Cooke triplet

Lens Design OPTI 517

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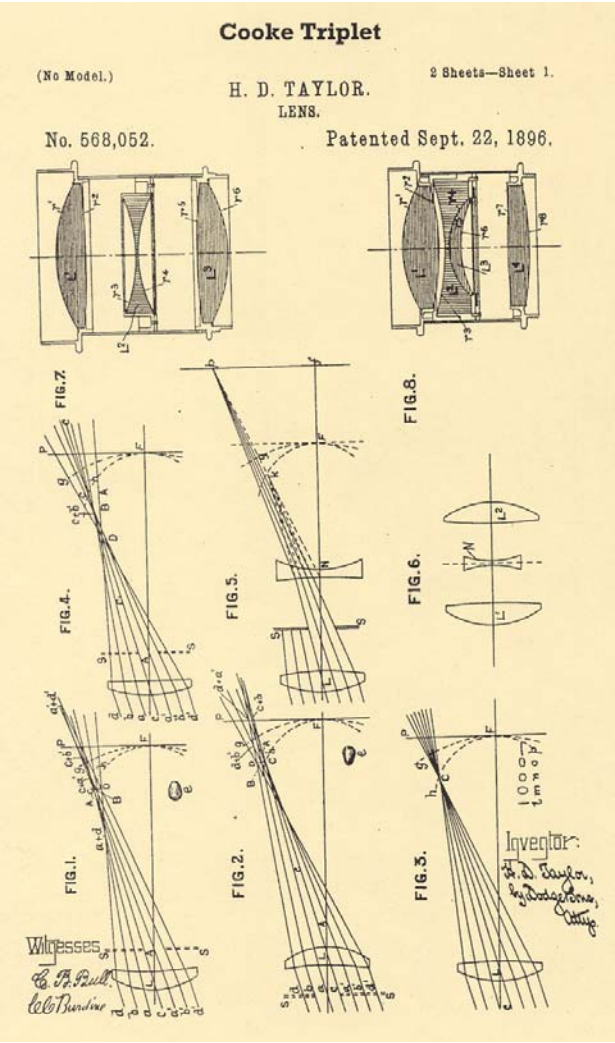
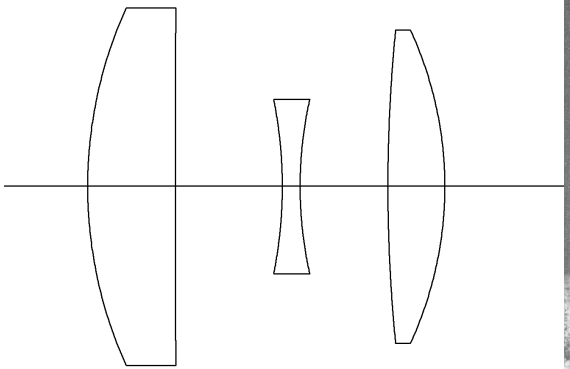
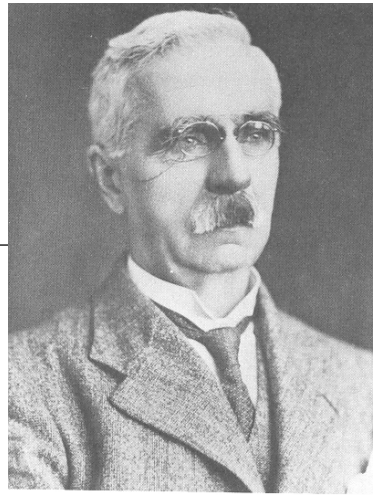
Cooke triplet

