Combinations of achromatic doublets

Introduction to aberrations

OPTI 518

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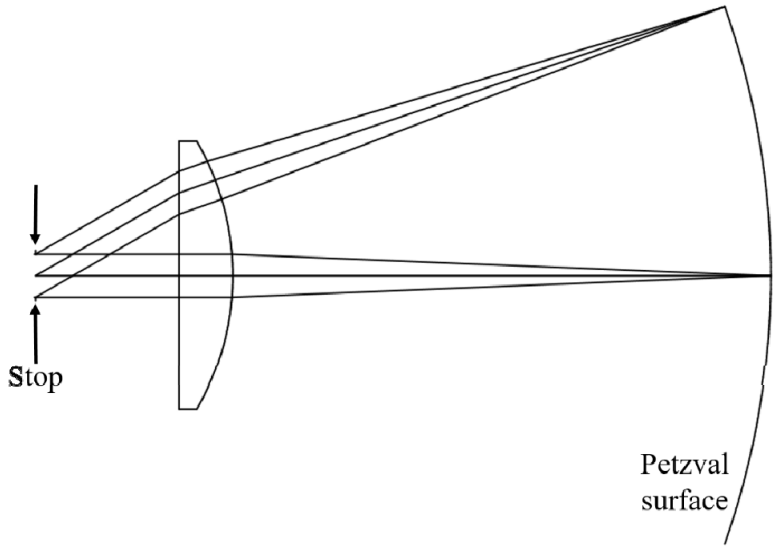
Plano convex lens



N-BK7 : Petzval radius -151.7 mm

$$C_{Petzval} = \frac{1}{\rho_{Petzval}} = -\phi \cdot \sigma_{IV} = -\left(\frac{\phi}{n}\right)$$

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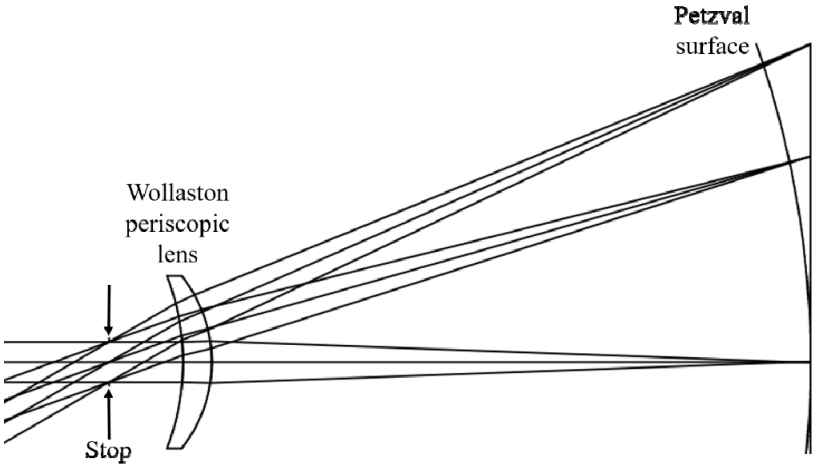
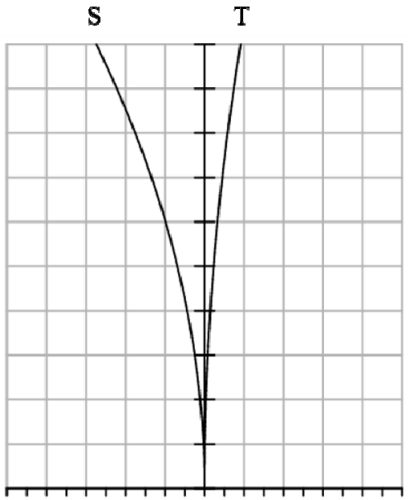
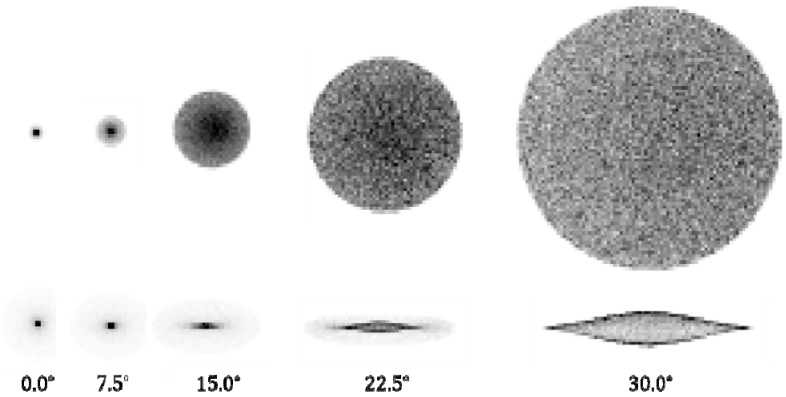
Wollaston meniscus lens







