

Einfache Optiksysteme

Inhalt: Einfache Optiksysteme

29.06.2008

1. Überblick
2. Achromate
3. Disk-Objektive
4. Kollimatoren
5. Telezentrische Systeme
6. Laser-Strahlführungen
7. Relay-Systeme
8. Scanner-Systeme

Einfache Optiksysteme

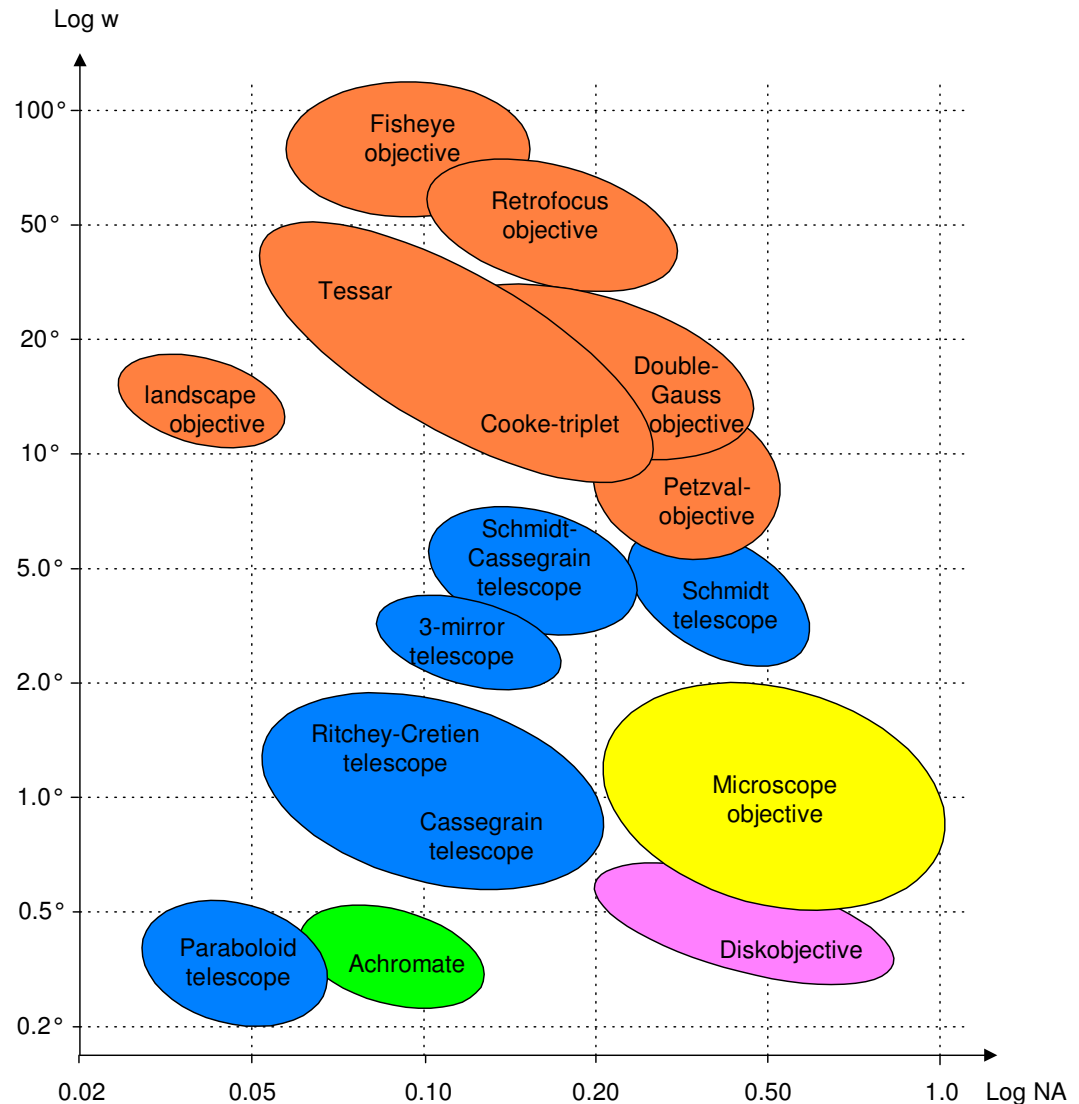
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Einfache Optiksysteme

Typklassen optischer Systeme

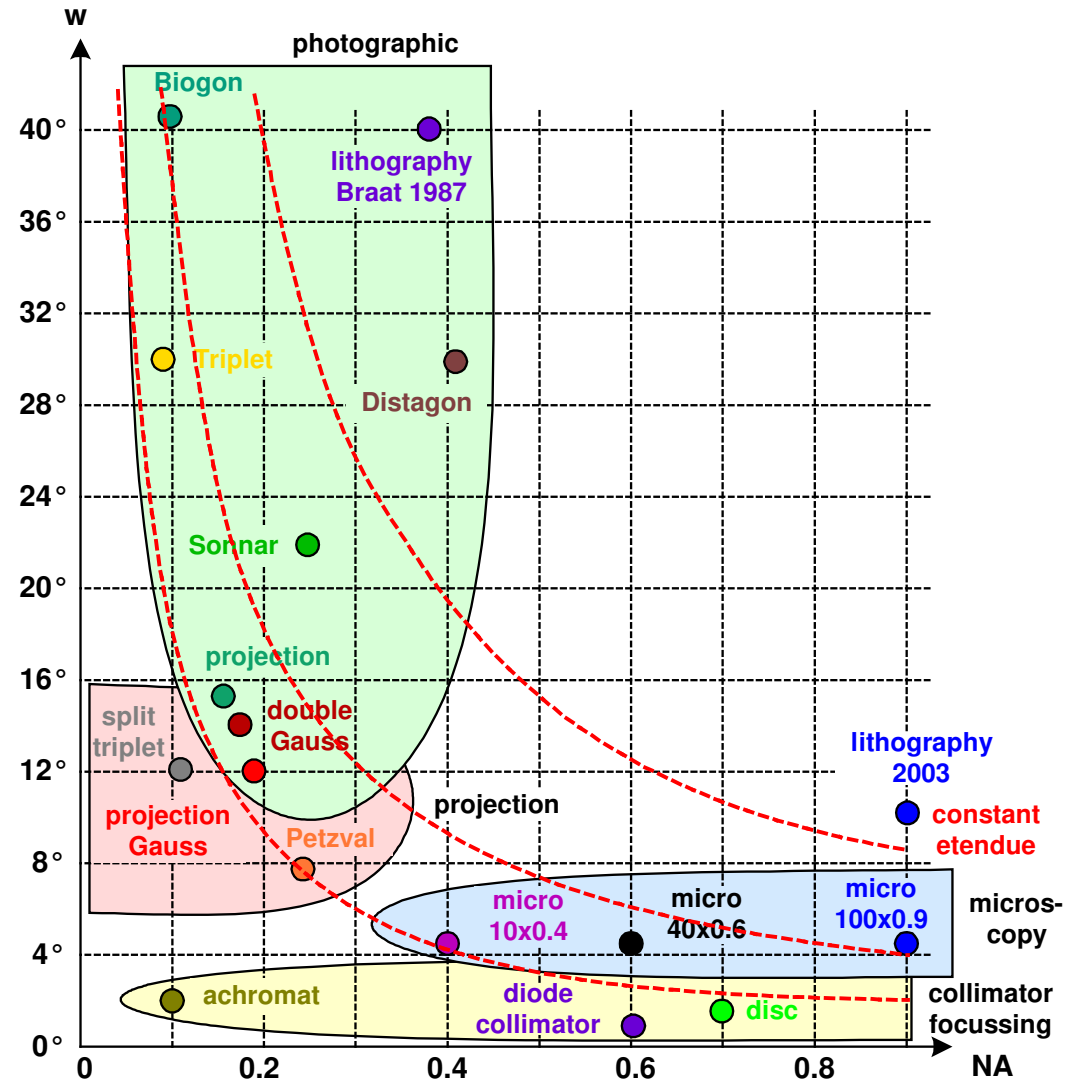
- Übersicht und Sortierung optischer Systemtypen in Diagramm: Öffnungs- / Feld-Größe (nach W. Smith)
- Chromatische Breite der Anwendung müßte 3. Koordinate sein



Einfache Optiksysteme

Field-Aperture-Diagram

- Classification of systems
- Aperture dominated :
Disk lenses, microscopy,
Collimator
- Field dominated :
Projection lenses,
camera lenses,
Photographic lenses



