Effects of Small Decentrations on Image Quality

It is possible to analyze the effects of small decentrations by expanding decentered ray trace equations in a power series and neglecting any terms higher than second-order. When this is done, a group of coefficients analogous to the third-order (Seidel) aberrations are produced which can be summed in any grouping to find the effects of required decenterings. There is one zero-order effect plus five second-order decentering aberration coefficients.

These coefficients are:

D0 a zero-order shift of the entire image, without degradation, in the plane of the decentration movement.

D1 a second-order comatic flare which is uniform over the whole field and symmetrical about the plane of decentration movement.

D2 a second-order astigmatic separation of the focal plane into two tilted intersecting focal planes in the plane of decentration, coupled with a circular blurring in the plane perpendicular to the plane of decentration.

Dp a second-order tilting of the focal plane (or planes, if D2 = 0).

D3 a second-order displacement of the image which bends the radial s (called tangential distortion); no image degradation occurs from D3.

D4 a second-order displacement of the image which is connected with D3; no image degradation occurs from D4.

These coefficients represent the relative sensitivity to tilting of the surface. The amount of tilt of each surface depends upon the type of decentering movement which the mounting allows. Thus, summing up these coefficients does not necessarily give a useful value. When they are properly combined, however, a set of aberrations are obtained which have the following characteristics (the letters C0, C1, C2, Cp, C3, and C4 in the following are the coefficients referred to in the output headings for decentered primary aberrations):

- C0 The displacement of the image, uniform over the field, is equal to C0 in the direction of the decentering movement.

- C1 The comatic flare, uniform over the field, has the following dimensions:

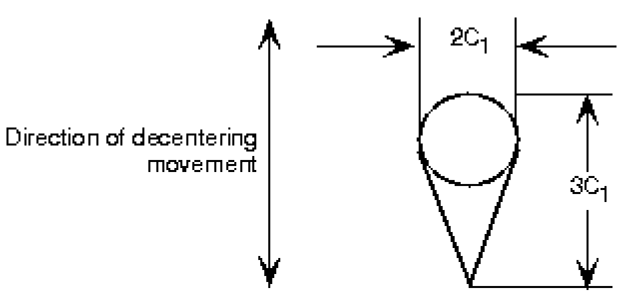

Figure 4. Comatic flare dimensions

C2 and Cp Case I: Decentration in the direction of the meridional plane

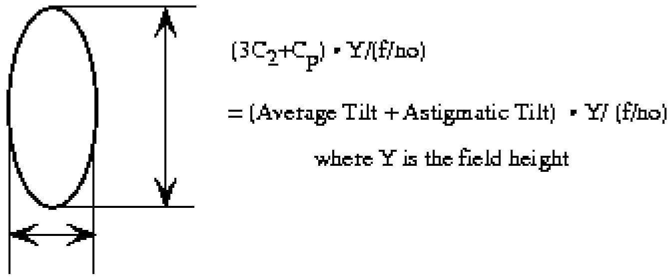

Figure 5. Decentration in the direction of the meridional plane

- (C2 + Cp) • Y/(f/#) = (Average Tilt - Astigmatic Tilt) • Y/(f/#)
- This is an ordinary astigmatic image which changes shape as the lens is focused, and possesses a sagittal and tangential focus.
- Case II: Decentration perpendicular to the meridional plane

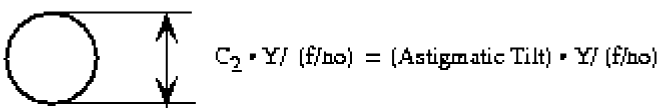

Figure 6. Decentration perpendicular to the meridional plane

- This is a circular image which is the circle of least confusion between two astigmatic images oriented at +45° .
- C3 and C4 Tangential Distortion

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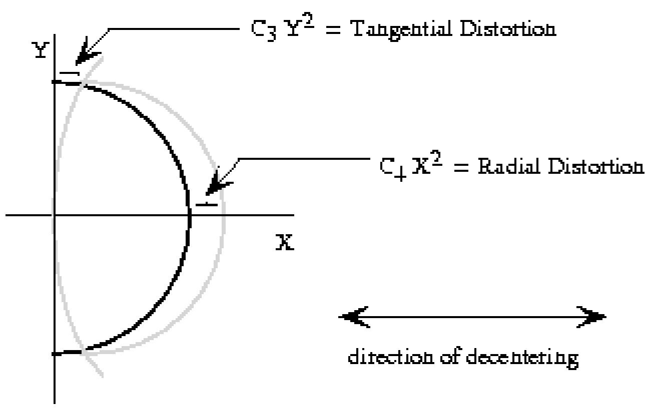

Figure 7. Tangential distortion

Because of the many possible orientations of decentering movement which can exist simultaneously in a complex lens system, the above representations are necessarily limited to special cases.

Decentering Movements

There are six types of errors which can occur in a lens which give rise to tilts of the surfaces:

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Wedge This is the tilt introduced in one surface of an element due to one edge being
thicker than the other.
Tilt This is the tilt of an entire element.
Roll This occurs when one surface of a component remains in contact with the lens
seat, but undergoes a rotating displacement about its center of curvature.  The other
surfaces of the component thereby become tilted and displaced.
Displacement or Barrel Displacement
 This is the lateral shift of a single component or group of  surfaces.

Barrel Tilt This is a rotation of a group of surfaces about the vertex of the first
as would occur if a subassembly of a lens could be tilted as a unit.
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Any proposed lens mount design can be broken down into groupings of these six types of decentering motions and the effects determined individually by using this program; the worst case effects can then be obtained by combining unfavorably all possible combinations. If there is no established form for the lens mount design (as would be the case in the development of a new lens design), it is useful to examine the sensitivity of the lens design to decentering. This can be adequately be done by examining the default groupings of tolerances defined by TOL or DEF TOL in the LDM.