$$W_{222} / W_{220P} = -0.8$$

- Artificially flattening the field
- Periscopic lenses

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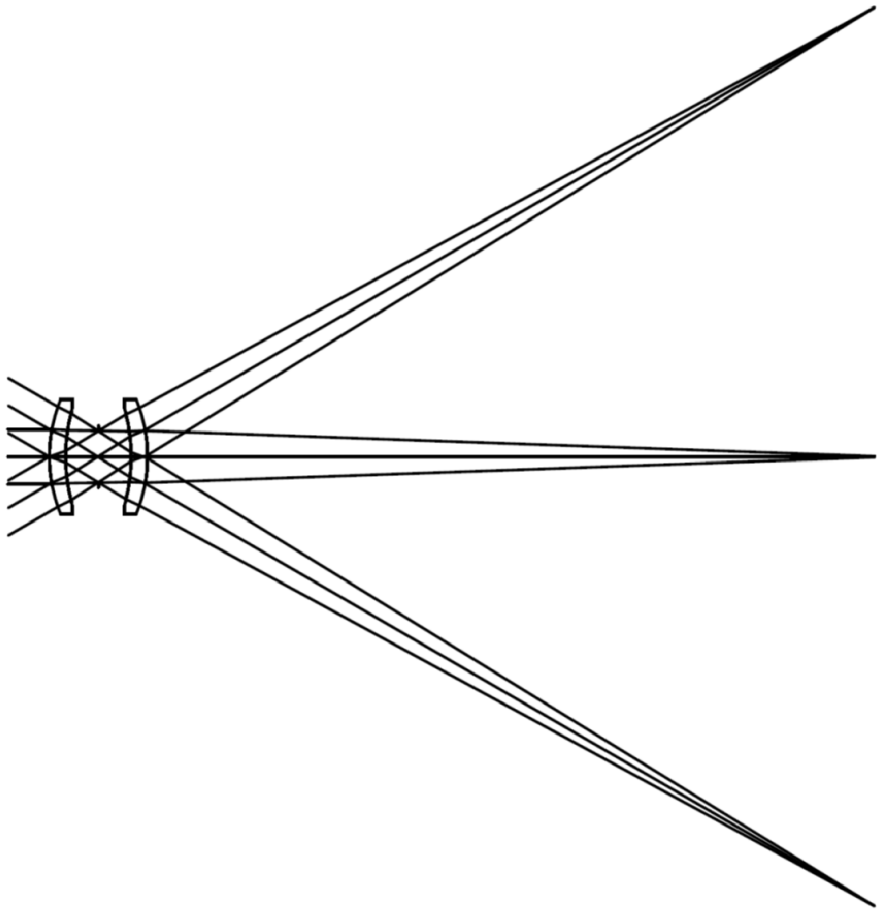
Periskop lens



- Principle of symmetry
- No distortion

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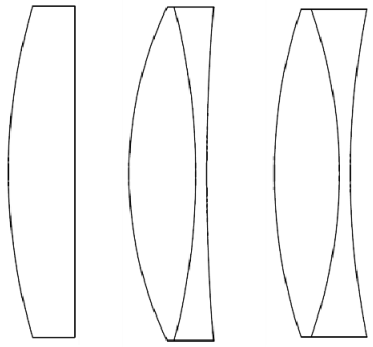
Field curvature



