The Fundamental Parameters of the Seidel Aberrations and Aplanatic Surfaces

Invited Talk for Tucson Student Chapter Optical Society of America

By

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Outline for TOSA Talk

- Seidel and His Aberrations
- Fundamental Parameters of the Seidel Aberrations
- Aplanatic Definitions
- Aplanatic Points & Conditions of a Surface
- What happens between these points/conditions
- Zemax Macro to Investigate
- Tools for optical design and aberrations reduction

Philipp Ludwig von Seidel

- In 1856 L. Seidel (1821-1896) published the 1st complete mathematical basis, on the formation of an image by a lens
- Identified and named seven independent aberrations
- In general one degree of freedom to correct one aberration

- L. Seidel, Zur Dioptrik, Astronomische Nachrichten, No. 1027, 289 (1856); No. 1028, 305; No. 1029, 321

Preparation Meets Opportunity

- After high school he spent one year of math tutoring under Schnurlein- student of Gauss
- 1840 Univ. of Berlin - student of Dirichlet, Encke
- 1842 Konigsberg - student of Bessel, Jacobi, Franz Neumann
- Studied Astronomy and Mathematical Analysis
- Problems with eyesight forced him into early retirement

Seidel Aberrations

- Spherical Aberration
- Coma
- Astigmatism
- Field Curvature
- Distortion
- Axial Color
- Lateral Color

Mathematical Formulas of Seidel Aberrations

Spherical $W_{040} = -\frac{1}{8} S_I$ $S_I = -\sum A^2 y \Delta\left\{\frac{u}{n}\right\}$

Coma $W_{131} = \frac{1}{2} S_{II}$ $S_{II} = -\sum A \bar{A} y \Delta\left\{\frac{u}{n}\right\}$

Astigmatism $W_{222} = \frac{1}{2} S_{III}$ $S_{III} = -\sum \overline{A^2} y \Delta\left\{\frac{u}{n}\right\}$

Field Curvature $W_{220P} = \frac{1}{4} S_{IV}$ $S_{IV} = -\sum \aleph^2 P$ $\aleph = Lagrange\,In\,\mathrm{var}iant$

Distortion $W_{311} = \frac{1}{2} S_V$ $S_V = -\sum \frac{\bar{A}}{A}\left[\aleph^2 P + \overline{A^2} y \Delta\left\{\frac{u}{n}\right\}\right]$

Axial Color $\delta_\lambda W_{020} = \frac{1}{2} C_L$ $C_L = \sum A y \Delta\left\{\frac{\delta_n}{n}\right\}$ $\frac{\delta_n}{n} = \frac{n-1}{nV}$

Lateral Color $\delta_\lambda W_{111} = \frac{1}{2} C_T$ $C_T = \sum \bar{A} y \Delta\left\{\frac{\delta_n}{n}\right\}$

Alternate Form for Distortion if $\bar{A} = 0$

$\Delta\left\{\frac{u}{n}\right\} = A\Delta\left\{\frac{1}{n^2}\right\} - yP$ $\aleph = \bar{A} y - A \bar{y}$

$S_V = -\sum \bar{A}\left[\overline{A^2} y \Delta\left\{\frac{1}{n^2}\right\} - \left(\aleph - \bar{A} y\right)\bar{y} P\right]$

Fundamental Parameters of the Seidel Aberrations

Refraction Invariant of the Marginal and Chief Rays

$$A \equiv ni = n'i' = nu + nyc = n'u' + n'yc$$

$$\overline{A} \equiv n\bar{i} = n'\bar{i}' = n\bar{u} + n\bar{y}c = n'\bar{u}' + n'\bar{y}c$$

