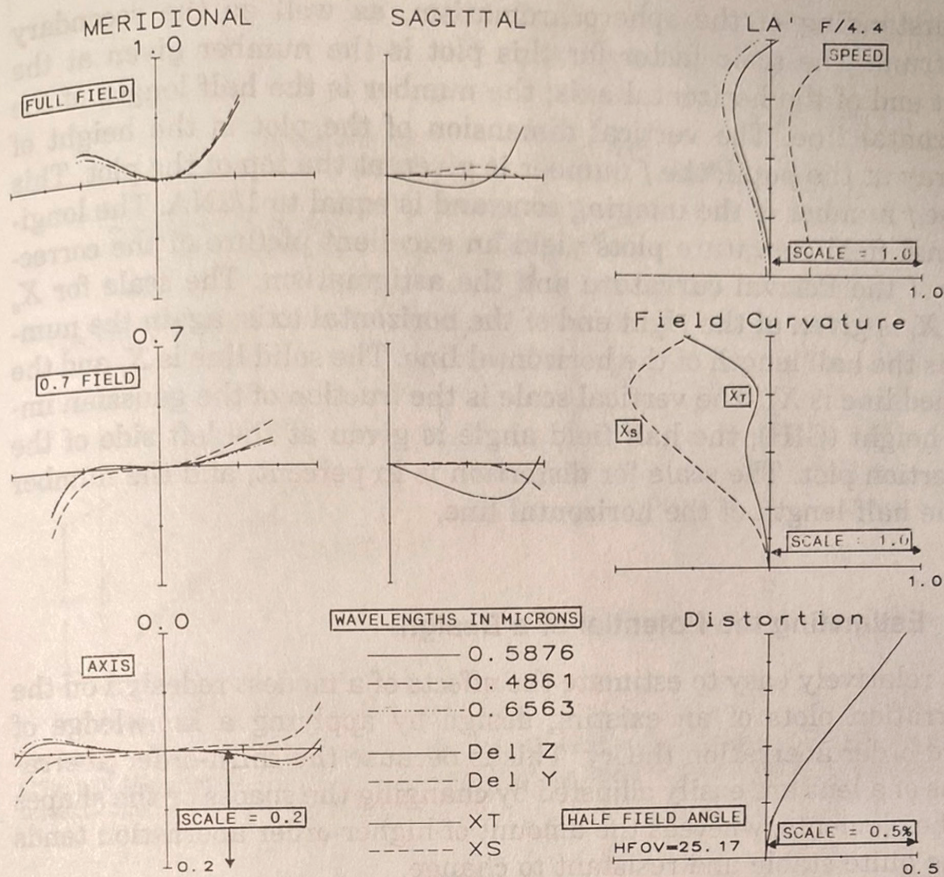


Figure 5.3 Sample aberration plot.

called H -tan U curves) for the axis, 0.7 field, and full field. The ray displacements are plotted vertically, as a function of the position of the ray in the aperture. The vertical scale is given at the lower end of the vertical bar for the axial plot; the number given is the half-length (i.e., from the origin to the end) of the vertical line in the plot. The horizontal scale is proportional to the tangent of the ray slope angle. Following the usual convention, the upper ray of the ray fan is plotted to the right. In the sagittal plots, the solid line is the transverse aberration in the z , or sagittal, direction and the dashed line is the ray displacement in the y direction (which is sagittal coma).

In addition to the ray intercept plots (which are, in general, probably the most broadly useful presentation of the aberration characteristics of a design), two aberrations are also presented as longitudinal plots. The longitudinal representations of spherical aberration and field curvature have been the classical, conventional presentation for decades, despite the fact that they give a very incomplete picture of the state of correction of the lens. However, a longitudinal plot of the spherical aberration in three wavelengths does allow a much clearer

Thus one can look at the aberration plots for a given design and, by applying the techniques outlined above, easily visualize what they will look like after an adjustment has been made to fit the design to the application at hand.

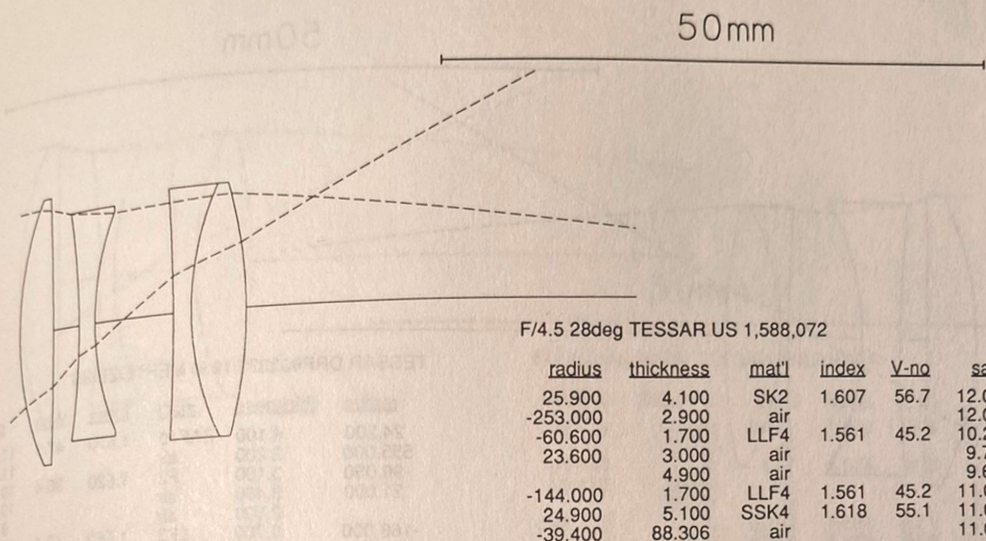
5.4 Scaling a Design, Its Aberrations, and Its MTF

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, aberrations expressed as angular aberrations, and any other *angular* characteristics remain completely unchanged by scaling.