- Old achromat
- New achromat

N-BK7 : Petzval radius -151.7 mm

N-BK7 and N-F2: Petzval radius -139.99 mm (+139.99 for negative doublet)

N-BAK1 and N-LLF6: Petzval radius -185 mm

$$C_{Petzval} = \frac{1}{\rho_{Petzval}} = -\phi \cdot \sigma_{IV} = -\left(\frac{\phi_1}{n_1} + \frac{\phi_2}{n_2}\right) = -\frac{\phi}{v_1 - v_2}\left(\frac{v_1}{n_1} - \frac{v_2}{n_2}\right)$$

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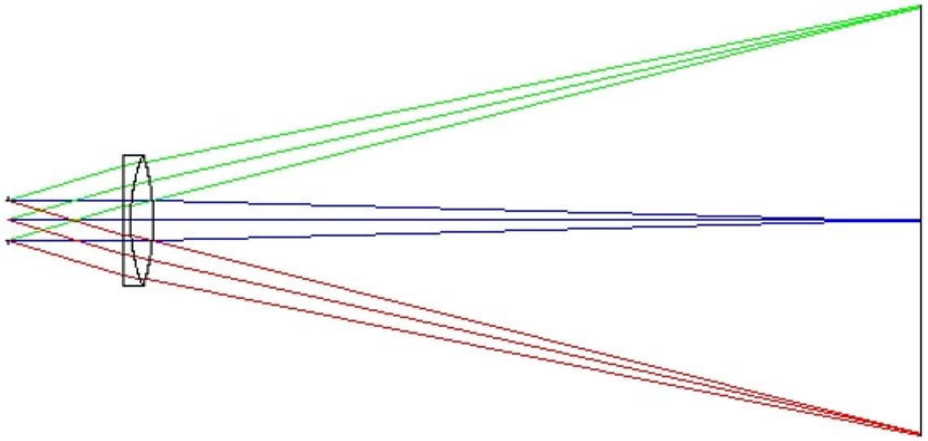
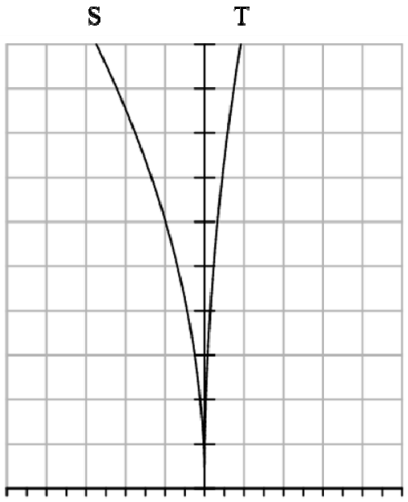
Chevalier landscape lens