Einfache Optiksysteme

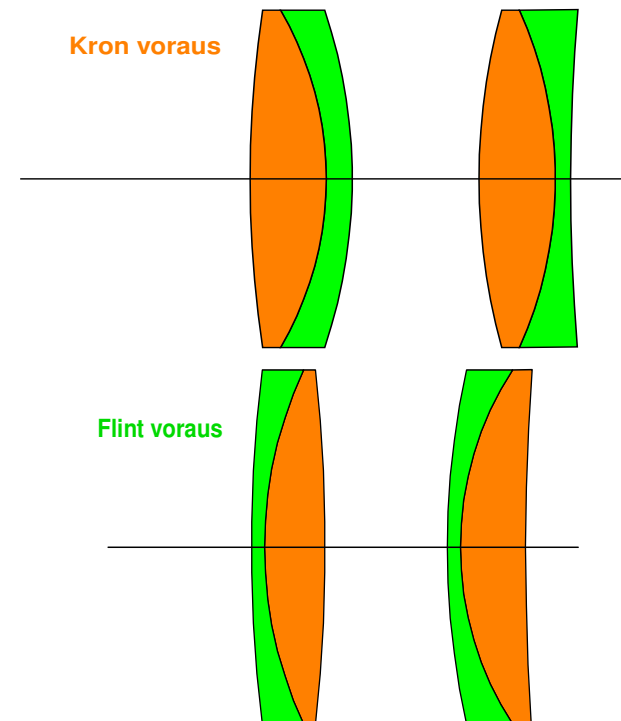
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Achromate

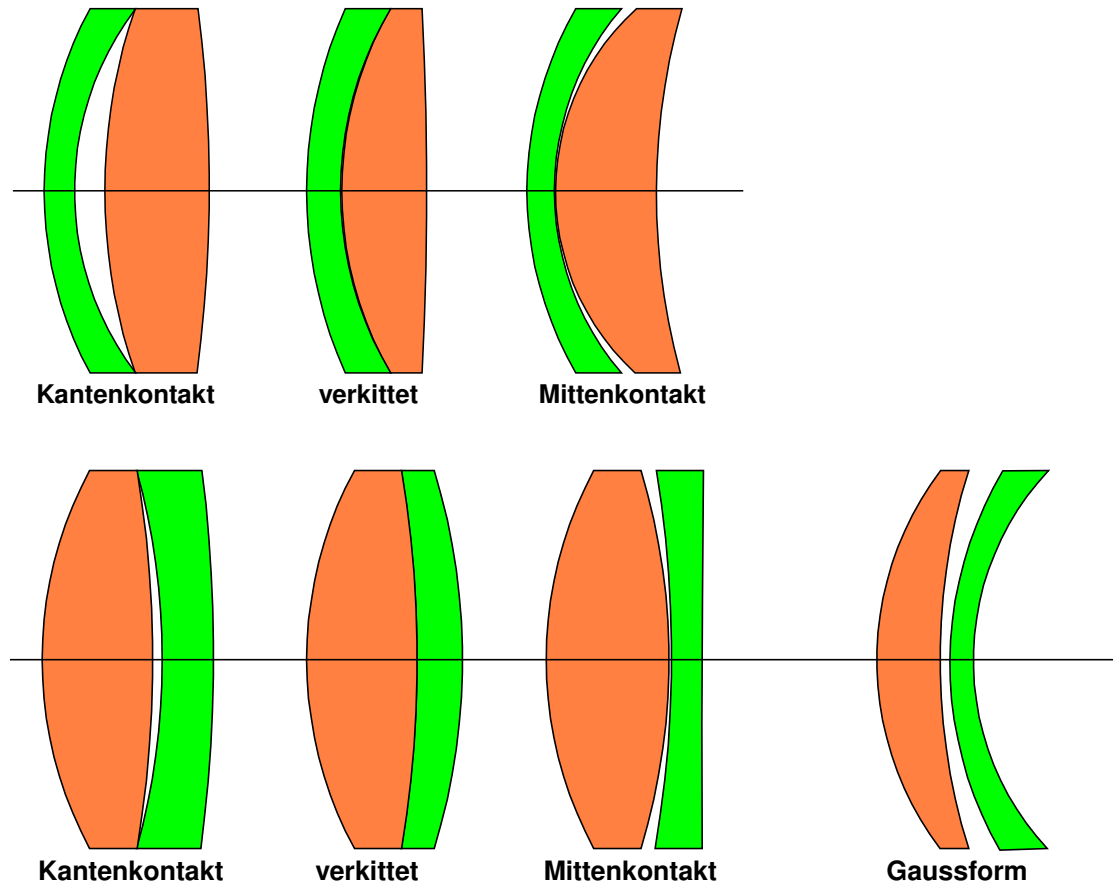
- Achromat:
 - Farbkorrektion durch verkitten von 2 unterschiedlichen Gläsern
 - Korrektur Öffnungsfehler am Rand
 - Aplanatische Komakorrektur möglich
- Vier grundsätzliche Lösungen möglich:
 - zwei Lösungen für Kron-voraus
 - zwei Lösungen für Flint-voraus
- Normalerweise:
 - Korrektion für Objekt im Unendlichen
 - sphärische Randkorrektur
 - axiale Farbkorrektur
 - Glaswahl für korrigierte Koma
 - beugungsbegrenzt bis NA 0.1



Einfache Optiksyste^me

Achromate : Bauformen

- Vorteil der Verkittung:
angespannte sphärisch unterkorrigierende Kittfläche ist stabil
- Nachteil der Verkittung:
einen Freiheitsgrad weniger
- Daher in der Praxis
unterschiedliche Bauformen



Einfache Optiksysteme

Achromate : Ansatz

- Berechnungsansatz:

1. Annahme zwei dicht zusammenstehende dünne Linsen

2. Brennweite/Brechkraft

$$F = F_1 + F_2$$

3. Achromasie

$$\frac{F_1}{v_1} + \frac{F_2}{v_2} = 0$$

- Einzelbrechkräfte

$$F_1 = \frac{1}{1 - \frac{v_2}{v_1}} \cdot F \qquad F_2 = \frac{1}{1 - \frac{v_1}{v_2}} \cdot F$$

- Fazit:

1. eine positive und eine negative Brechkraft

Reihenfolge egal (Kron/Flint voraus)

2. große v -Differenz entspannt Einzellinsen

3. Achromasie unabhängig von Durchbiegung

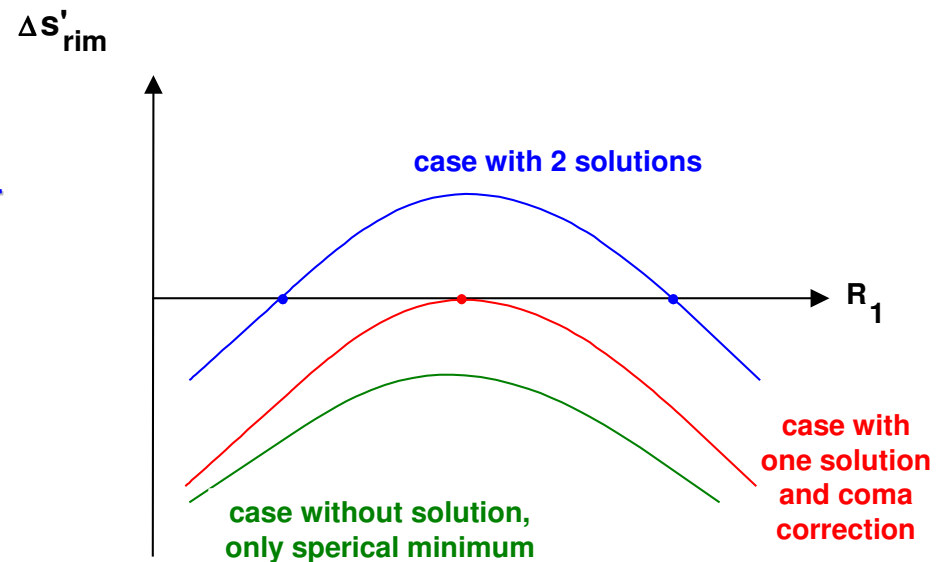
4. Durchbiegung dient der sphärischen Randkorrektur

5. Aplanasie nur durch spezielle Glaswahl möglich

Einfache Optiksyste

Achromate : Korrektio

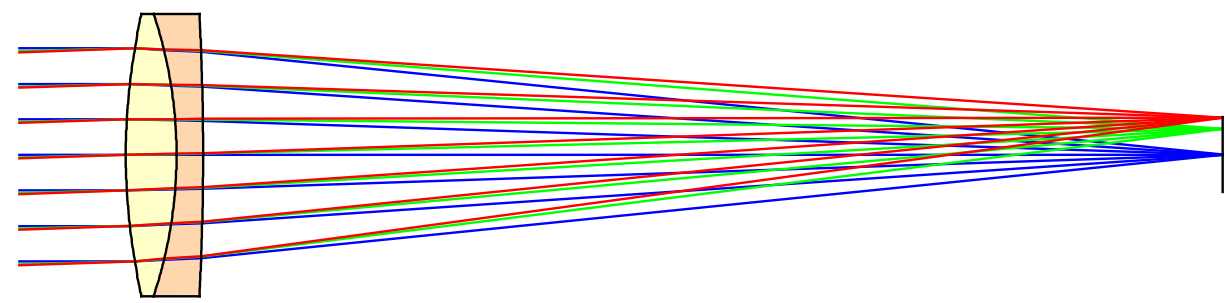
- Verkitteter Achromat: 6 Freiheitsgrade
 - 3 Radien, 2 Brechzahlen, Verhältnis v_1/v_2
- Korrektio der sphärischen Aberration: zerstreue Kittfläche
 - $n_{zer} > n_{sam}$
- Glaswahl: alternativ
 1. Aplanatische Komakorrektur
 2. Minimierung sphärischer Zonenfehler
 3. Sekundäres Spektrum minimieren
 4. Gaussfehler minimieren
- Es gibt drei Lösungsbereiche für die Glaswahl:
 1. keine sphärische Randkorrektur
 2. Zwei Lösungen
 3. Eine Lösung, aplanatisch



