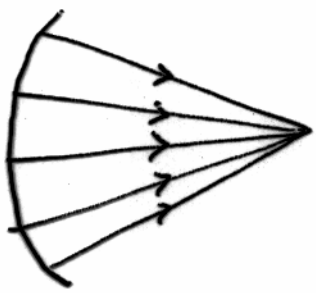
Aberrations

- Chromatic
  - is due to the fact that the refractive index of lenses, etc. varies with wavelength; therefore, focal lengths, imaging conditions, etc. are wavelength-dependent

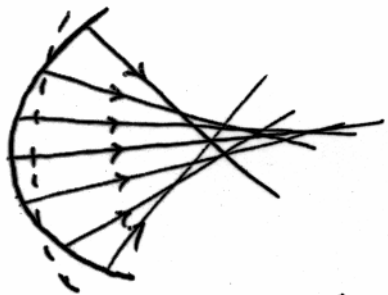
- Geometrical
  - are due to the deviation of non-paraxial rays from the approximations we have used so far to derive focal lengths, imaging conditions, etc.; therefore, rays going through imaging systems typically do not focus perfectly but instead scatter around the “paraxial” (or “Gaussian”) focus

Geometrical aberrations

- Deviation of the wavefront from its "ideal" spherical shape due to imperfect refraction by the optical elements



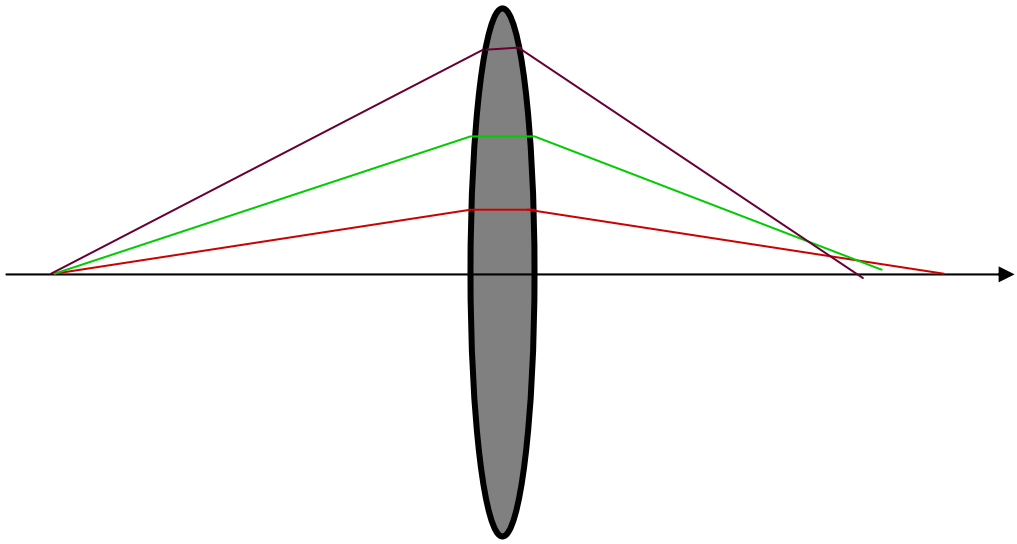
perfect spherical wavefront (focuses to a point)



aberrated wavefront does not come to a focus → image is blurred

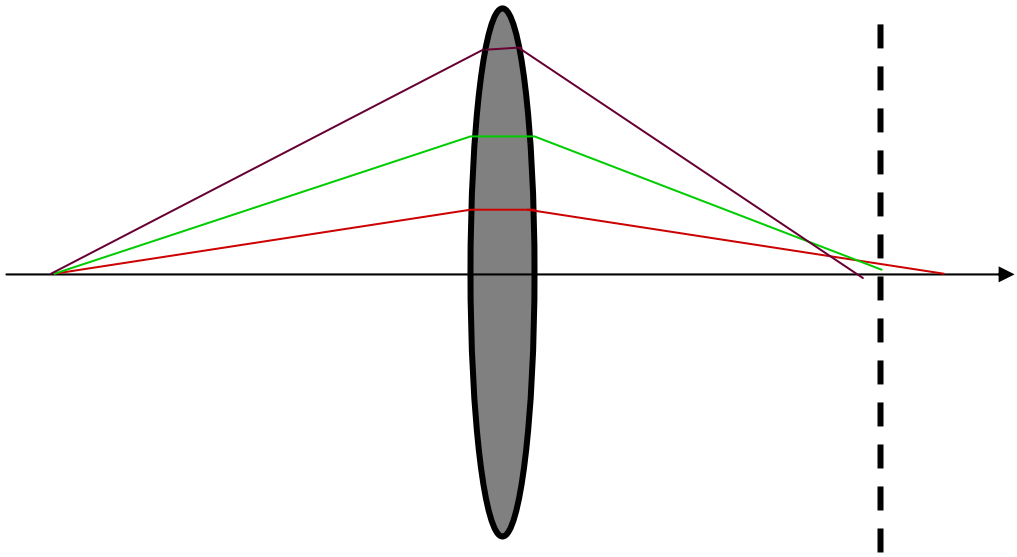
Optical elements (lenses, mirrors) produce perfect (non-aberrated) wavefronts only in the paraxial approximation (i.e., for angles of propagation near the optical axis).
At larger angles, 5 kinds of aberrations (called "Seidel" aberrations) occur

