FIELD CURVATURE (FC)

**Definition**

Field curvature is an image defect that causes off-axis points to focus in different focal planes than the axial image point. An extended object will focus onto a curved image plane.

**Petzval Curvature:** A longitudinal shift in image position with object size or field angle. As a real object moves off axis, it moves away from the lens and the image position shifts. This is an inherent property of optical systems.

**Notes**

1) Image is still stigmatic, but lies on a curve instead of a line.
2) FC is inherent in every optical system and is a function of surface curvatures and the index of refraction of the lenses.
3) FC is independent of stop shift, pupil position, or spacing of lenses.
4) In the presence of astigmatism, two curved focal lines exist denoted S and T for sagittal and tangential.
5) No rays have to be traced to compute FC.
6) FC is a symmetric aberration.
7) When constructing a compound lens, cemented surfaces should have smaller curvatures to minimize Petzval curvature.
8) Petzval curvature is field curvature in the absence of astigmatism.

**Formulas**

**FC with no Astigmatism (Petzval Curvature)**

Wavefront Aberration: $W_{220} \cdot r^2 \rho$

Seidel Coefficient (Petzval Curvature):

$S_{IV} = - \sum_{\text{All Surfaces}} M^2 c_i \Delta \left( \frac{1}{n_i} \right) = - \sum_{\text{All Surfaces}} M^2 P_i$

Relation: $W_{220} = W_{220P} = \frac{1}{4} S_{IV}$

$M = n\bar{y}u - n\bar{y}T$

**Field Curvature with Astigmatism**

Wavefront Aberration: $W_{220} \cdot r^2 \rho$

Relation: $W_{220} = \frac{1}{4} S_{III} + \frac{1}{4} S_{IV}$

$M = S_{III} + S_{IV}$

$T = S_{III} + S_{IV}$

$M = \frac{1}{4} S_{III} + \frac{1}{4} S_{IV}$

$W_{220S} = -(W_{220P} + \frac{1}{4} W_{222}) \cdot r^2 \rho^2$

$W_{220T} = -(W_{220P} + \frac{1}{4} W_{222}) \cdot r^2 \rho^2$

$W_{220M} = -(W_{220P} + W_{222}) \cdot r^2 \rho^2$

$W_{220} = \frac{1}{4} (2S_{III} + S_{IV})$

**Minimizing and Correcting**

The general concept for correcting field curvature is that the total aberration is a function of surface curvature and index of refraction, not spacing.

$W \propto \sum_{\text{Surfaces}} \frac{c_i}{n_i} = \sum_{\text{Surfaces}} \frac{1}{n_i R_i}$

1) Using a “Field Flattener” lens. This is usually a negative lens (opposite FC) placed at or very near to final image. Due to its close proximity, the image is effected little, but the $\Sigma C/n$ is reduced.
2) Use a curved screen or detector to match the field curvature.
3) Use high index glass to reduce the value of $\Sigma C/n$.
4) The total power of the system contains $d(nC_i)^2$. By increasing $d$ (spacing of lenses), the powers of each lens can be reduced, thus reducing $\Sigma C/n$ which is independent of spacing.
5) Astigmatism can be introduced to cancel the field curvature. ($M=S+T=0$)
6) Make lens meniscus shaped (equal $R$ on both sides). A thin lens with this shape has no power. A thick lens does. $\Sigma C/n$ is not effected, but total power is.