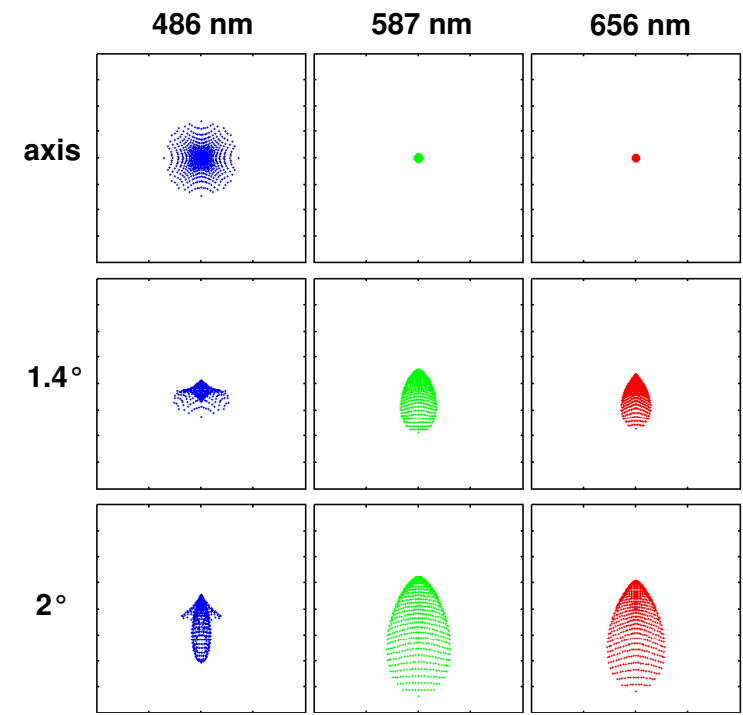
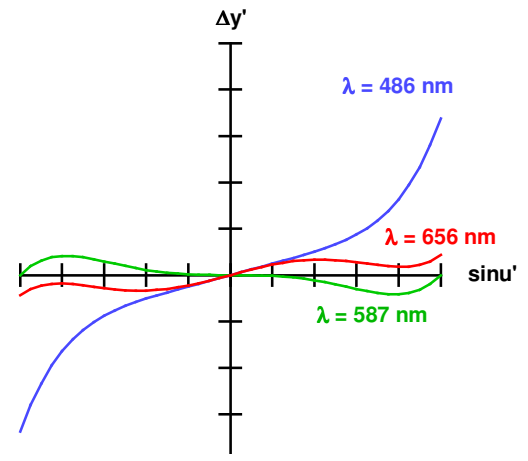
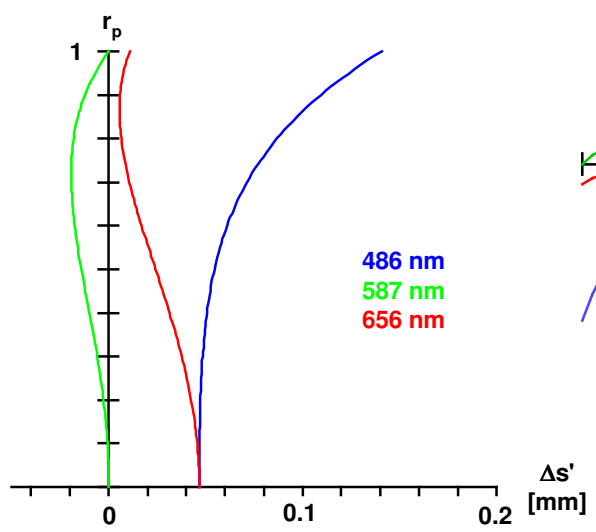
Einfache Optiksyste_me

Achromate

- Achromate



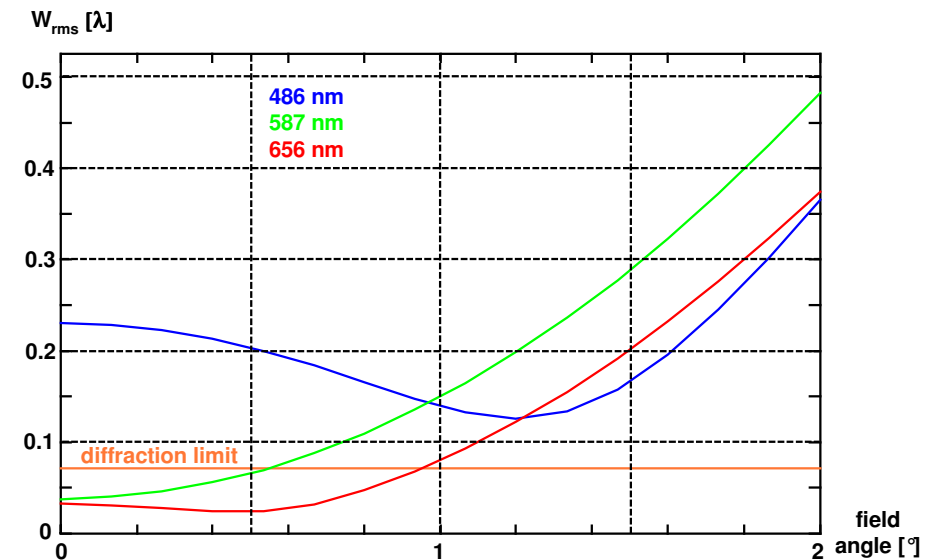
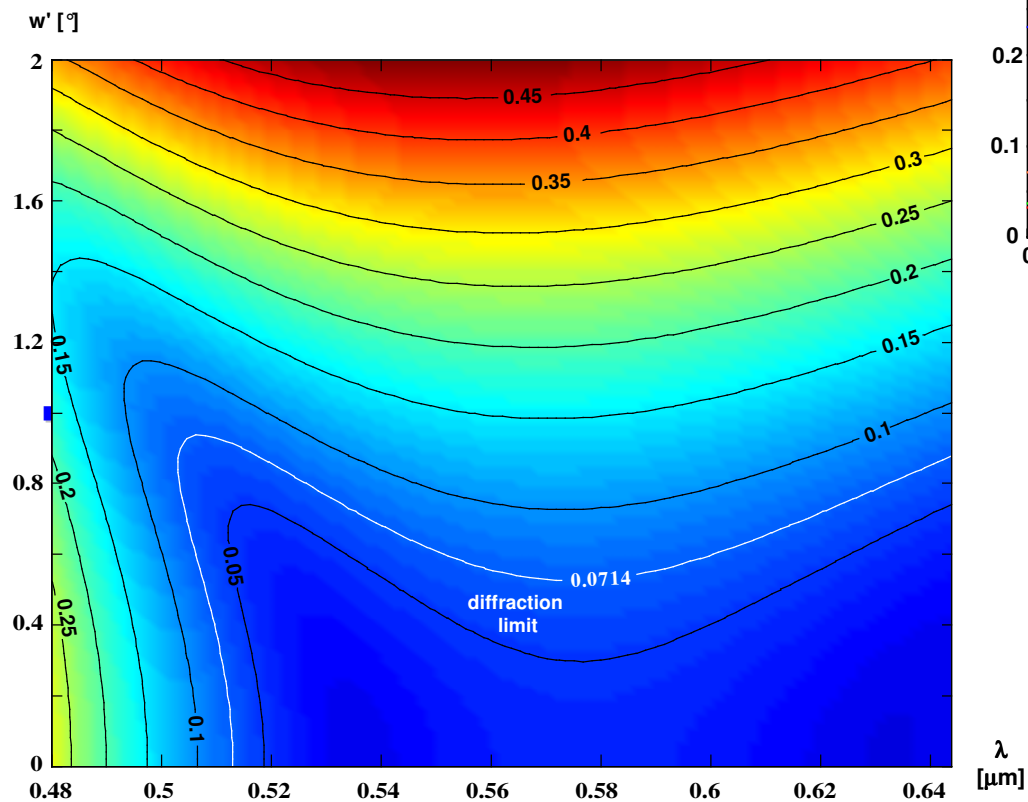
- Longitudinal aberration
- Transverse aberration
- Spot diagram



Einfache Optiksyste_me

Achromate

- Diffraction limit
- small field of view
- Performance decrease in the blue



Einfache Optiksyste_me

Optimierung

- Ideal aplanatic solution for glass selection:

