Refractive Optical Design Systems

- Many different types of lens systems used
- Want to look at each from the following
- Field of View
- Performance Requirements
- F#
- Packaging requirements
- Spectral Range

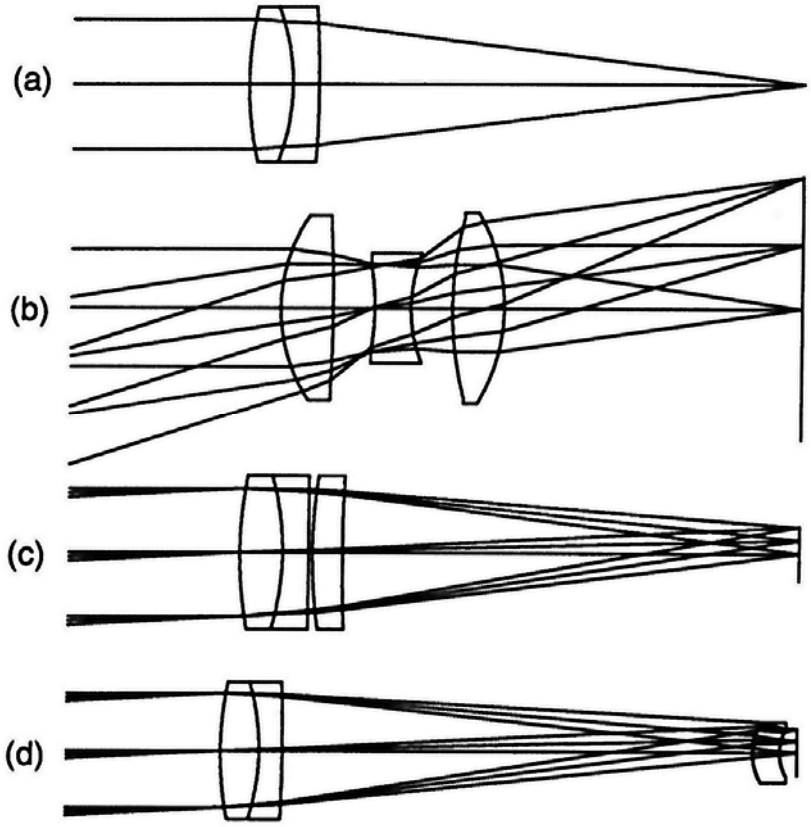
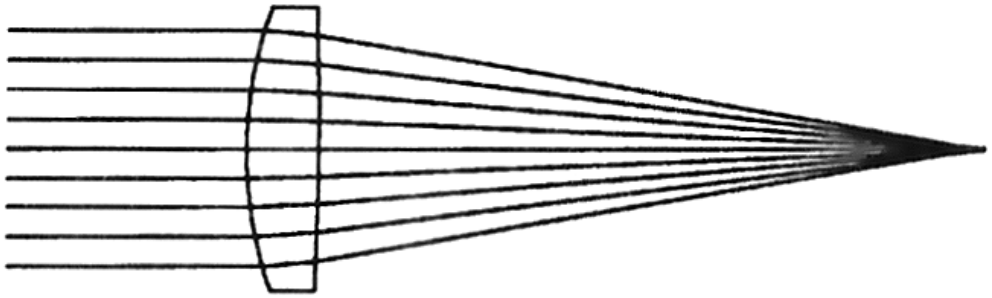


Figure 8.1
Doublets and Triplets

Single Element

- Poor image quality
- Very small field of view
- Chromatic Aberrations – only use a high f#
- However fine for some applications eg Laser with single line
- Where just want a spot, not a full field of view



(a) Single element lens

Landscape Lens

- Single lens but with aperture stop added
- i.e restriction on lens separate from the lens
- Lens is “bent” around the stop
- Reduces angle of incidence – thus off axis aberrations
- Aperture either in front or back
- Simple cameras use this