$$W_{222} / W_{220P} = -0.8$$

- F/5 telescope doublet used in reverse and with an aperture stop in front

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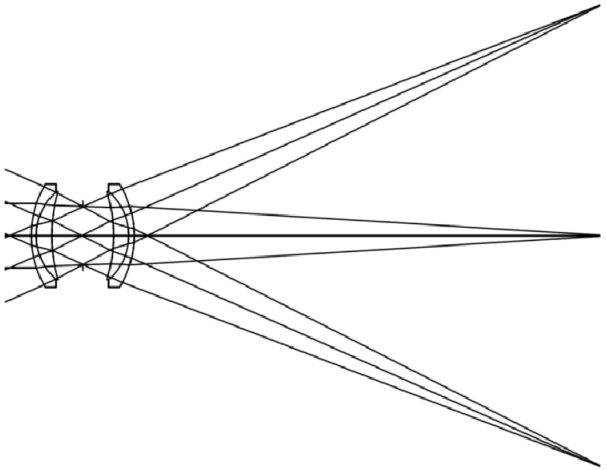
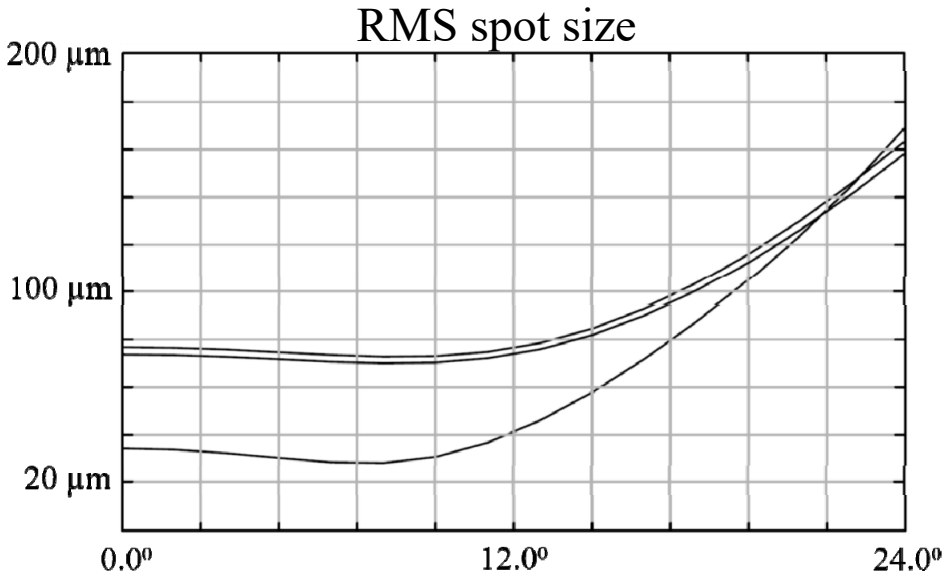
Rapid rectilinear



- F/8
- Glass selection is key

to minimize spherical aberration while artificially flattening the field



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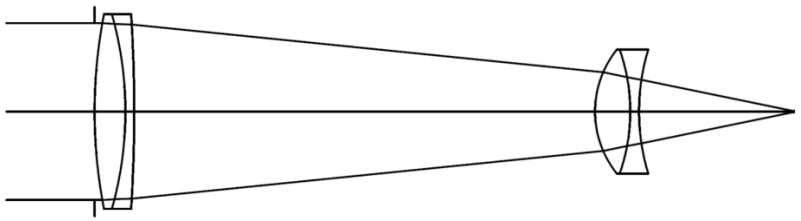
Lister microscope objective