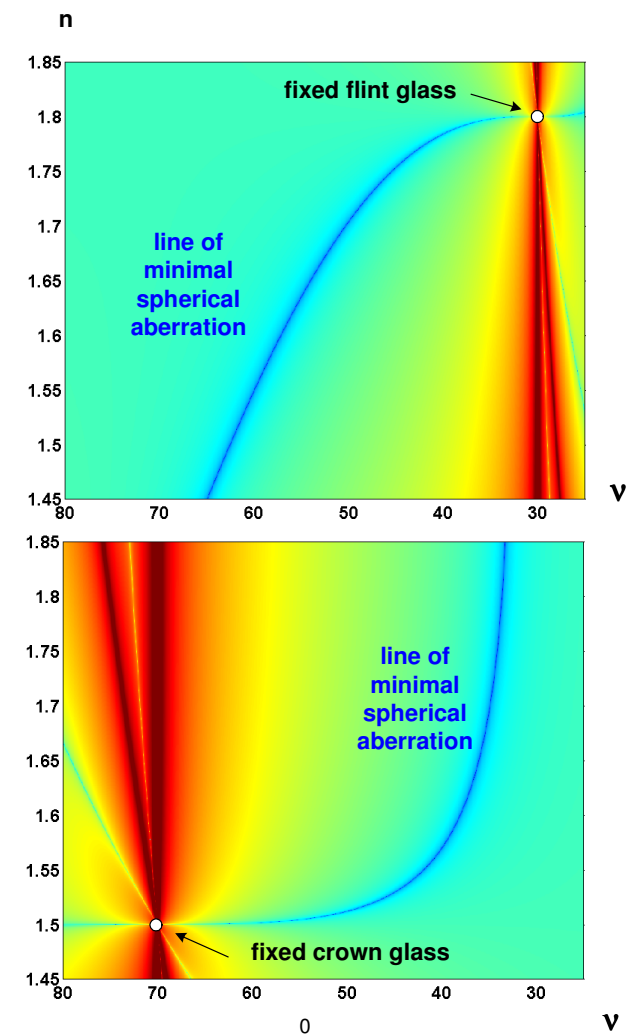
1. fixed flint glass

curved line in glass diagram for optimal crown glass combination

2. fixed crown glass

curved line in glass diagram for optimal flint glass combination

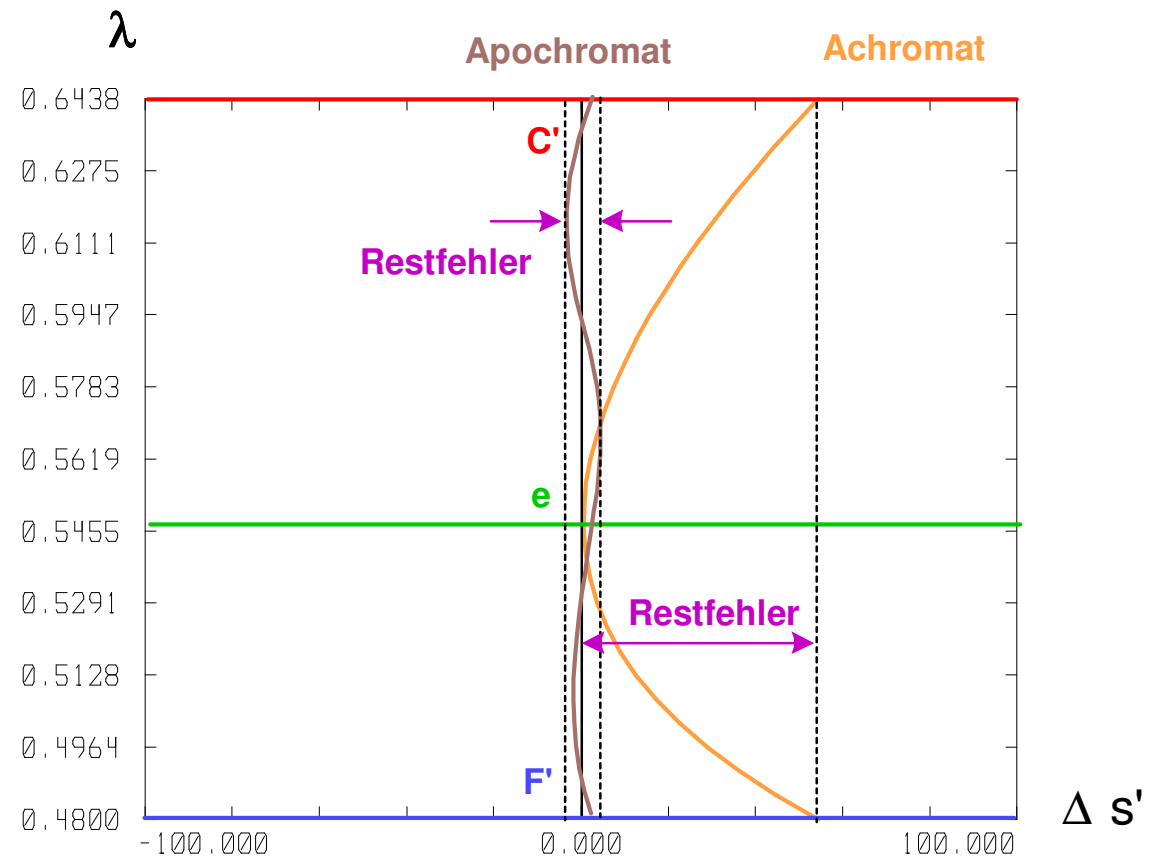
- Reality:
Only glasses near by due to discrete structure



Einfache Optiksysteeme

Farbkorrektur

- Achromatische Korrektur :
Stets höchstens 2 Farben mit gleicher Schnittweite
- Apochromatische Korrektur :
Korrektur für mehrere
Farben, kleinere Restfehler
(sekundäres Spektrum)



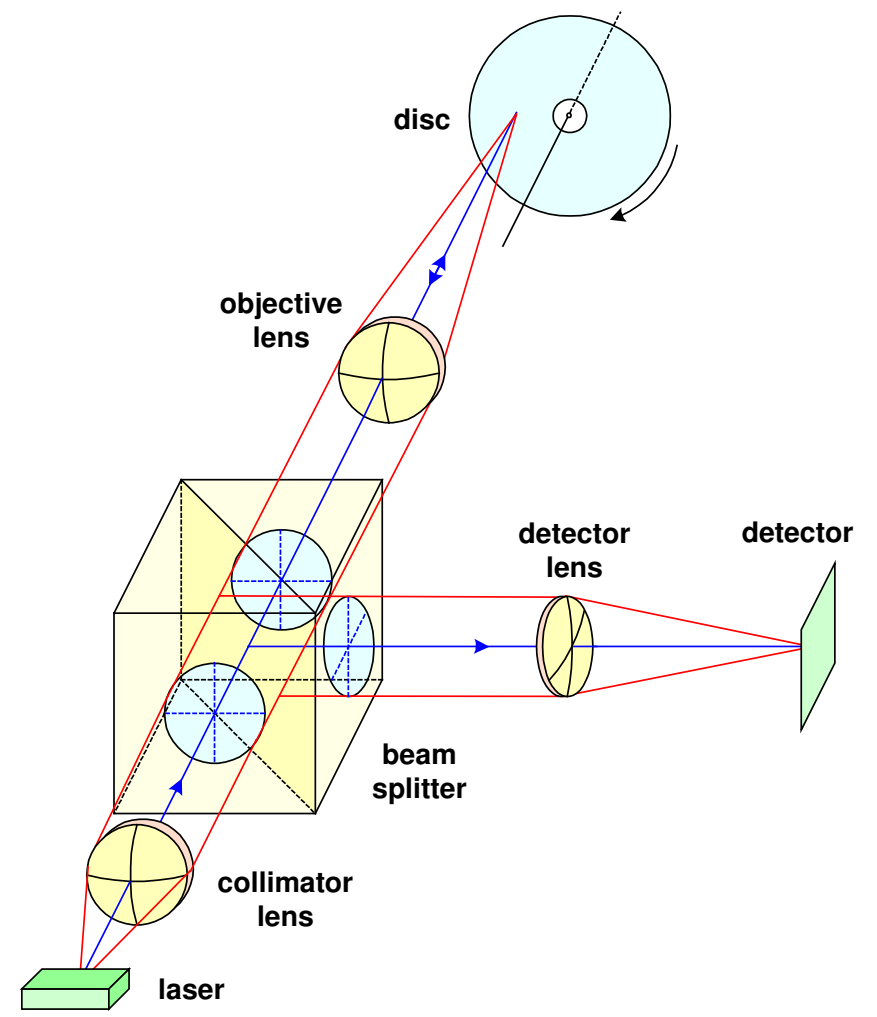
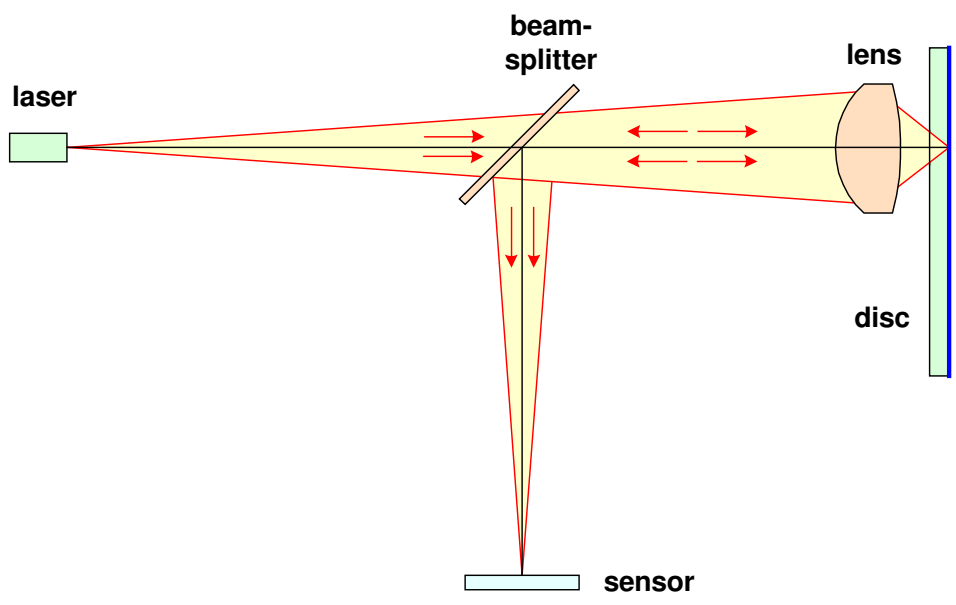
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Einfache Optiksyste Disk and Pick-up Lenses