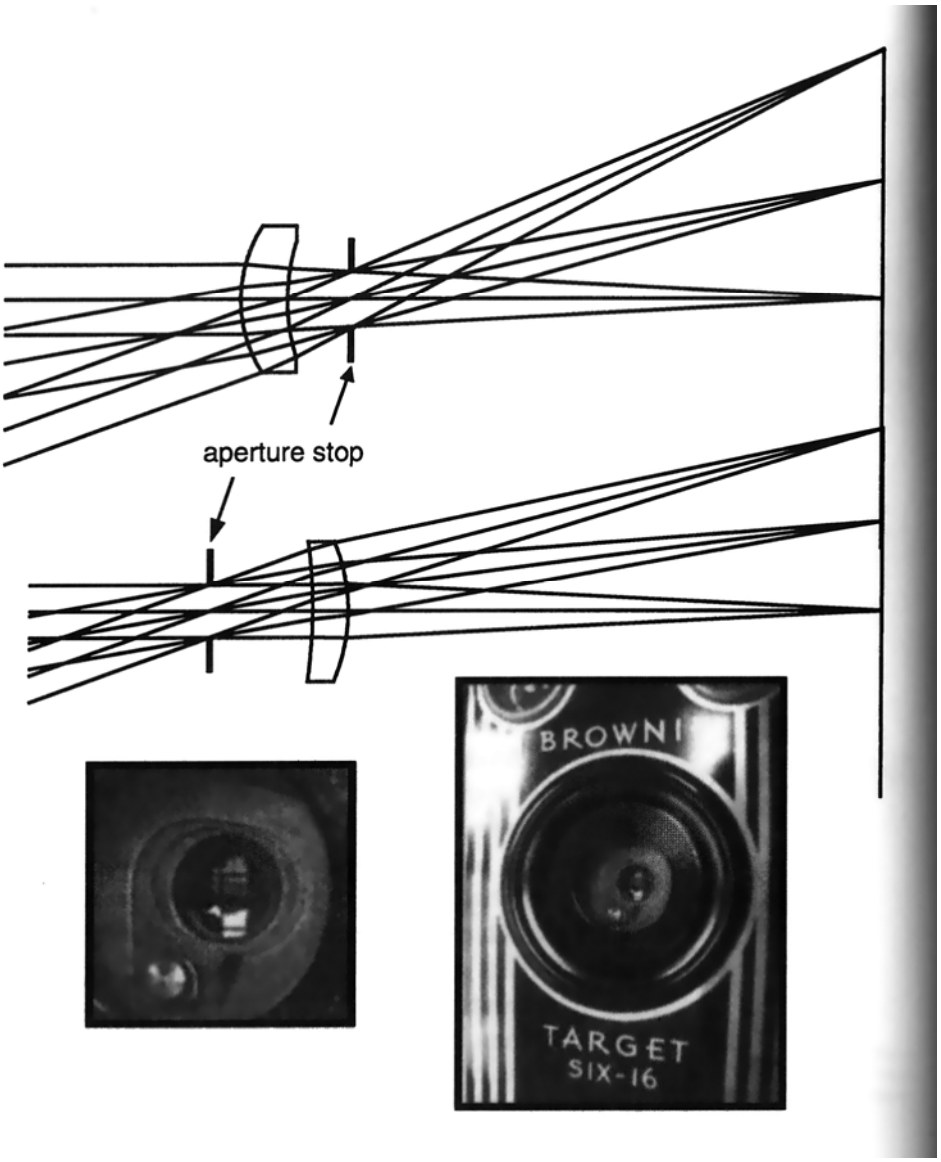
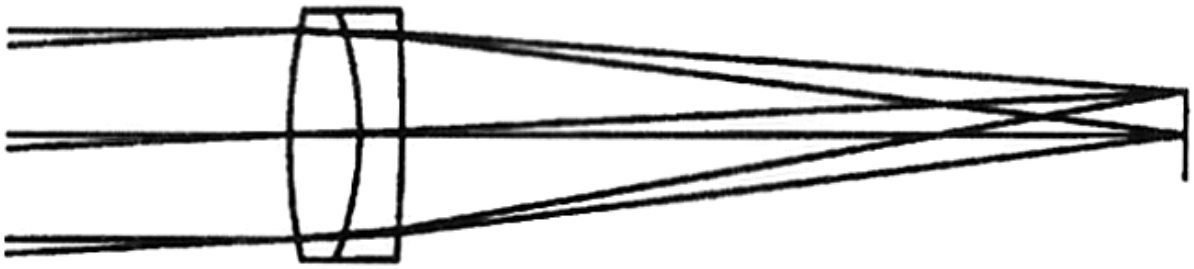


Figure 8.3
Landscape Lens with Stop Aft and Forward of Lens

Achromatic Doublet

- Brings red and blue into same focus
- Green usually slightly defocused
- Chromatic blur 25 less than singlet (for f#=5 lens)
- Cemented achromatic doublet poor at low f#
- Slight improvement if add space between lens
- Removes 5^{th} order spherical