- Telecentric

$$\sigma_{IA} = \sigma_{IB} = 0$$

$$\sigma_{II} = \phi_A^2 y_A^2 \sigma_{IIA} + \phi_B^2 y_B^2 \sigma_{IIB}$$

$$\sigma_{IIA} = -\frac{y_B^2}{(1-y_B)^2}\sigma_{IIB}$$

$$y_B = 1/2$$

$$\sigma_{IIA} = -\sigma_{IIB}$$

$$\sigma_{III} = (1-y_B) + (1+y_B\sigma_{IIB}) = 0$$

$$S_{III}^* = S_{III} + 2\cdot\bar{S}S_{II} + \bar{S}^2 S_I$$

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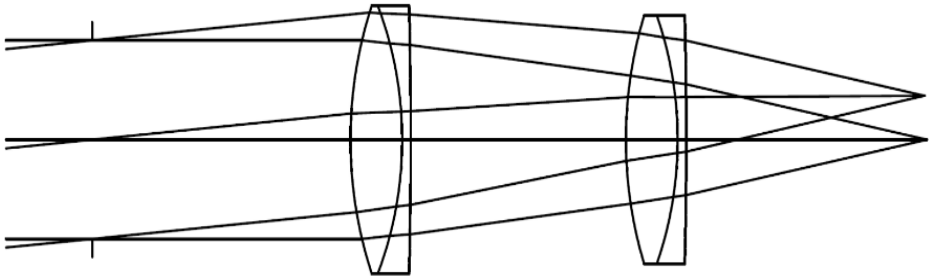
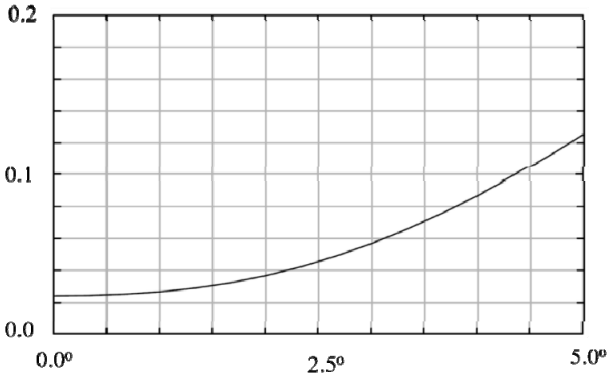
Lister microscope objective

Practical solution



- RMS spot size in waves



- Two identical doublets
- Spherical aberration and coma are corrected
- Astigmatism is small
- Telecentric
- Less vignetting

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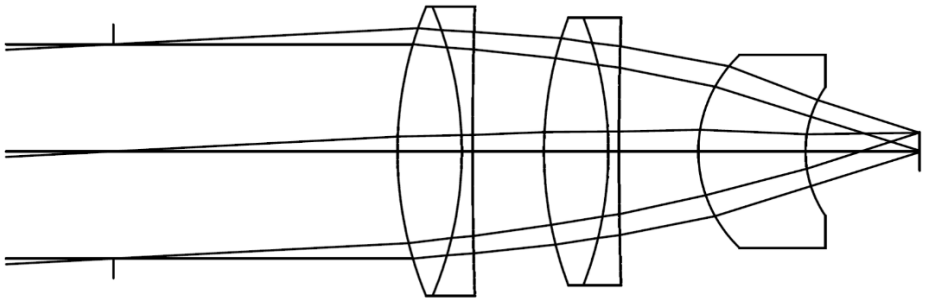
Aplanatic concentric meniscus lens



- Optical speed is increased by an N factor

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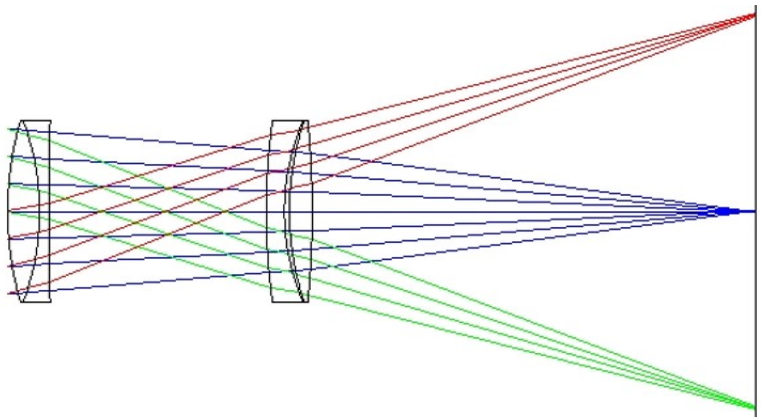
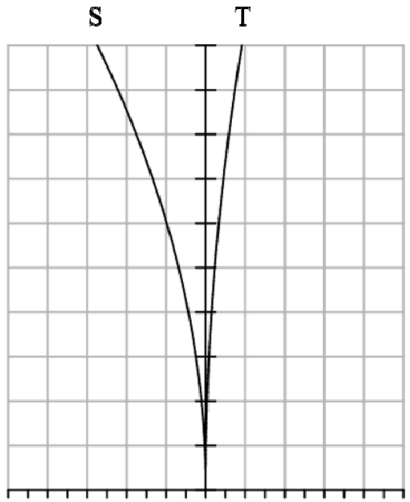
Petzval portrait objective



f'=144 mm; F/3.7; FOV=+/- 16.5º.