y is the marginal ray height at the surface in question

$$\Delta\left(\frac{u}{n}\right) = \left(\frac{u'}{n'} - \frac{u}{n}\right)$$

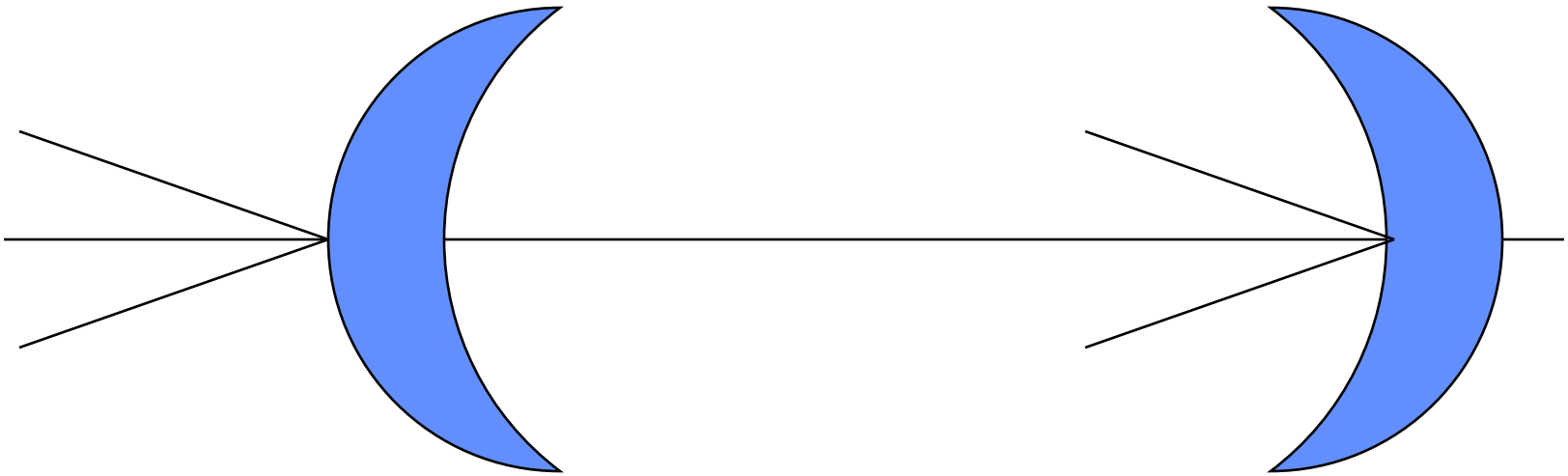
Aplanatic Surface: Zero Spherical and Coma at the Surface

Methods to make Aberrations Zero at a Surface

$$S_I = -\sum A^2 y\Delta\left(\frac{u}{n}\right) \quad S_{II} = -\sum A\bar{A} y\Delta\left(\frac{u}{n}\right) \quad S_{III} = -\sum \bar{A}^2 y\Delta\left(\frac{u}{n}\right)$$

- Aberration at surface is product of three or four quantities
- Make y = zero
- Make refraction invariant(s) zero
- Make delta u/n zero