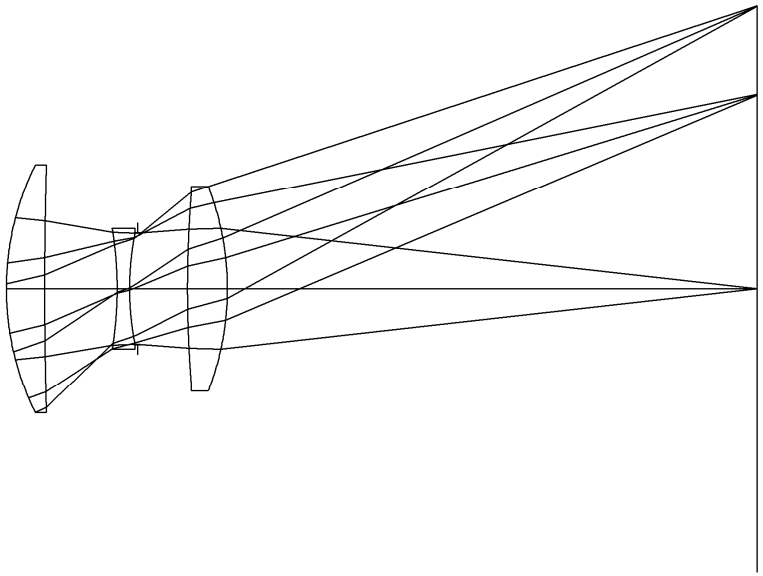




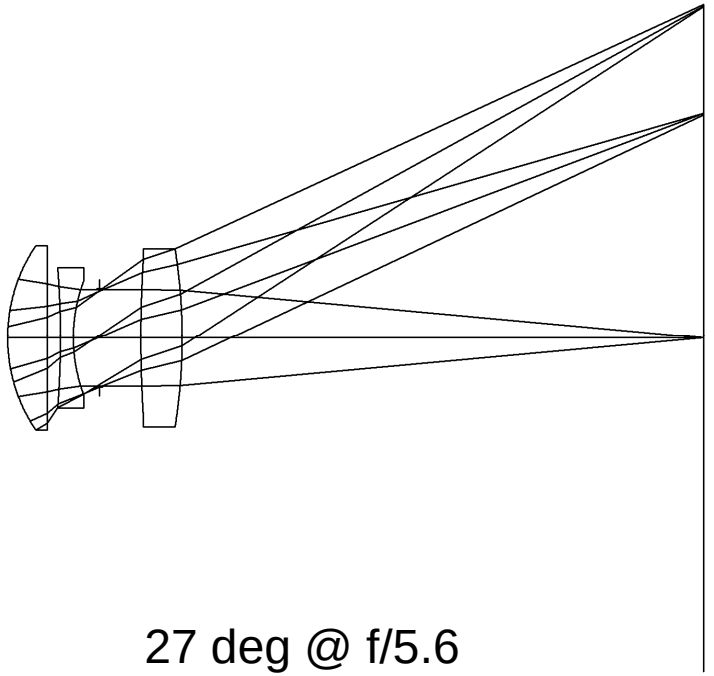


- A new design
- Enough variables to correct all third–order aberrations
- Thought of as an afocal front and an imaging rear
- 1896
- Harold Dennis Taylor