$$W_{222} / W_{220P} = -0.8$$

- Chromatic aberration and spherical aberration corrected at each doublet
- Positive coma in the first doublet corrected with negative coma of aberration of the second doublet
- Negative astigmatism introduced by the negative coma of the second doublet to artificially flatten the field of view.

$$S_{III}^{*} = S_{III} + 2 \cdot \bar{S} S_{II} + \bar{S}^{2} S_{I}$$

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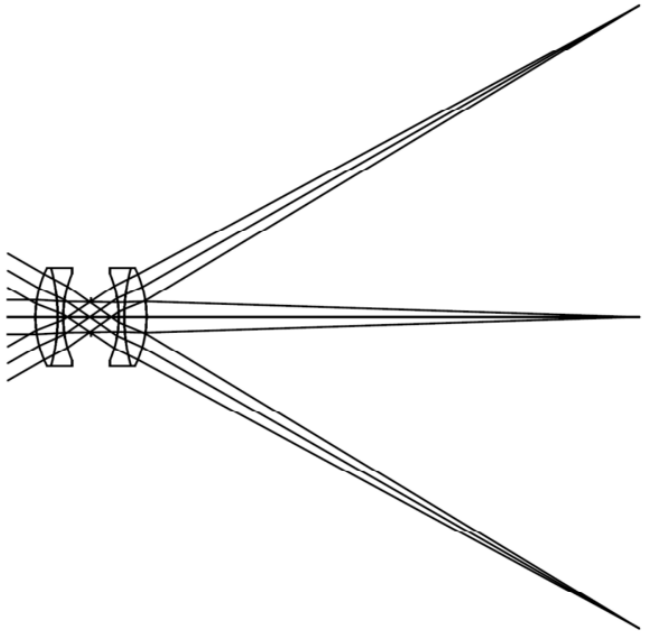
Concentric lens

- Use of new glasses
- Reduced Petzval sum
- Nearly flat field
- Surfaces nearly concentric
- Limited by spherical aberration due to strong curvatures.



N-BAK1 and N-LLF6: Petzval radius -185 mm

$$C_{Petzval} = \frac{1}{\rho_{Petzval}} = -\phi \cdot \sigma_{IV} = -\left(\frac{\phi_1}{n_1} + \frac{\phi_2}{n_2}\right) = -\frac{\phi}{\nu_1 - \nu_2}\left(\frac{\nu_1}{n_1} - \frac{\nu_2}{n_2}\right)$$

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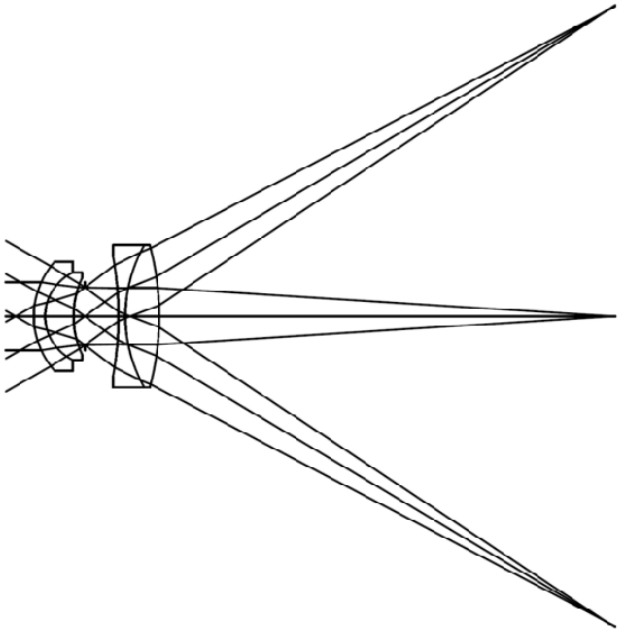
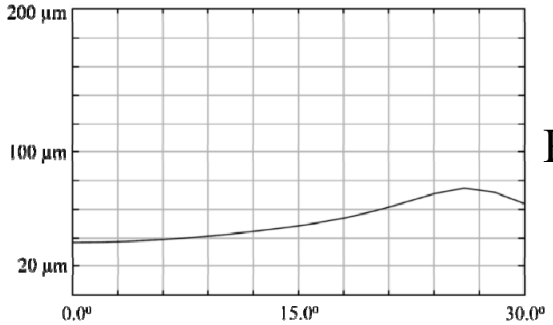
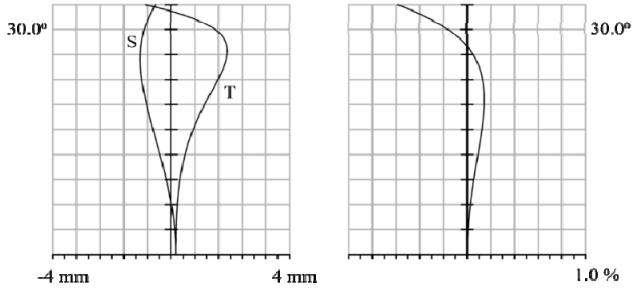
Anastigmatic lens