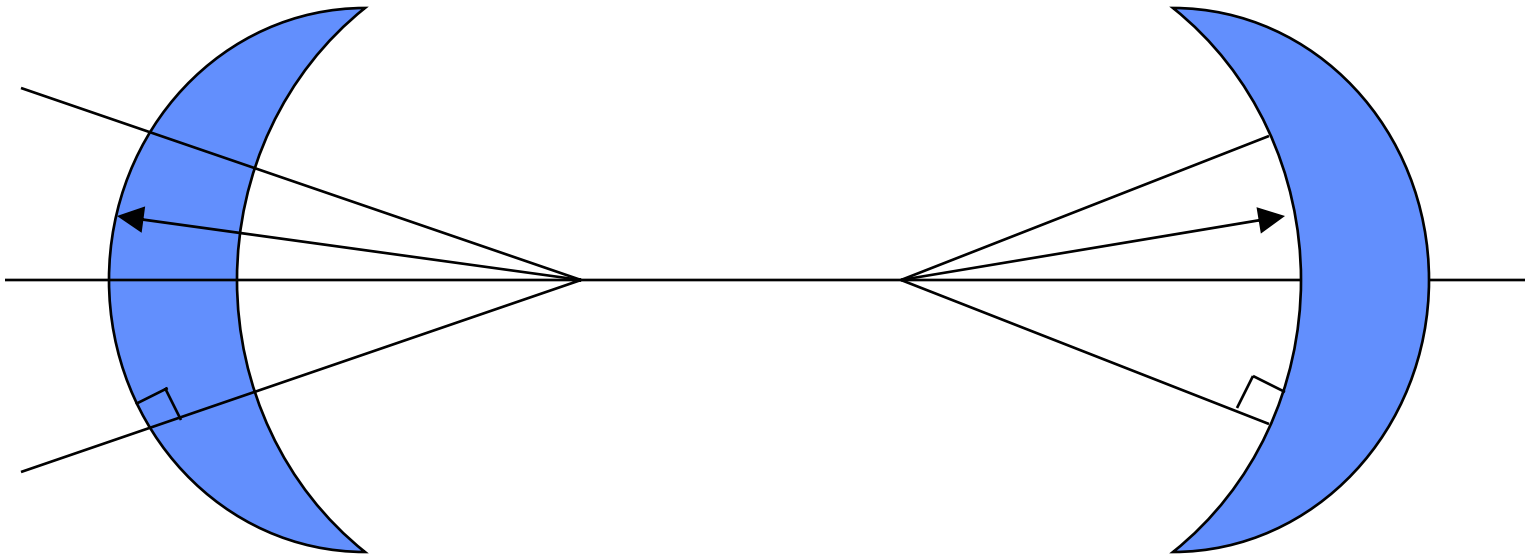
Marginal Ray Height y=0



Convex Surface

Concave Surface

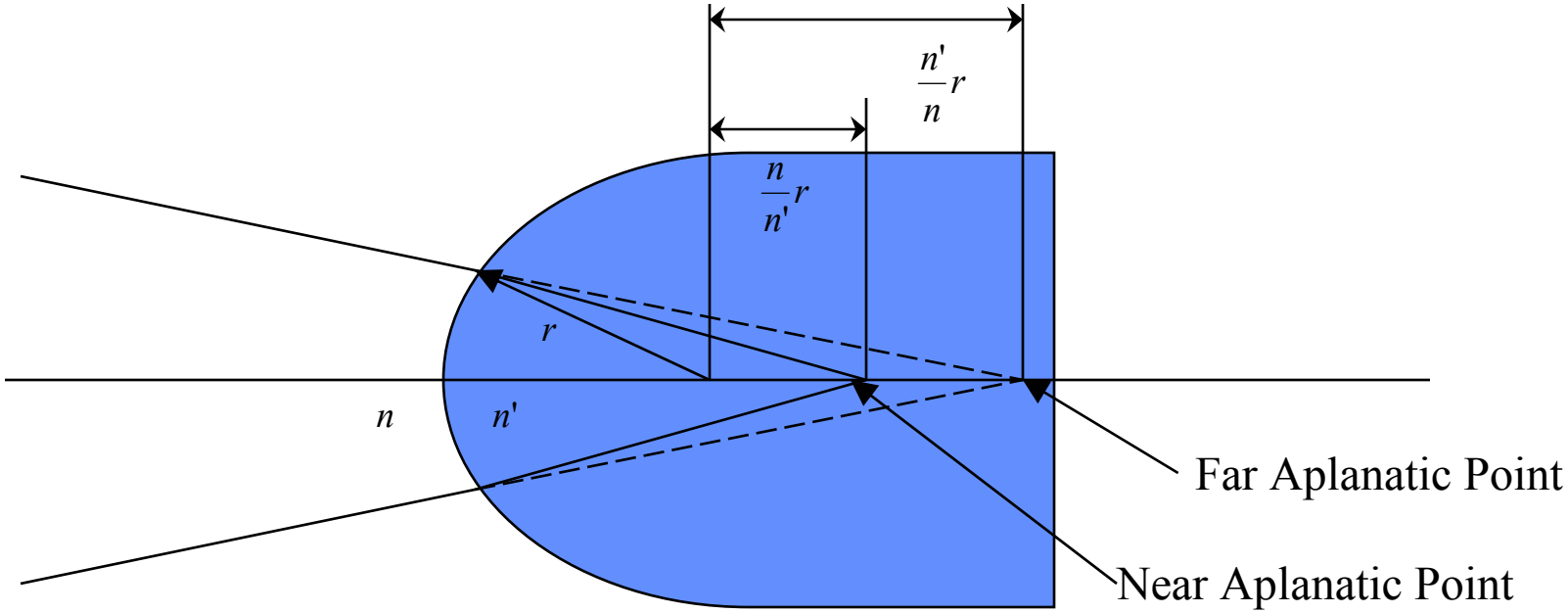
Marginal Ray Refraction Invariant A=0 because AOI=0