Cooke triplet field-speed trade-off's



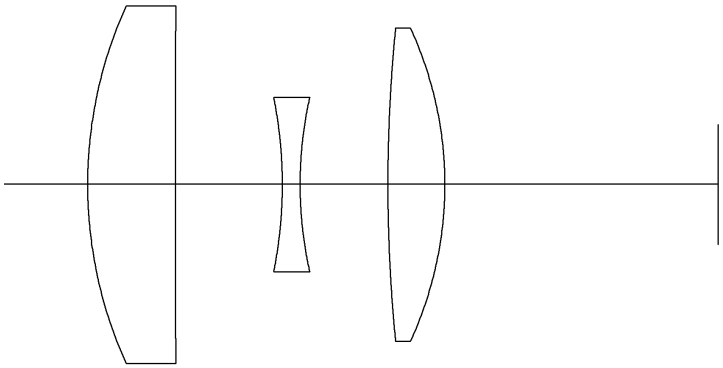
24 deg @ f/4.5



27 deg @ f/5.6

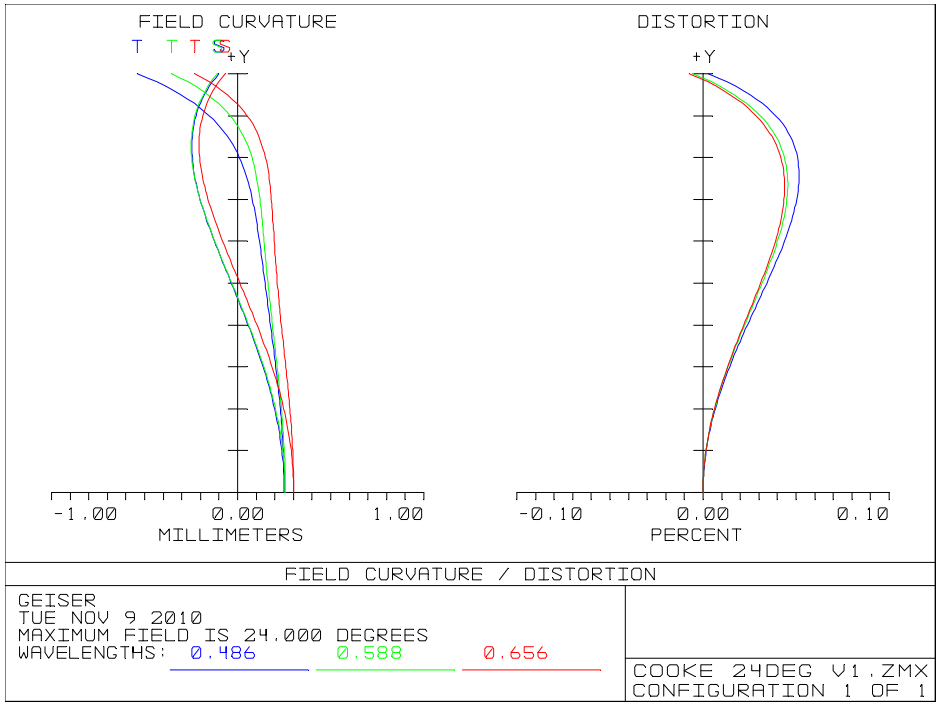
Aberration correction

- Powers, glass, and separations for: power, axial chromatic, field curvature, lateral color, and distortion. Lens bendings, for spherical aberration, coma, and astigmatism. Symmetry.