RMS spot size



- Corrected for spherical aberration, coma, astigmatism, and field curvature
- Distortion is negligible
- Combination of an old achromat and a new achromat

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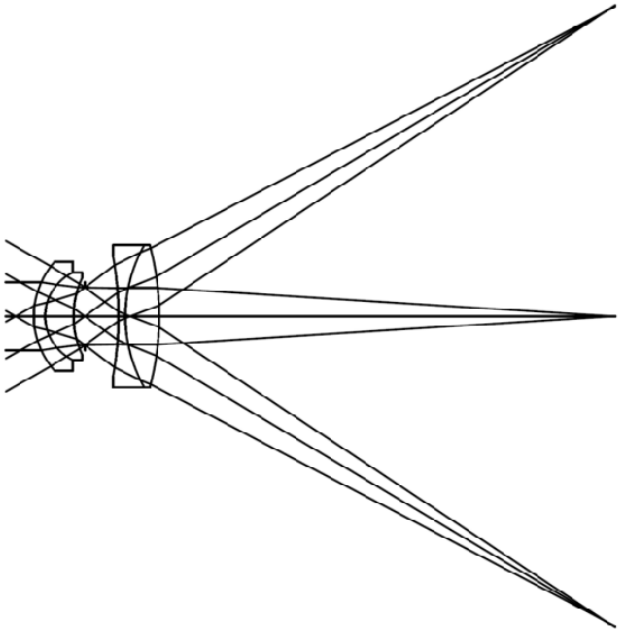
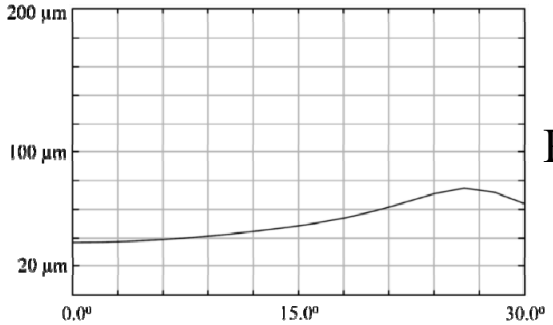
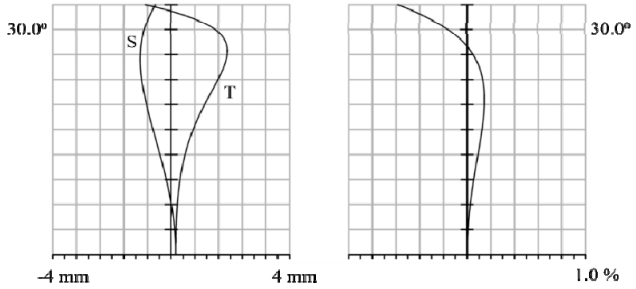
Anastigmatic lens





RMS spot size



- Corrected for spherical aberration, coma, astigmatism, and field curvature
- Distortion is negligible
- Combination of an old achromat and a new achromat