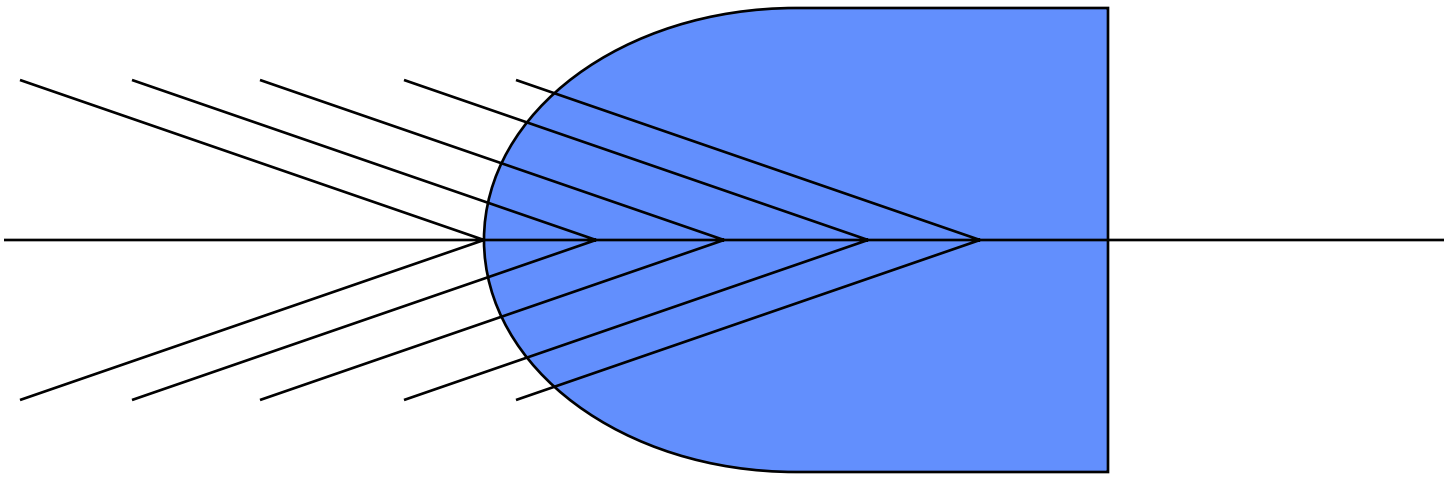
Convex Surface

Concave Surface

Delta u/n=0 when aiming for far aplanatic point and refracts to near aplanatic point