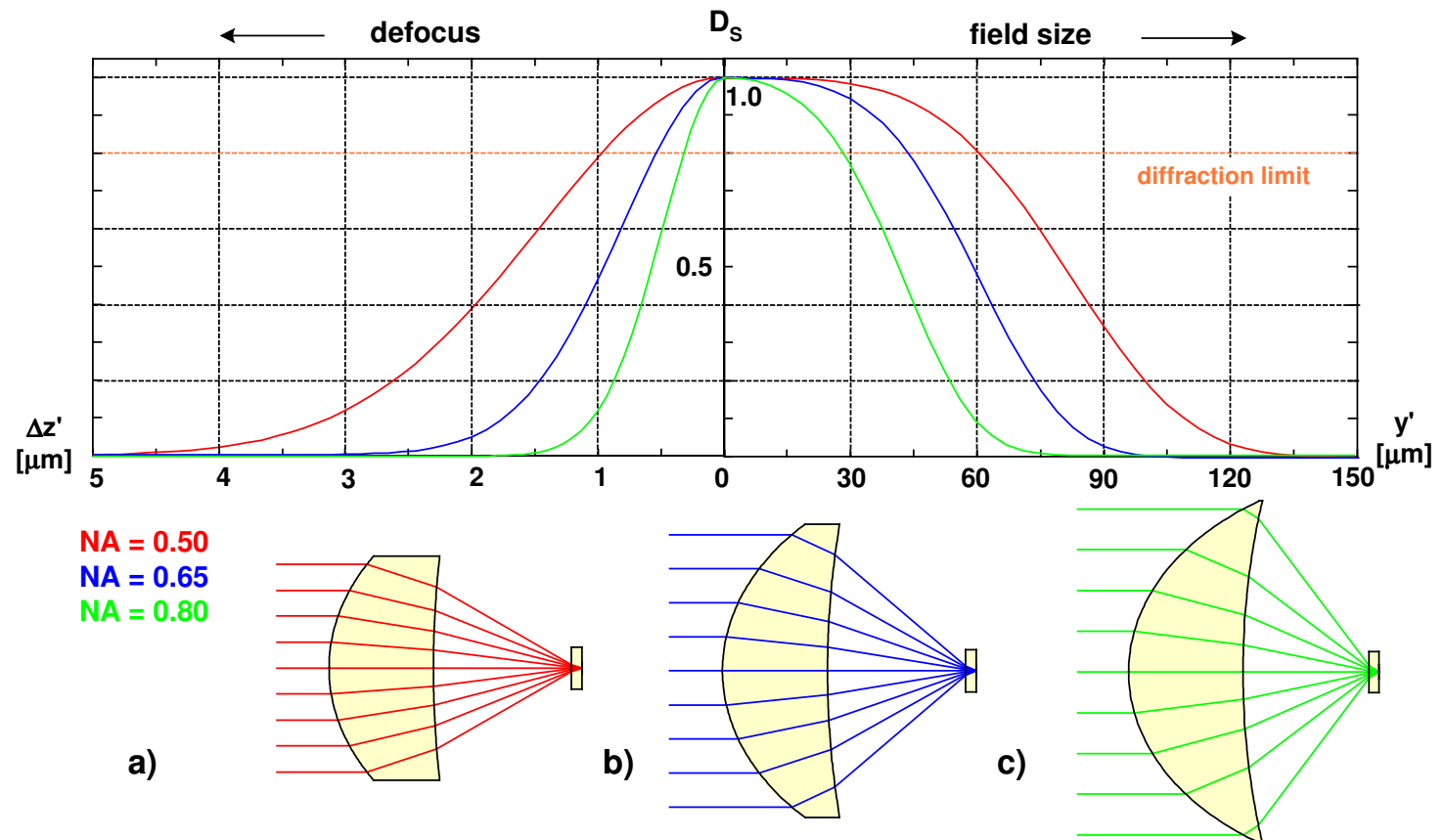
- Read and write on disks with laser
- Monochromatic, no field of view
- High volume : plastic optics
- Simple version :
one lens



Einfache Optiksyste_me

Disk and Pick-up Lenses

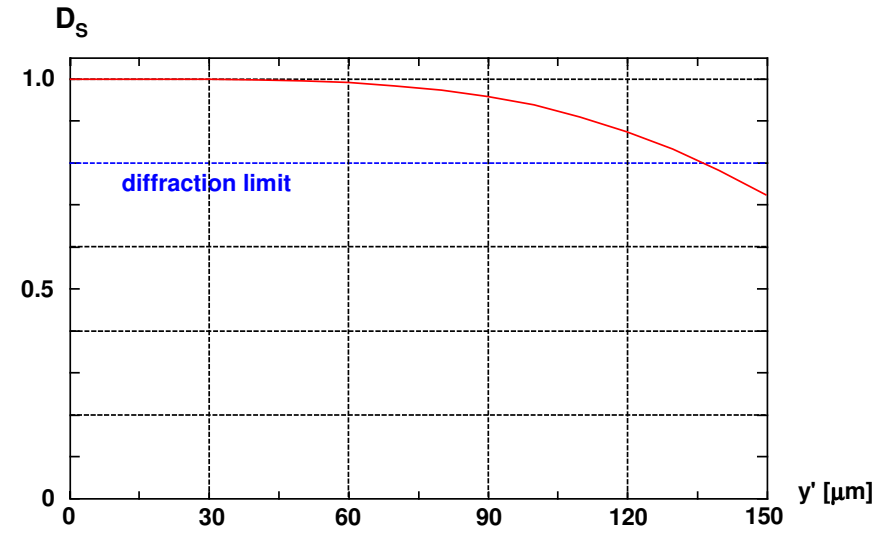
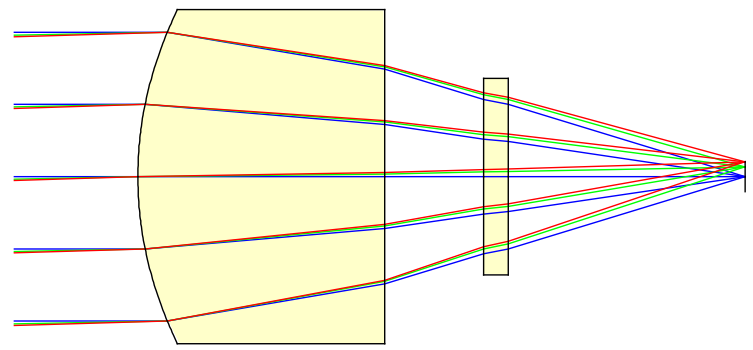
- Decrease of performance with defocus and field size
- High numerical aperture more critical
- Aspherical singlet solution



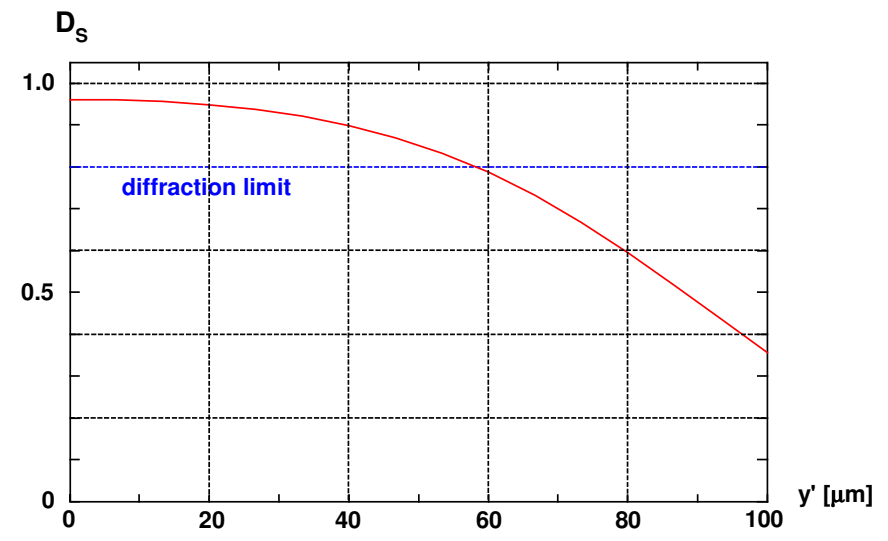
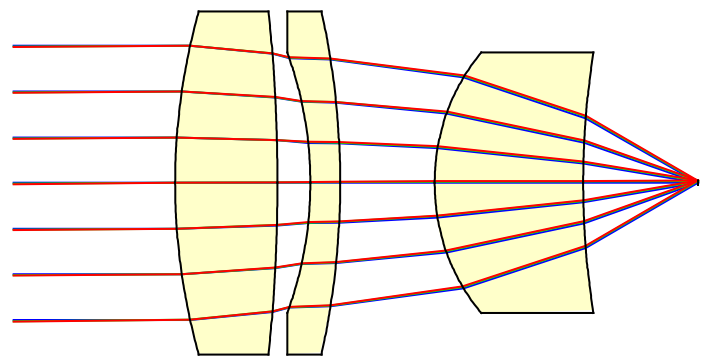
Einfache Optiksysteeme