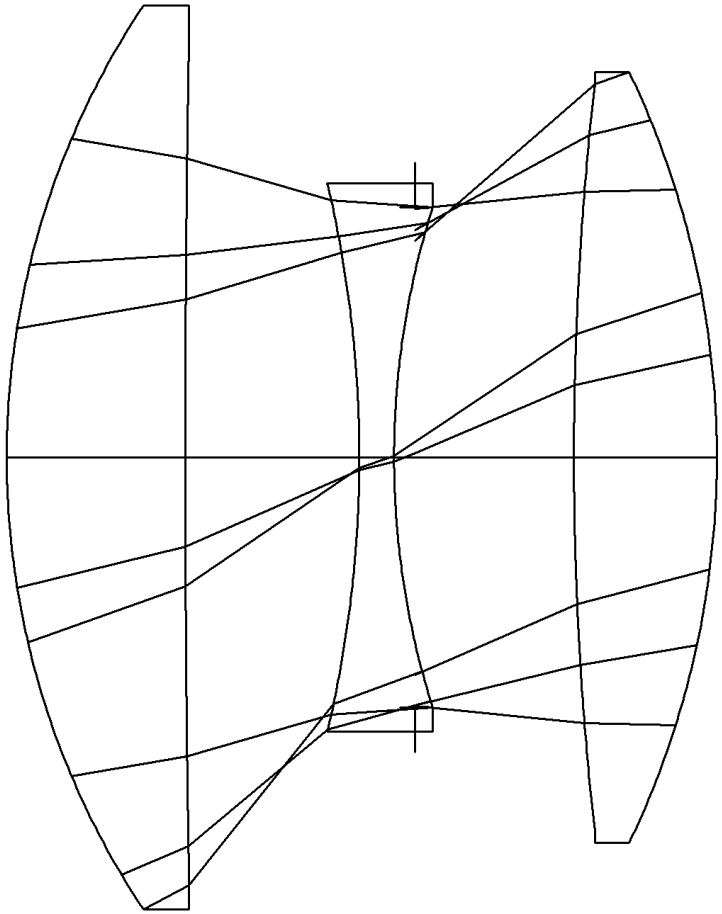


- Power: $$y_a\phi_a + y_b\phi_b + y_c\phi_c = y_a\phi$$
- Axial color: $$y_a^{\,2}\phi_a/V_a + y_b^{\,2}\phi_b/V_b + y_c^{\,2}\phi_c/V_c = 0$$
- Lateral color: $$y_a\,\bar{y}_a\phi_a/V_a + y_b\,\bar{y}_b\phi_b/V_b + y_c\,\bar{y}_c\phi_c/V_c = 0$$
- Field curvature: $$\phi_a/n_a + \phi_b/n_b + \phi_c/n_c = 0$$

- Crossing of the sagittal and tangential field is an indication of the balancing of third-order, fifth-order astigmatism, field curvature, and defocus.



The strong power of the first positive lens leads to spherical aberration of the pupil which changes the chief ray high whereby inducing significant higher order aberrations.



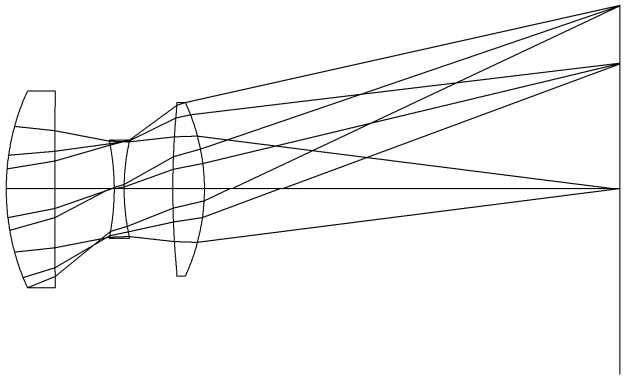
$$\bar{Y} = \bar{y} + a\bar{y}^3$$

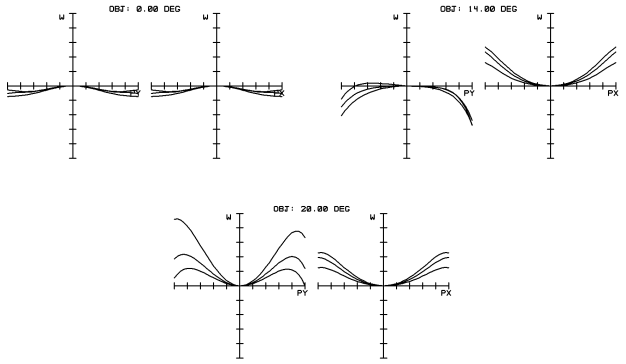
$$\bar{Y}^2 = \bar{y}^2 + 2a\bar{y}^4 + a^2\bar{y}^6$$

$$W_{222} \propto \bar{Y}^2$$

$$W_{422} \propto a\bar{y}^2 W_{222}$$

Cooke triplet example from Geiser OE





- 5 waves scale
- visible

F1=34 mm
F2=-17 mm
F3=24 mm

1 STANDARD	23.713	4.831	LAK9
2 STANDARD	7331.288	5.86	
STO STANDARD	-24.456	0.975	SF5
4 STANDARD	21.896	4.822	
5 STANDARD	86.759	3.127	LAK9
6 STANDARD	-20.4942	41.10346	
IMA STANDARD	Infinity		

From Geiser OE f/4 at +/- 20 deg. f=50 mm.