The exact *diffraction* MTF cannot be scaled with the lens data. The diffraction MTF, since it includes diffraction effects which 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 MTF is quite inaccurate unless the aberrations are very large (and the MTF is correspondingly poor).

A diffraction MTF can be scaled *very* approximately as follows: Determine the OPD which corresponds to the MTF value of the lens for several spatial frequencies. This can be done by comparing the MTF plot for the lens to Figs. 4.3 and 4.4, which relate the MTF to OPD. Then multiply the OPD by the scaling factor and, again using Figs 4.3 and 4.4, determine the MTF corresponding to these scaled OPD values. Obviously the accuracy of this procedure depends on how well the simple relationships of Figs. 4.3 and 4.4 represent the usually complex mix of aberrations in a real lens.

In the event that a proposed change of aperture or field is expected to produce a change in the amount of the aberrations, one can attempt to scale the MTF as affected by aberration. This is done by determining the type of aberration which most severely limits the MTF, then scaling the OPD according to the way that this aberration scales with aperture or field, in a manner analogous to that described in Sec. 5.3. In general, OPD as a function of aperture varies as one higher exponent of the aperture than does the corresponding transverse aberration. For example, the OPD for third-order transverse spherical (which varies as Y^3) varies as the fourth power of the ray height. In a form analogous to Eqs. 5.3 and 5.4, which indicate a power series expansion of the transverse aberrations as a function of aperture and



EFL = 99.88
 BFL = 88.31
 NA = -0.1111 (F/4.5)
 GIH = 52.94 (HFOV=27.92)
 PTZ/F = -3.331
 VL = 23.40
 OD = infinite conjugate

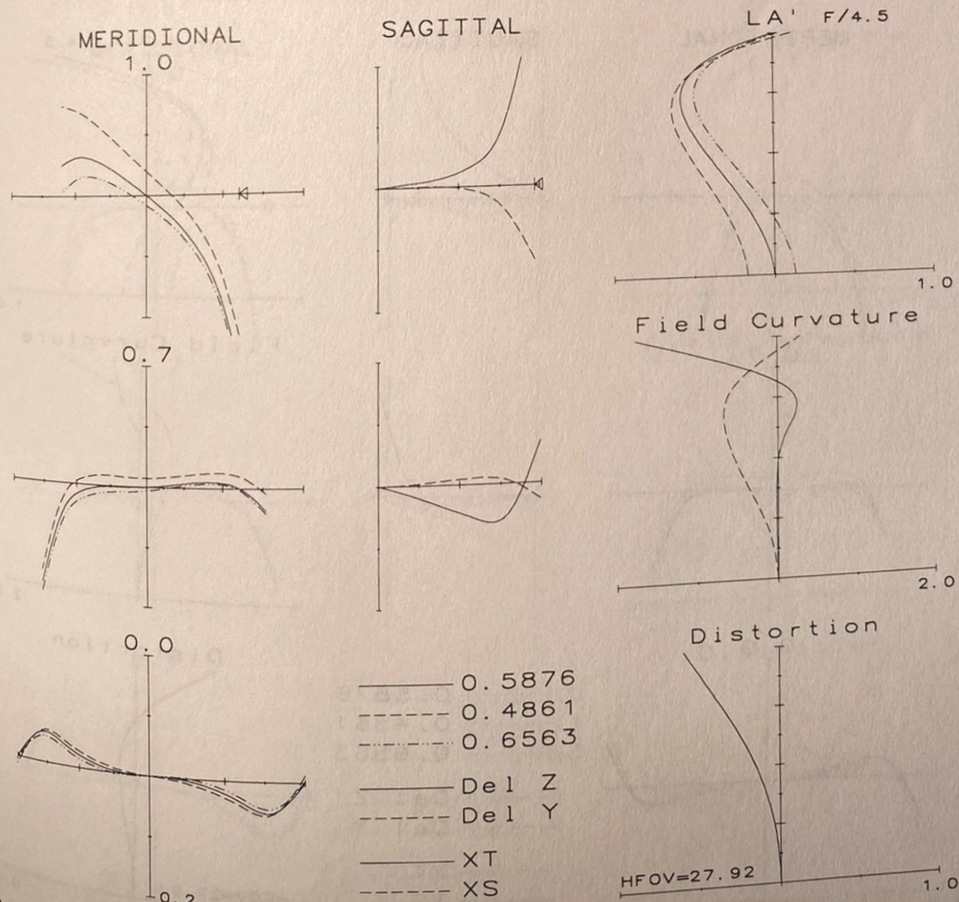


Figure 12.2