Disk and Pick-up Lenses

- Aspherical singlet



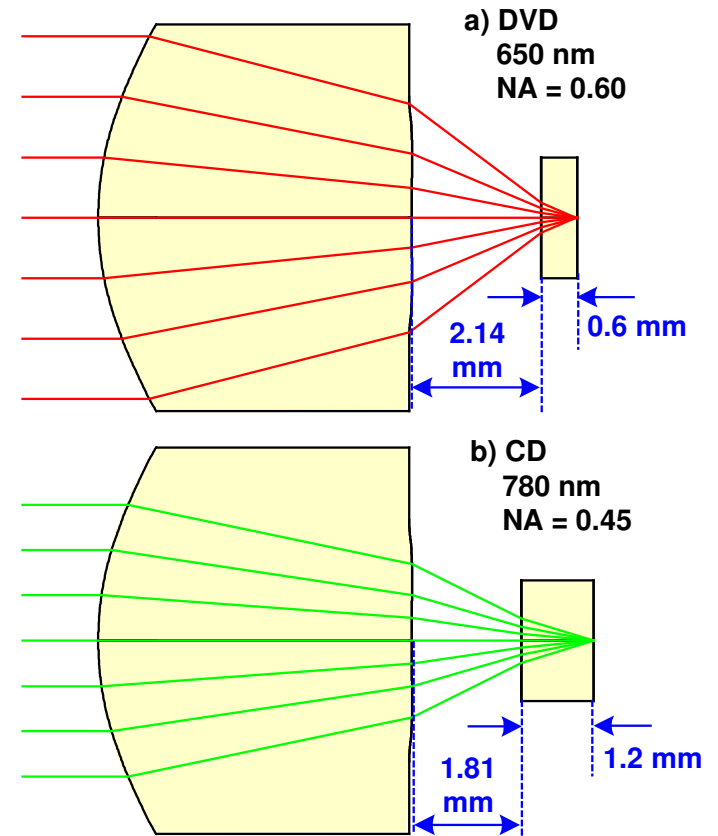
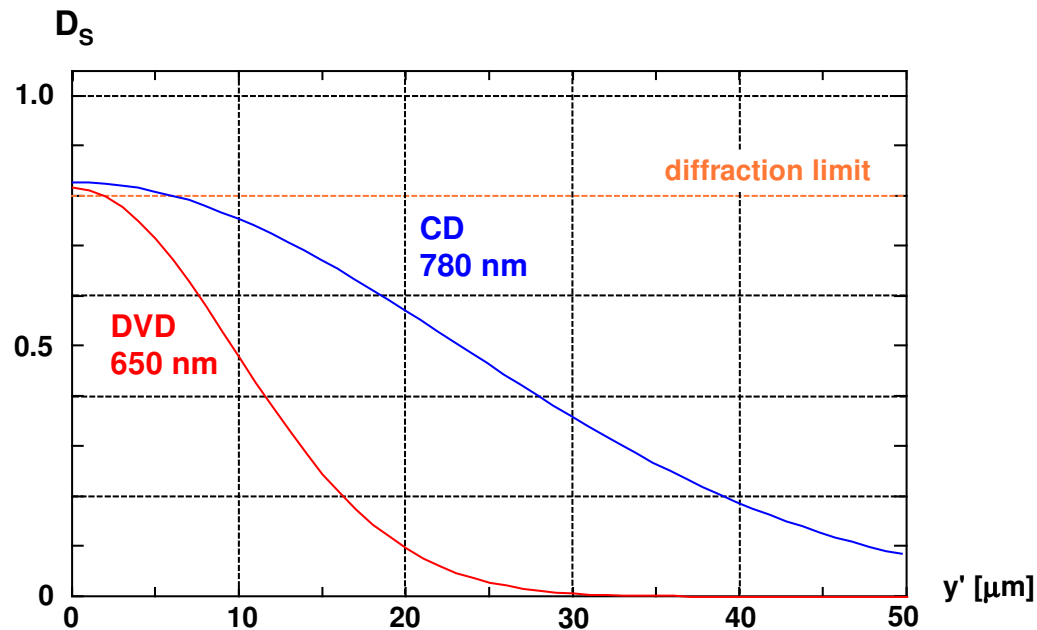
- three-lens glass solution



Einfache Optiksysteme

Disk and Pick-up Lenses

- CD-DVD dual-band solution
 CD : 780 nm, NA = 0.45, t = 1.2 mm
 DVD : 650 nm, NA = 0.60 , t = 0.6 mm
- Adjusting one distance



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Einfache Optiksysteme

Collimation

- Collimating source radiation:
Finite divergence angle is reality
- Geometrical part due to finite size :

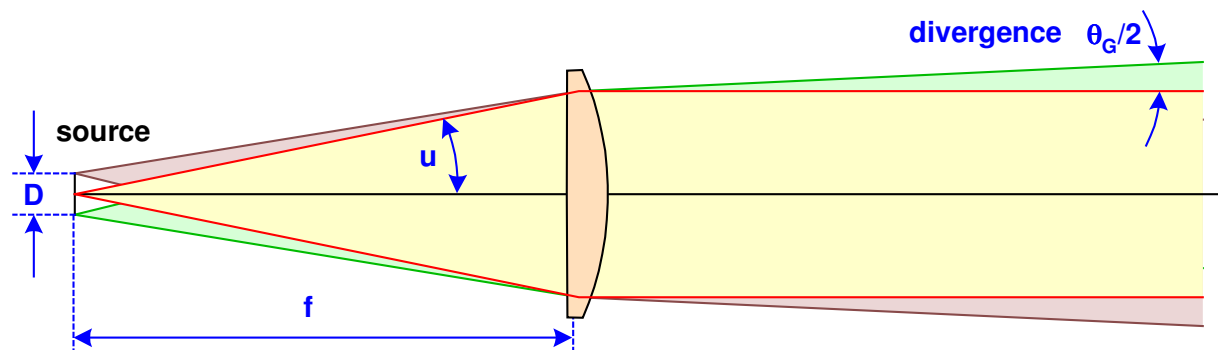
$$\theta_G = \frac{D}{f}$$

- Diffraction part:

$$\theta_D = \frac{\lambda}{D}$$

- Defocusing contribution to divergence

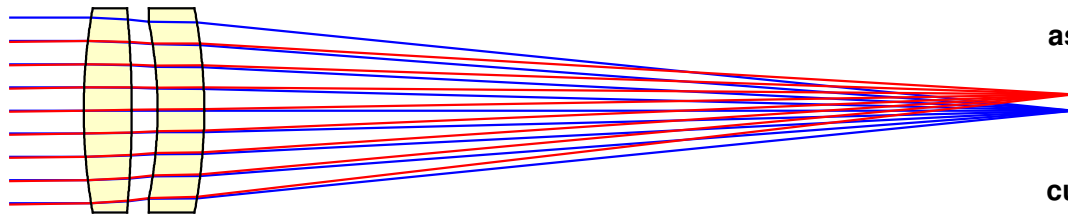
$$\Delta\theta = -\frac{2\Delta z}{f} \cdot \sin u$$