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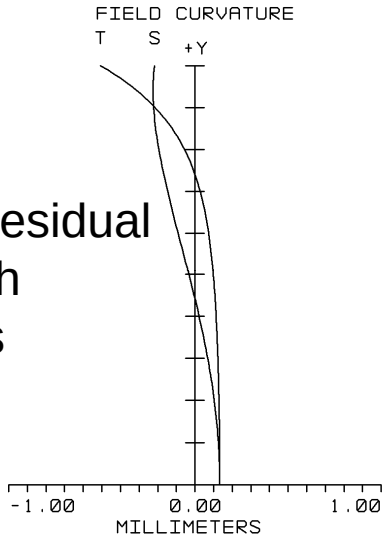
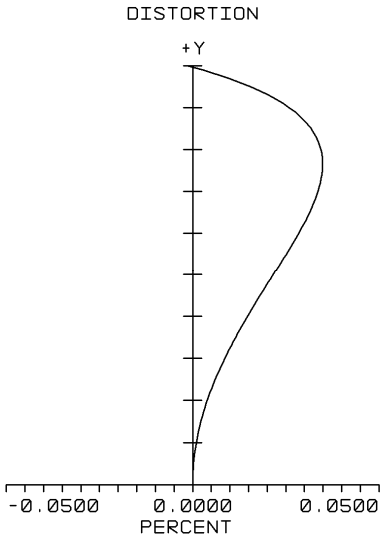
Aberration coefficients

Surf	W040	W131	W222	W220	W311	W020	W111
1	5.883061	16.491222	11.556926	37.942379	61.278483	-0.000000	-0.000000
2	4.697811	-50.633600	136.433840	-0.122724	-366.963936	0.000000	-0.000000
STO	-22.370883	117.170758	-153.424726	-36.207024	295.715864	0.000000	-0.000000
4	-9.649013	-65.348394	-110.643768	-40.440216	-324.276663	-0.000000	-0.000000
5	1.689360	24.150389	86.310980	10.370424	382.592103	-0.000000	-0.000000
6	22.084875	-42.606408	20.549199	43.901573	-52.258664	0.000000	-0.000000
TOT	2.335211	-0.776033	-9.217549	15.444412	-3.912814	0.000000	0.000000

TOTALS

2.3352	-0.7760	-9.2175	10.8356	-3.9128
82.2662	-16.2711	-95.1410	-32.1261	29.4709
-2.1155	3.7462	6.6350	-6.7109	2.3168
-0.7484	-0.5892	-4.6825	-1.2398	