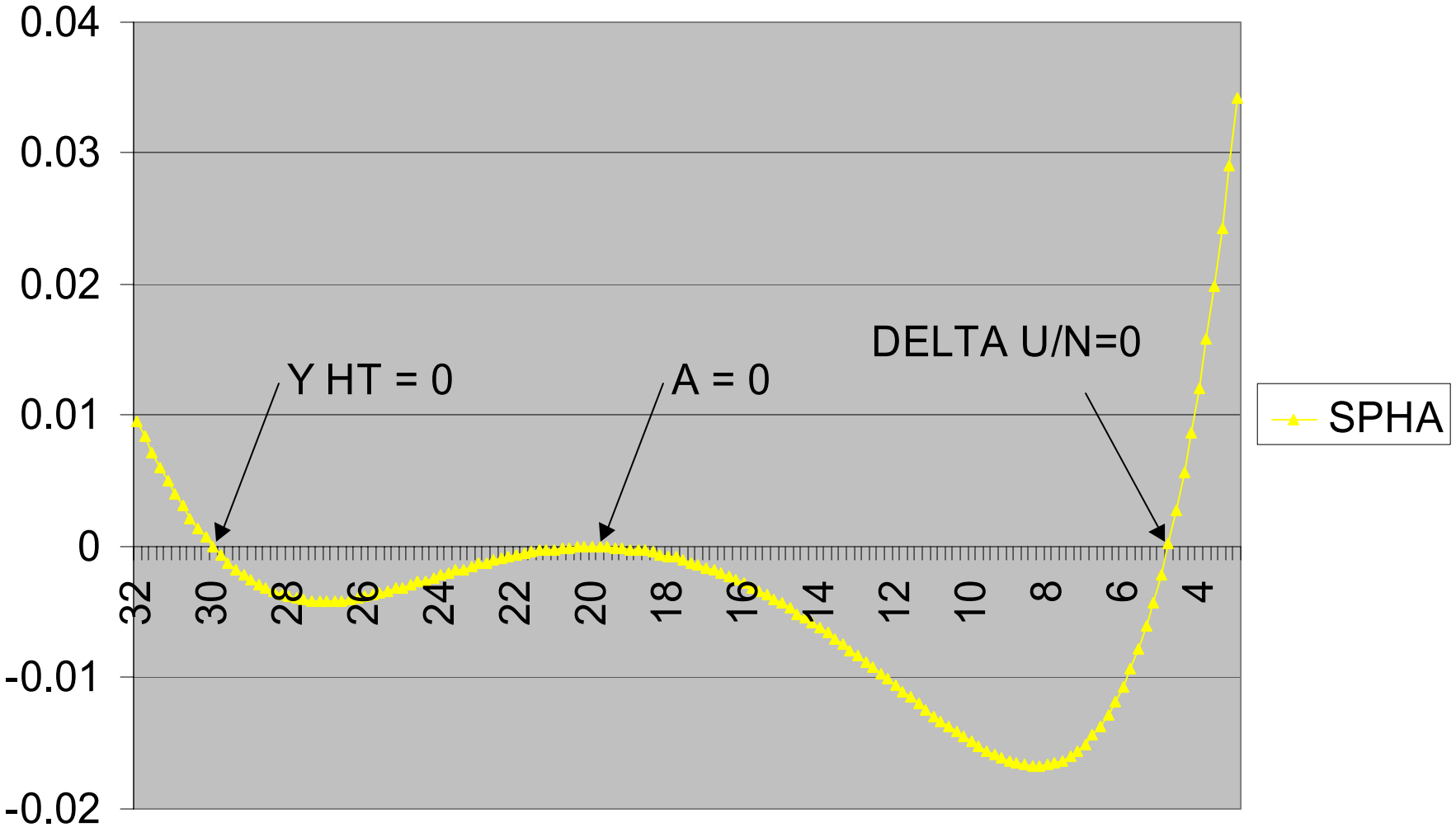


Zooming through the aplanatic conditions of a spherical refractive surface w/ Zemax Macro