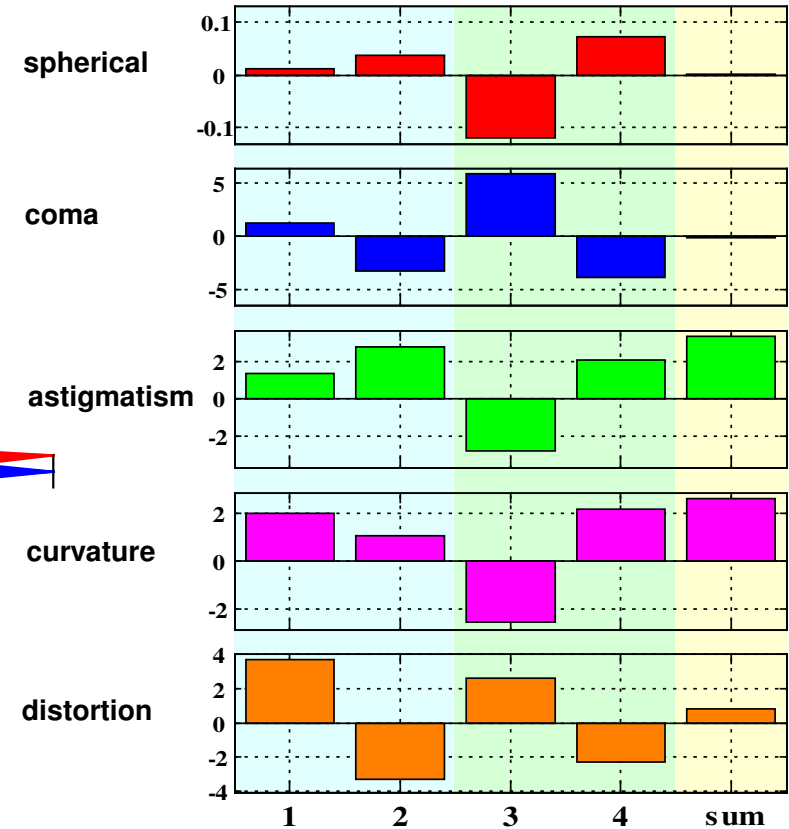
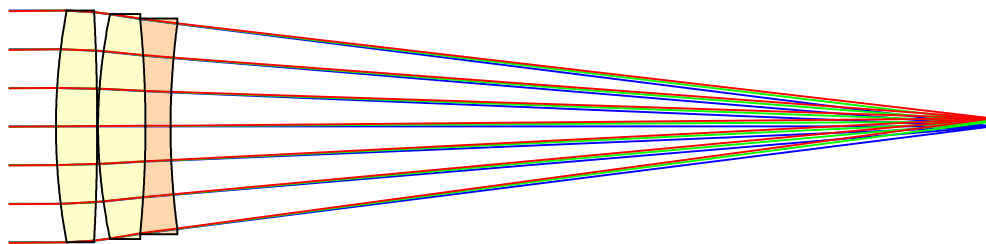
Einfache Optiksysteeme

Collimator Optics

- Monochromatic doublet
- Correction only spherical and coma:
Seidel surface contributions
Limiting : astigmatism and curvature



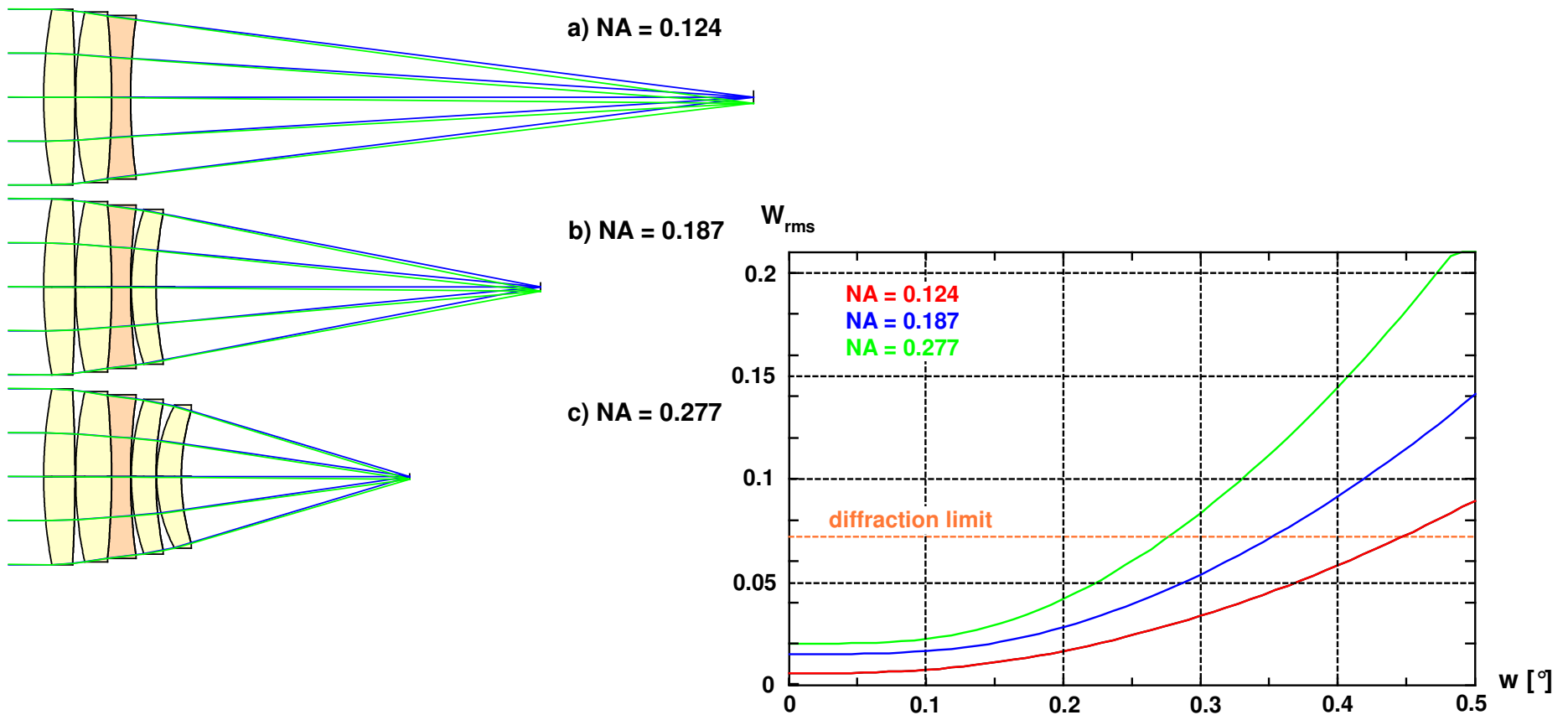
- Enlarged aperture : meniscus added



Einfache Optiksyste_me

Collimator Optics

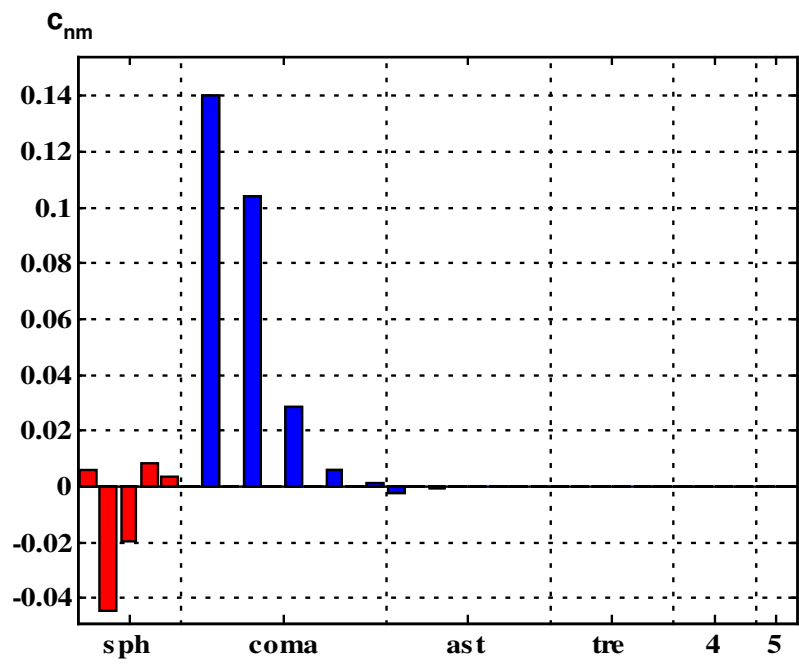
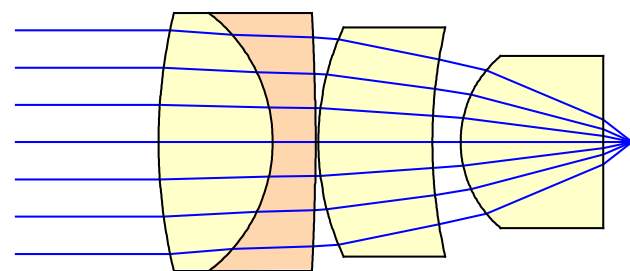
- Enlarging numerical aperture by aplanatic-concentric meniscus lenses
- Extreme good correction of spherical aberration