Petzval/Astigmatic residual
de-stresses as much
As possible the lens

Petzval radius
Is -142 mm

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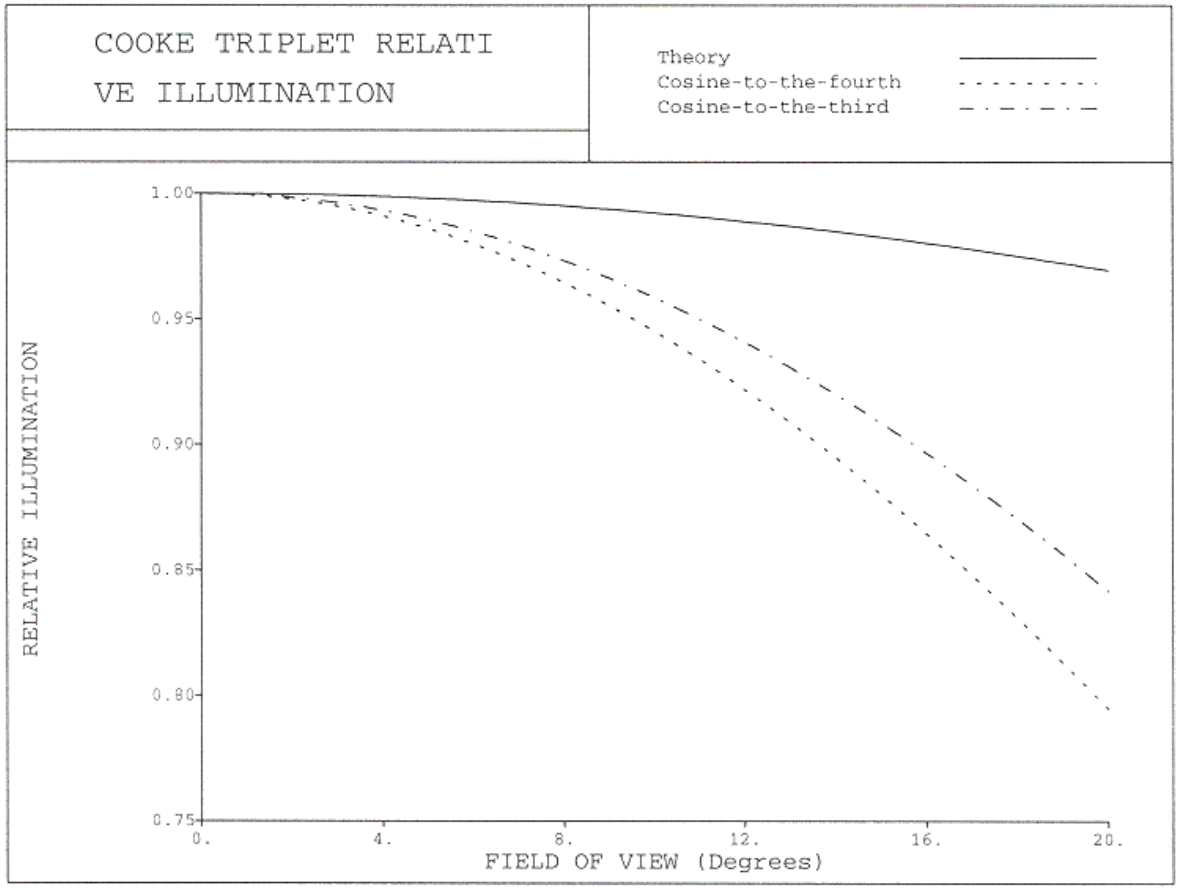
Geometrical causes for uneven illumination: Cosine to the four power law, vignetting, image distortion, pupil distortion.



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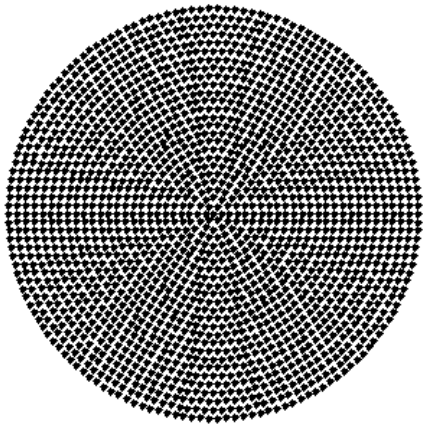
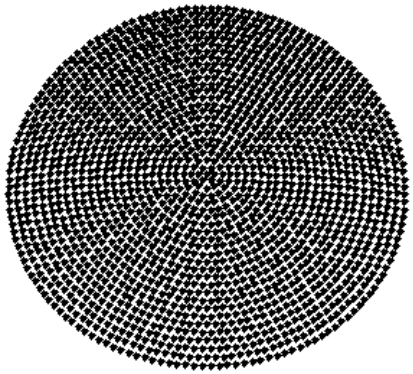
Cross section of ray bundle at stop and entrance pupil for a Cooke triplet lens