Optical design

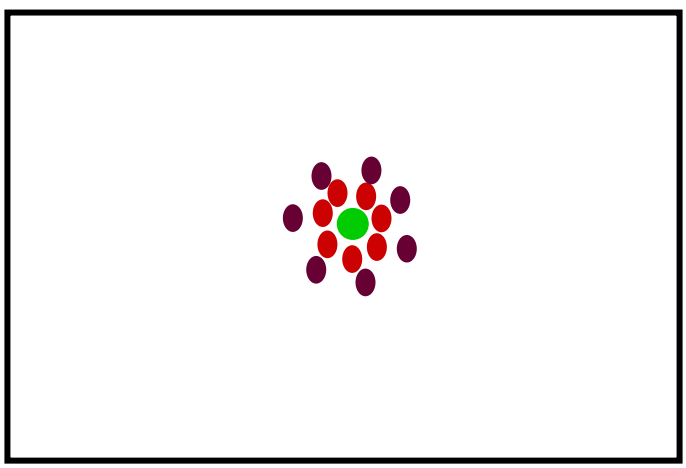


Exact ray-tracing

Optical design

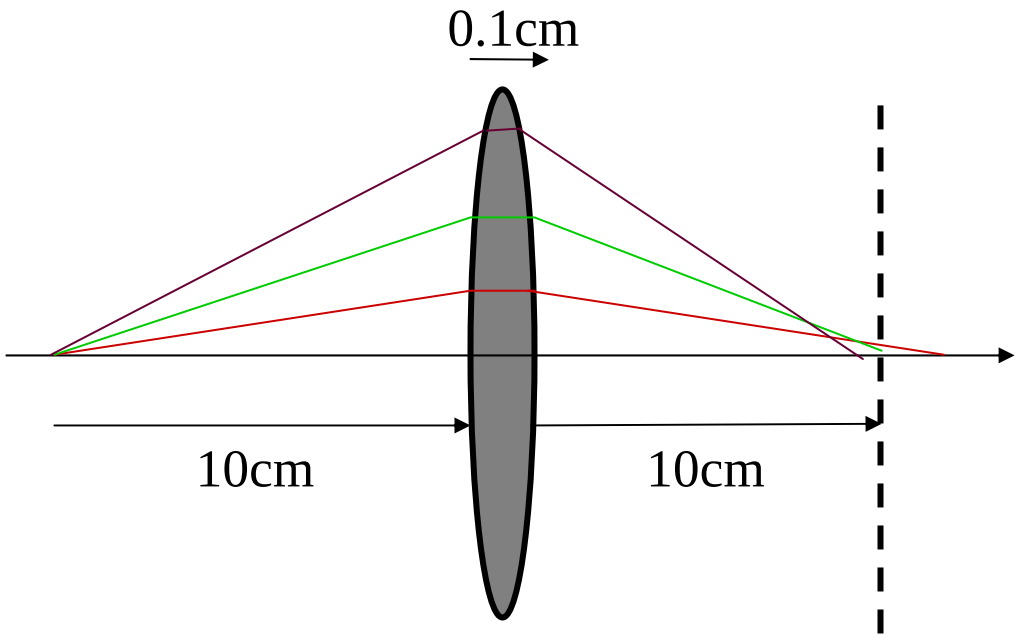


Exact ray-tracing



ray scatter diagram ($\Leftrightarrow$ defocus)

Optical design



Surface name	Curvature	Index to the right	Distance to next element
S0	Inf	1.0	0.1
S1	21.6	1.54	0.001
S2	-21.6	1.0	0.1
S3	...	...	...
S4	...	...	...

Features of optical design software

- Databases of common lenses and elements sold by vendors
- Simulate aberrations and ray scatter diagrams for various points along the field of the system
- Standard optical designs (e.g. achromatic doublet, Cooke triplet)
- Permit optimization of design parameters (e.g. curvature of a particular surface or distance between two surfaces) *vs* designated functional requirements (e.g. field curvature and astigmatism coefficients)
- Also account for diffraction by calculating the modulation transfer function (MTF) at different points along the field

Vendors

- Optical design
  - Code V
  - Oslo
  - Zemax
  - Accos
  - Asap
  - consultants
- Optics & opto-mechanics
  - Newport
  - Newfocus
  - Coherent
  - Opto-Sigma
  - Thorlabs
  - Edmund
  - specialized shops

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