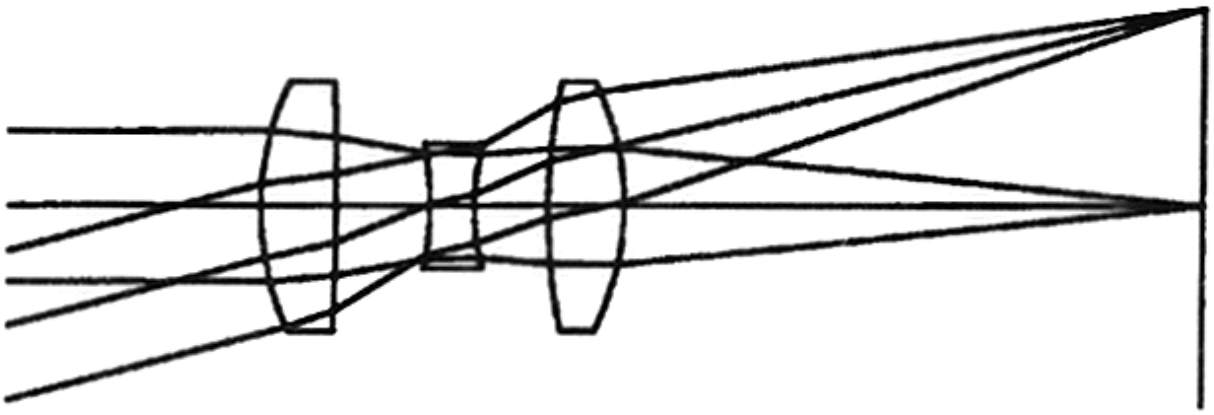
(c) Achromatic doublet

Cooke Triplet Anastigmats

- Three element lens which limits angle of incidence
- Good performance for many applications
- Designed in England by Taylor at “Cooke & Son” in 1893
- Created a photo revolution: simple elegant high quality lens
- Gave sharp margins and detail in shadows
- Lens 2 is negative & smaller than lenses 1 & 3 positives
- Have control of 6 radii & 2 spaces
- Allows balancing of 7 primary aberrations

1. Spherical
2. Coma
3. Astigmatism
4. Axial colour
5. Lateral colour
6. Distortion
7. Field curvature

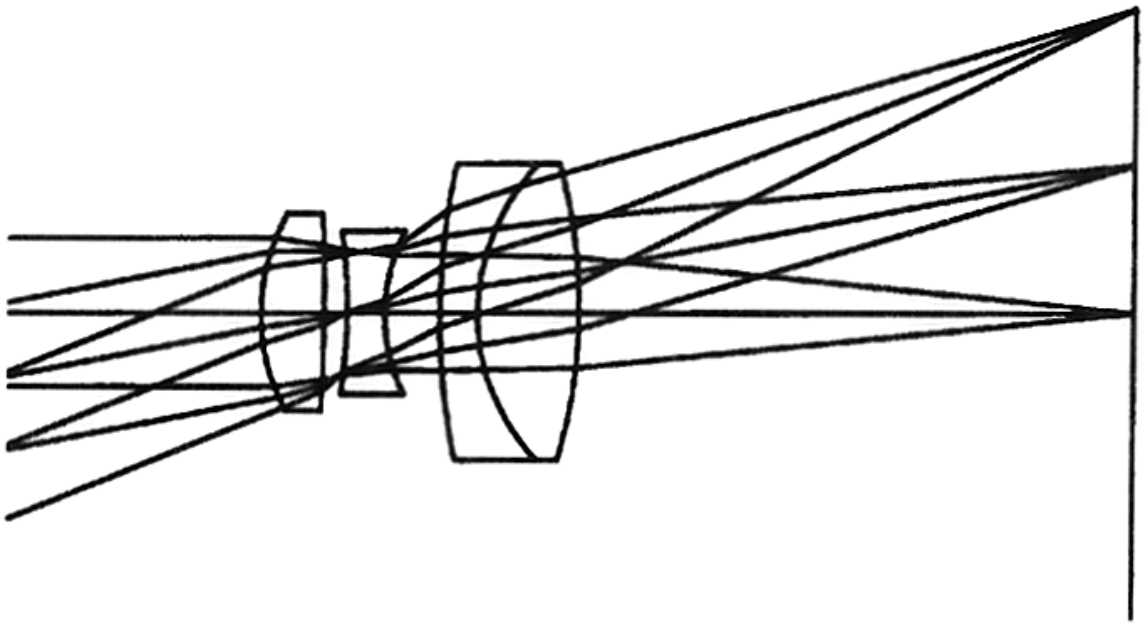
- Also control of focal length
- However tradeoffs eg f#:6 has 10^{o} field of view & good quality
- F#:1.4 has 30^{o} field of view but poor quality