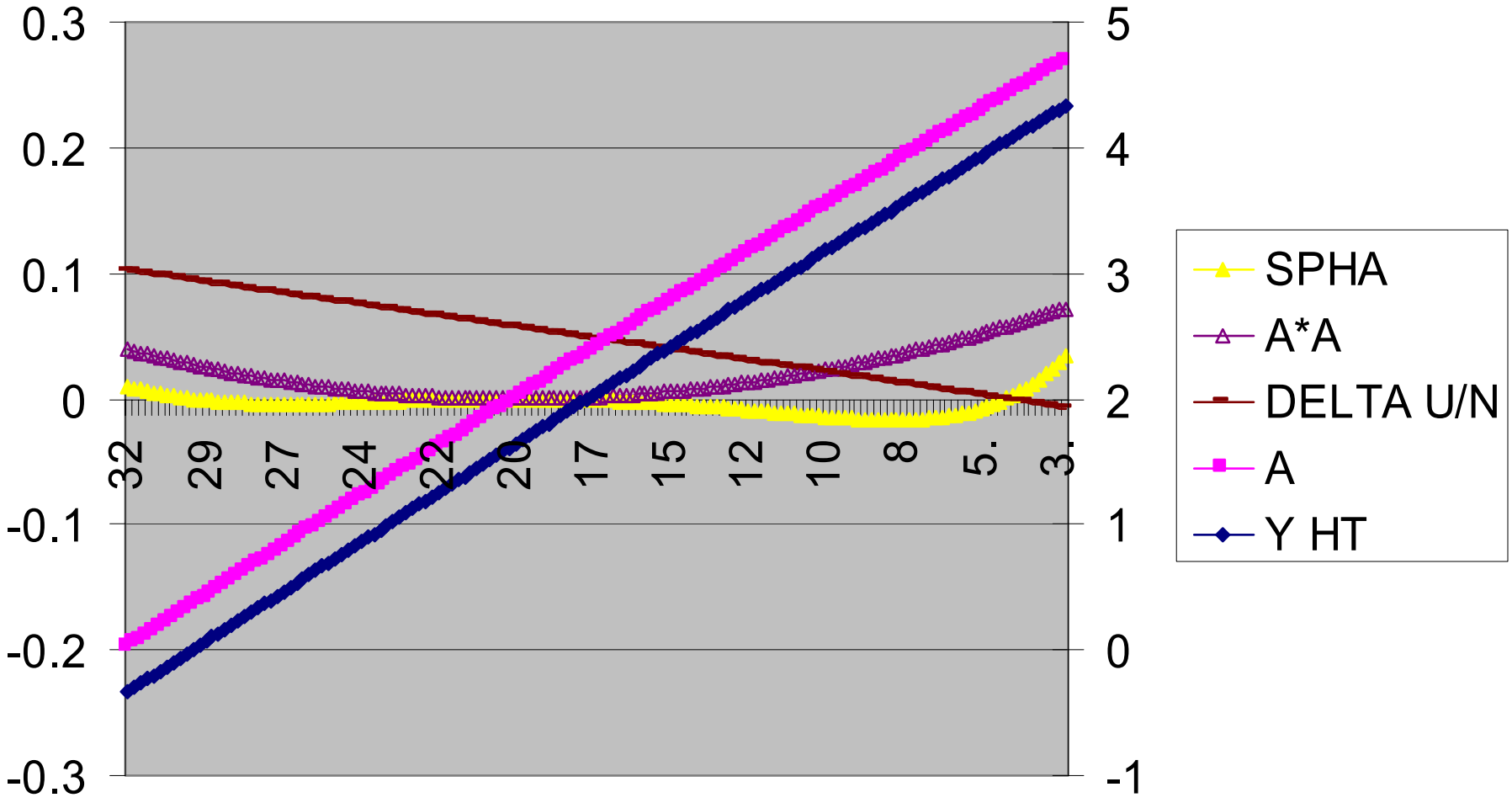


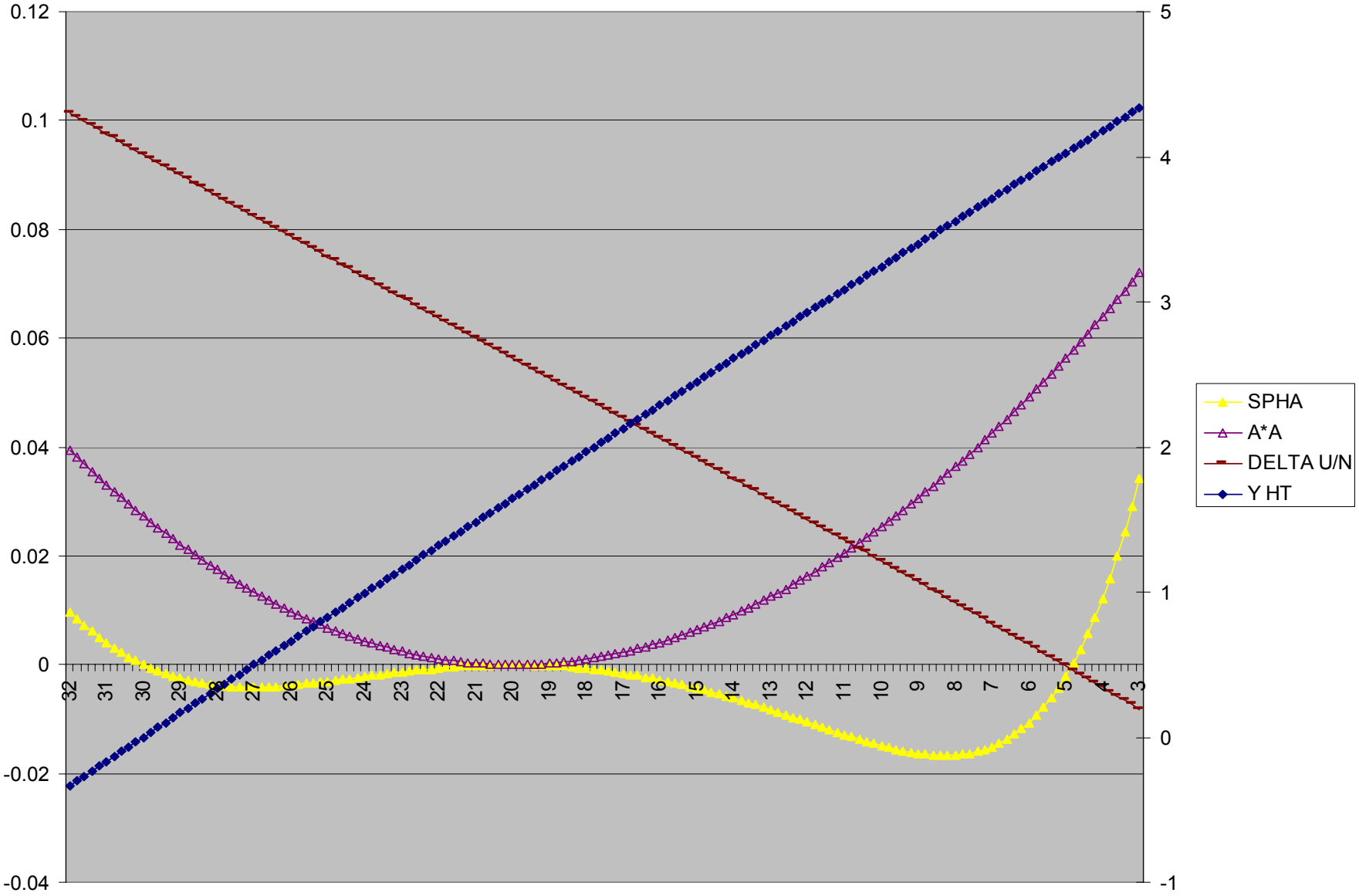
Please Note: Refraction of rays not shown