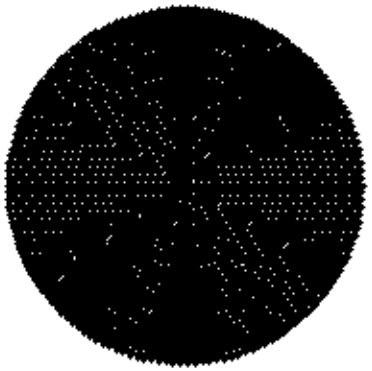


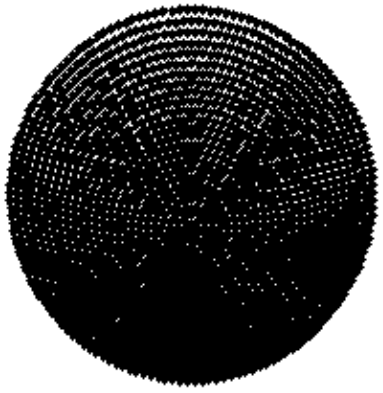
On-axis



24 deg off-axis

At stop with no
Ray aiming





At entrance pupil
With ray aiming

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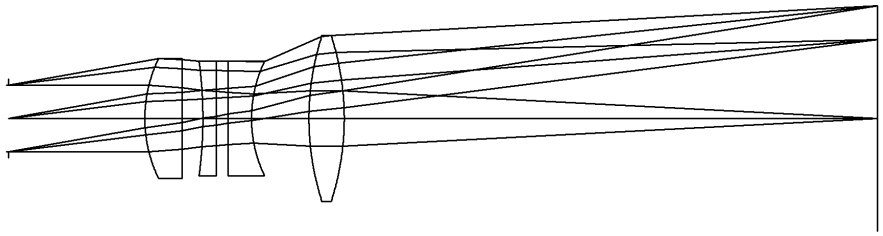
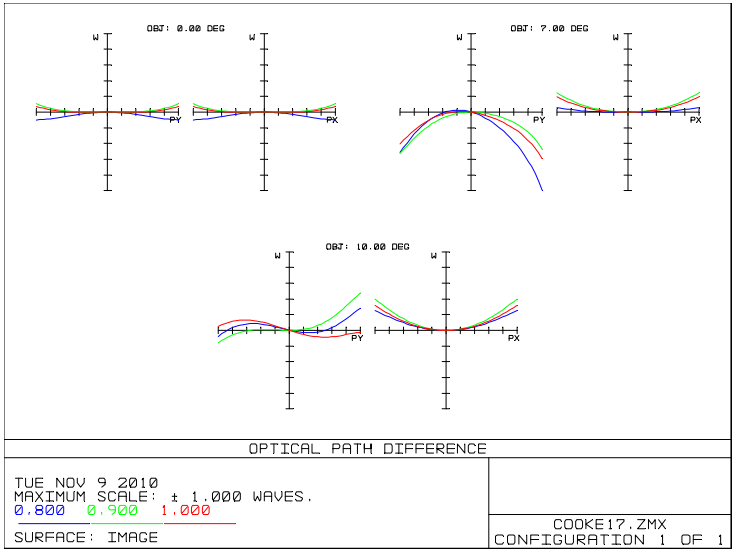
Other Cooke triplet issues

- Aberrations are interlocked
- Two fourth-order solutions depending on negative lens shape correcting SA
- From parallel plate or plates
- Tessar lens
- Alternate solution with positive middle lens
- Higher index helps but there is a limit as the Abbe number difference decreases
- Cooke triplet is an stressed lens
- Telecentric solution
- Afocal front and imager

Designing with off-the-shelf lenses





Surf	Type	Radius	Thickness	Glass	Diameter	Conic	Comment
OBJ	STANDARD	Infinity	Infinity		0	0	
STO	STANDARD	Infinity	20.4795		10	0	
2	STANDARD	20.67	5.6	BK7	17.94473	0	eo-45279
3	STANDARD	Infinity	3.1109		17.5803	0	
4	STANDARD	-64.84	2	BK7	17.18685	0	mg-01LPK1
5	STANDARD	Infinity	1.8011		17.15615	0	
6	STANDARD	Infinity	3.5	SF11	17.12374	0	eo-45031
7	STANDARD	19.62	8.6343		17.06787	0	
8	STANDARD	40.42	5.3	BK7	24.49965	0	eo-45297
9	STANDARD	-40.42	80.07258		24.91046	0	
IMA	STANDARD	Infinity			33.72505	0	

F=96 mm
f/9
+/- 10 deg

OPTI517
student

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