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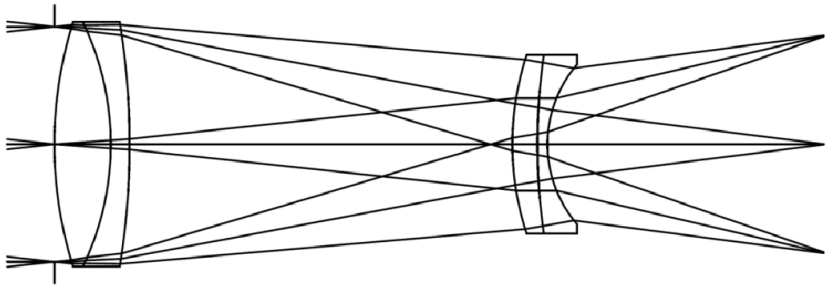
Telephoto lens

Telephoto lens with BK7 and SF5 glasses.
f'=100 mm, F/4, FOV=+/- 6.2º, TTL/F=0.8.



$$S_{III}^{*} = S_{III} + 2\cdot\bar{S}S_{II} + \bar{S}^{2}S_{I}$$

$$S_{III}^{*} = S_{III} = \mathcal{H}^{2}\phi_{B}\sigma_{IIIB} = \mathcal{H}^{2}\phi_{B}$$

$$\phi_{A} = -\phi_{B}$$

$$\bar{W}_{131} = W_{311} + \frac{1}{2}\mathcal{H}\cdot\Delta\left\{\bar{u}^{-2}\right\}$$

- Corrected for spherical aberration, coma, astigmatism, and field curvature
- Distortion is not corrected
- Telephoto ratio=TTL/f

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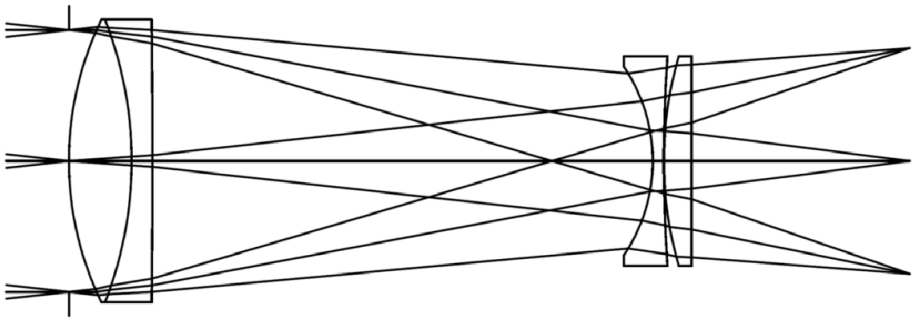
Telephoto lens

Telephoto lens with BK7 and F6 glasses.
f'=100 mm, F/4, FOV=+/- 6.2º, TTL/F=0.8



- Corrected for spherical aberration, coma, astigmatism, and field curvature
- Distortion is also corrected

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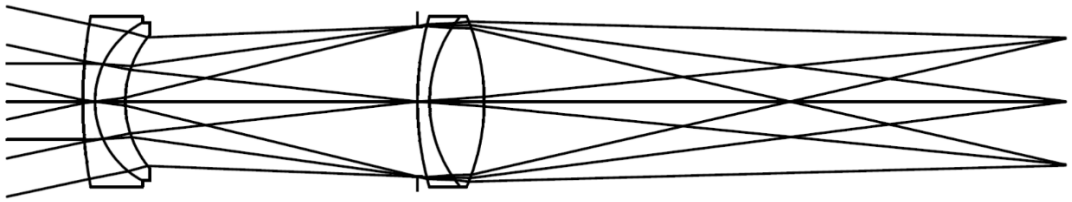
Reverse telephoto lens



Reverse telephoto lens with BK7 and SF5 glasses. f'=100 mm, BFL=200 mm, TTL= 324 mm, FOV=+/-12º, F/4

- Corrected for spherical aberration, coma, astigmatism, and field curvature
- Distortion is small ~-1.5%
- Large back focal length/distance

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