Seidel Coefficient S1



Seidel Coefficient S1

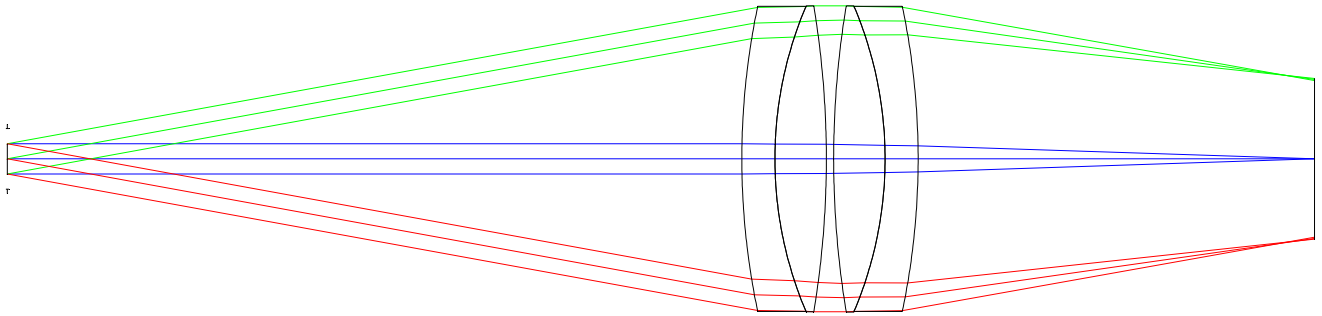




Plossl Eyepiece Design

Please Note: This optical design is backwards

SF12/Bk7 Both



	W040	W131	W222	W220P	W311	W020	W111
TOT	0.02	0.45	2.20	0.66	28.74	-0.29	-6.20

LAYOUT

PLOESSL EYEPIECE
THU JAN 4 2001
TOTAL LENGTH: 177.95883 MM

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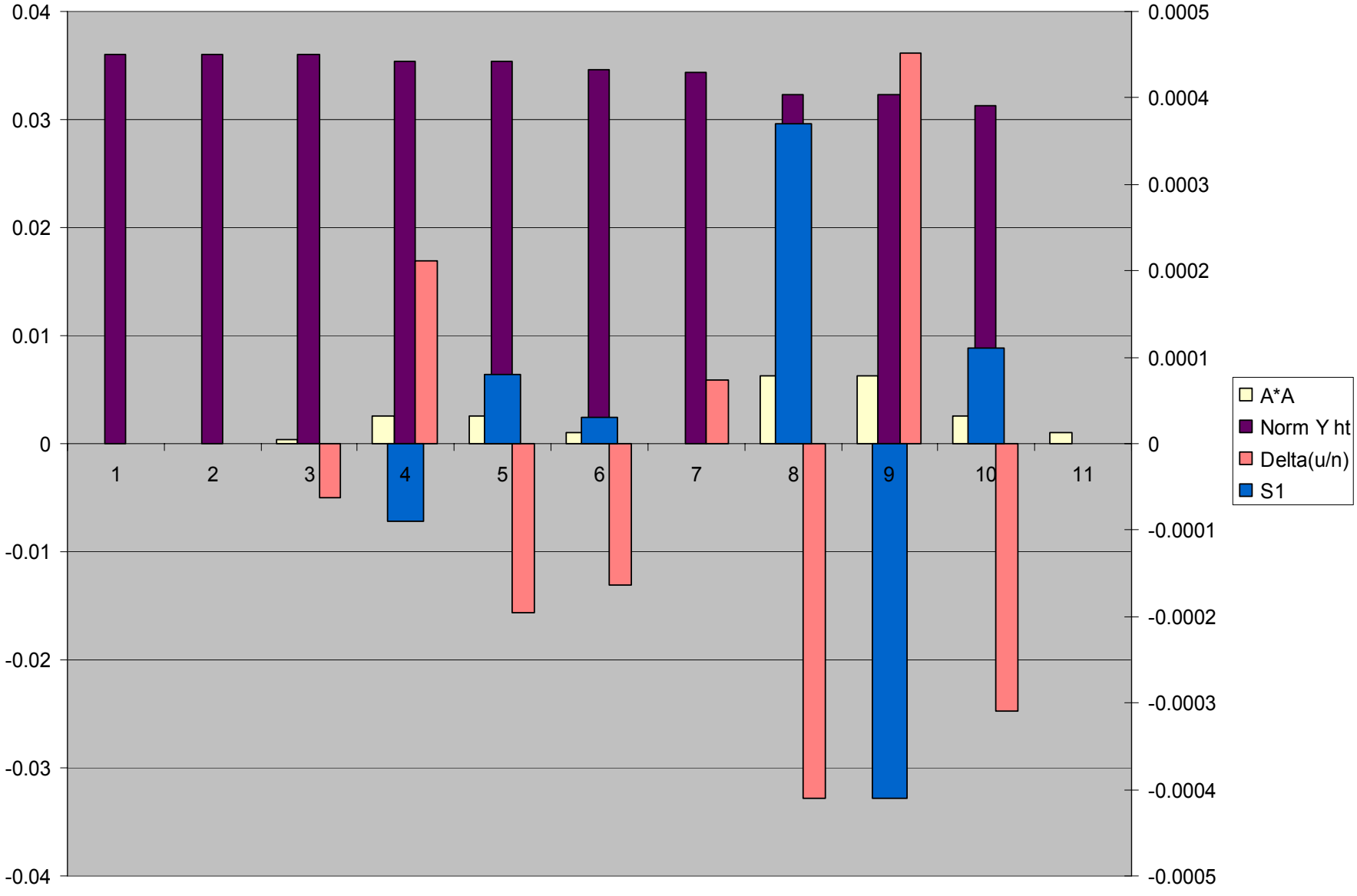

Summary of Seidel's

- "A good lens designer must understand what is behind 3rd order aberrations and theory. It is crucial, critical, and essential that you know the 3rd order aberrations"
- Break the Seidel Aberrations down to their fundamental parameters
- Understand how optical design variables affect these fundamental parameters and you have arrived at the genesis of 3rd order lens design theory
- My approach to understanding aplanatic conditions
- Thanks you for your invitation and attention