(d) Cooke triplet

Zeiss Tessar

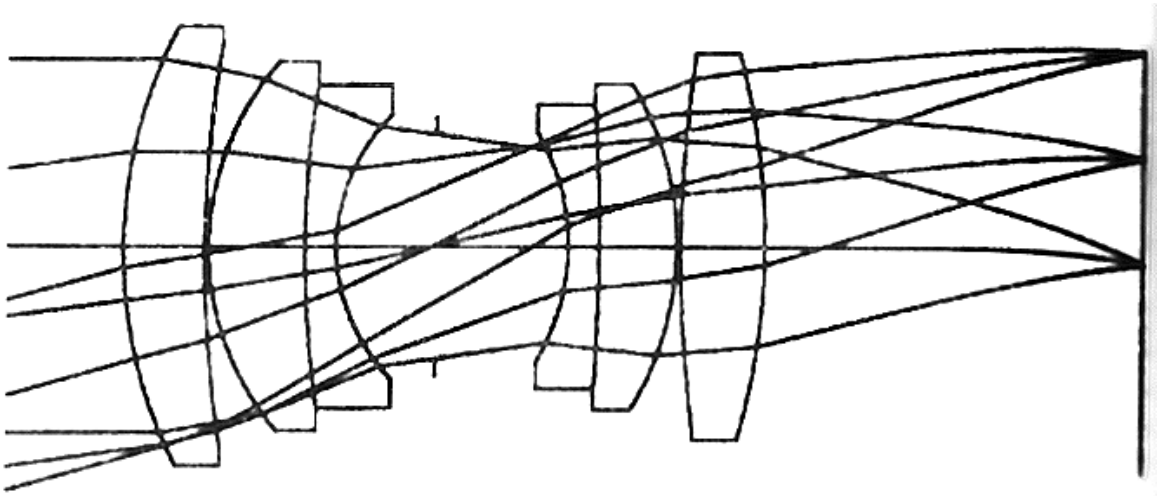
- Derived from Cooke by Paul Rudolph at Zeiss Jena in 1902
- Replaced back lens with doublet (tessares or 4 in Greek)
- Gets higher resolution, excellent contrast, very low distortion
- Want to eliminate aberrations when they occur
- "Clip at the bud"
- Lens 1 focuses light from infinity
- Lens 2 (diverging) diverts converging light to lens 3 as diverging
- Lens 3 takes diverging rays and focuses then & sets f#
- Lens 3 makes most changes, creates most aberrations
- Thus replace with doublet
- Enhanced by special low dispersion glass developed by Zeiss
- Leica famous 50 mm f3.5 Elmar lens of 1920 was a Tessar



(e) Zeiss Tessar

Doublet Gauss or Biotar

- Split optical power to minimize aberrations
- Negative element with smaller diameter for field curve correction
- For and aft spots minimize angle of incidence
- Doublet Gauss adds for & aft negative lens: more stops
- 2 positives at either end
- Symmetric pattern around stops
- Very good for high speed lenses: eg. f#:1.4
- Basis for most fix focal length high end camera lenses



(f) Double Gauss

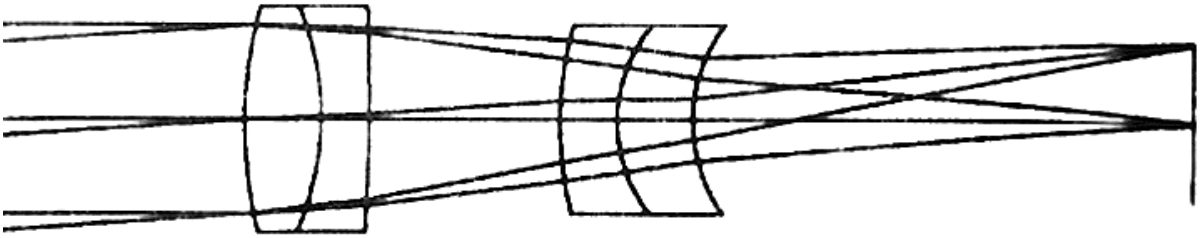
Petzval Lens

- Very old lens – designed by Joseph Petzval in 1840
- Petzval was the founder of geometric optics
- Targets smaller fields of view and moderate f# >= 3.5
- 2 separate doublets with aperture stop in between
- Lower chromatic aberrations than one doublet
- Still used in aerial cameras

(g) Petzval lens

Telephoto

- Add negative lens to doublet
- Acts like Galilean telescope



(h) Telephoto lens

Wide Angle

- Add 3 strong negative front element
- Bring light in from a wide angle – make objects seem more distant
- Then converging group with small field of view