Einfache Optiksyste_me

Collimator Optics

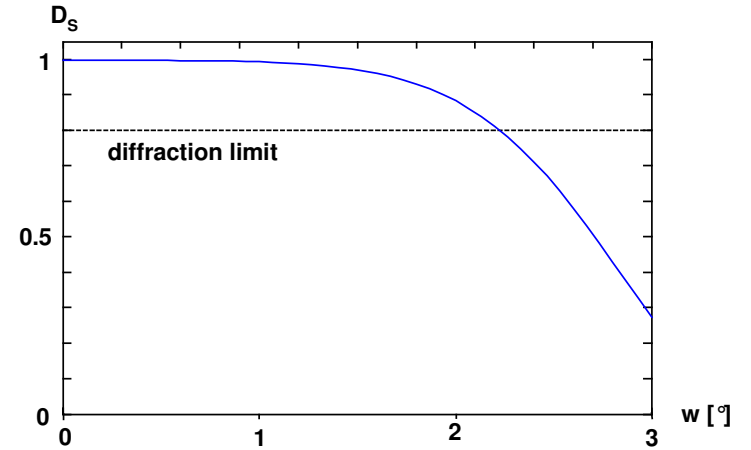
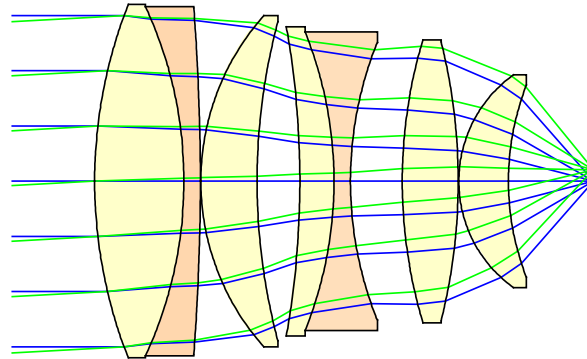
- Problem of high-NA collimators:
small field of view
- Example : $NA = 0.6$, $w = 0.13^\circ$
- Field correction cumbersome:
Zernike coefficients shows
residual coma



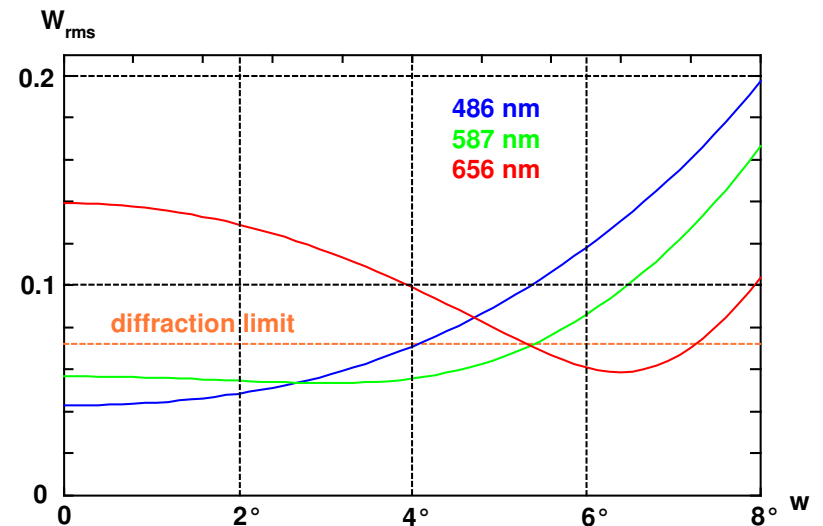
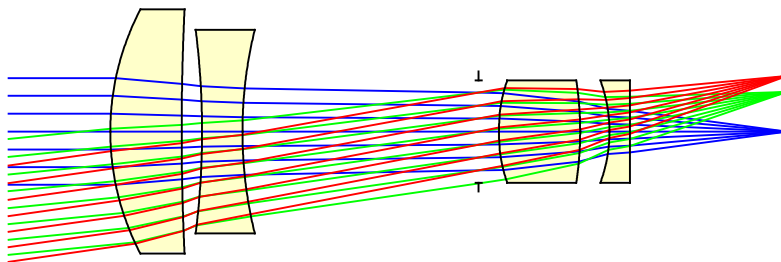
Einfache Optiksyste_me

Collimator Optics

- Collimator with large field :
NA = 0.75
 $w = 2.2^\circ$



- Collimator lens for visible spectrum
NA = 0.17, $w = 8^\circ$



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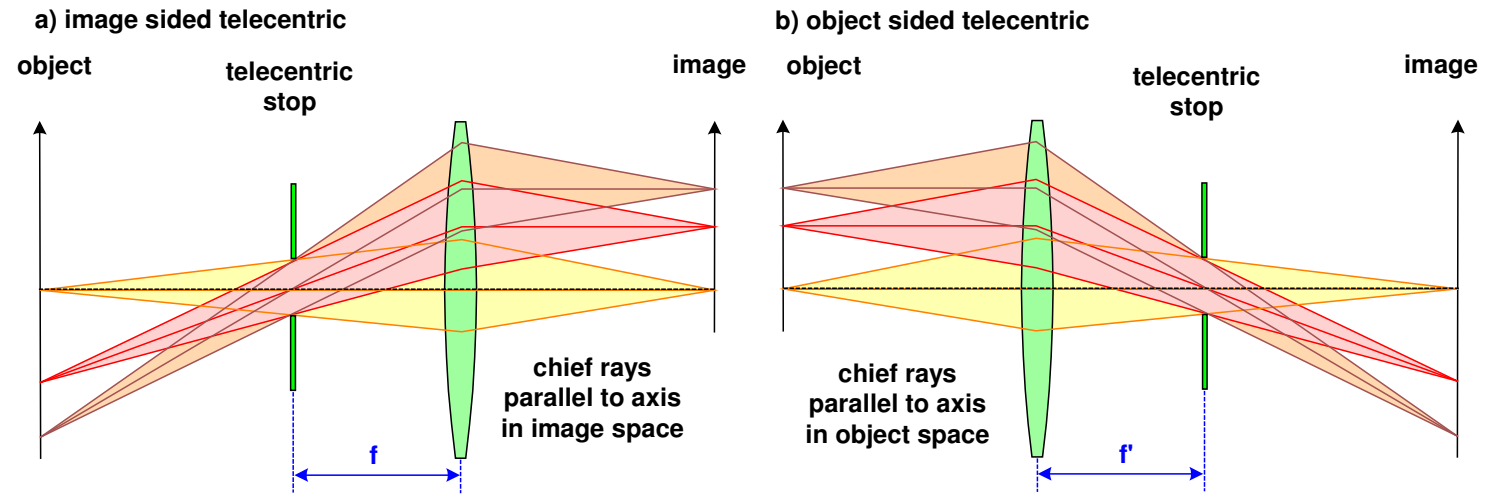
Einfache Optiksysteme

Telecentric Systems

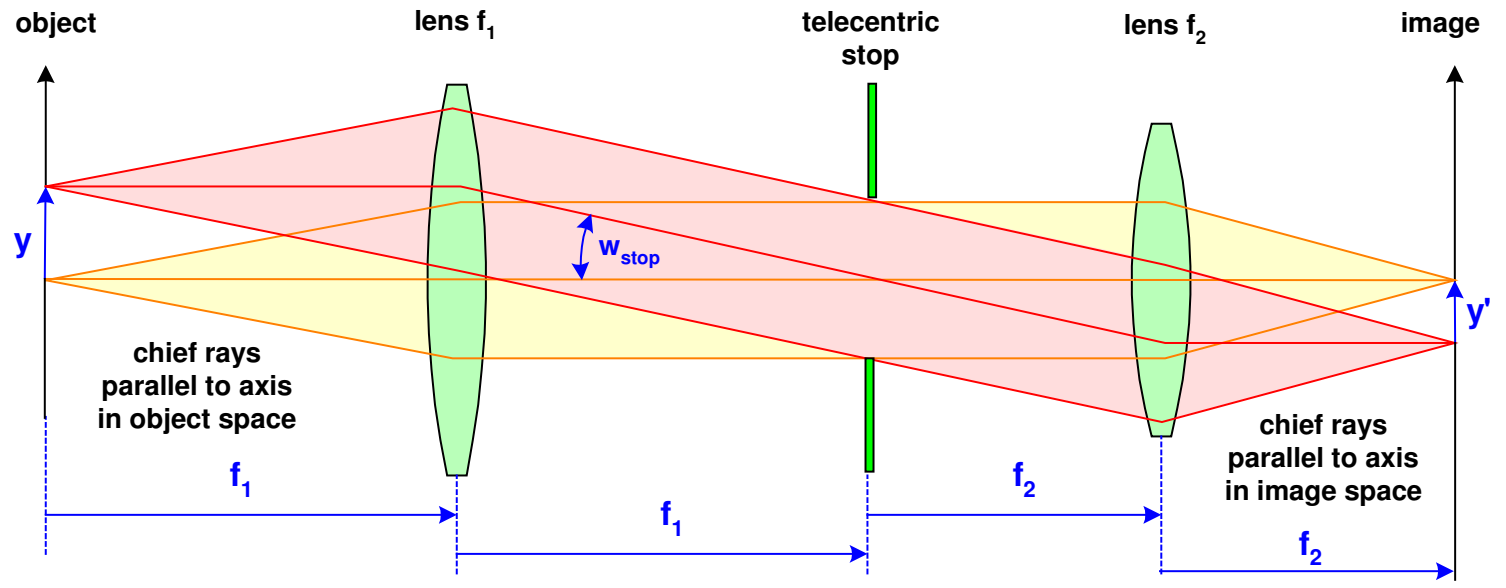
- Principle:
 - Chief ray parallel to optical axis
 - Stop position in focal plane
 - Pupil position in infinity
- Three possibilities :
 1. Object-sided
 2. Image-sided
 3. Double-sided
- Advantages :
 - invariant magnification during defocussing
- Problems :
 - Large diameters necessary

Einfache Optiksyste Telecentric Systems

- Cases 1 and 2



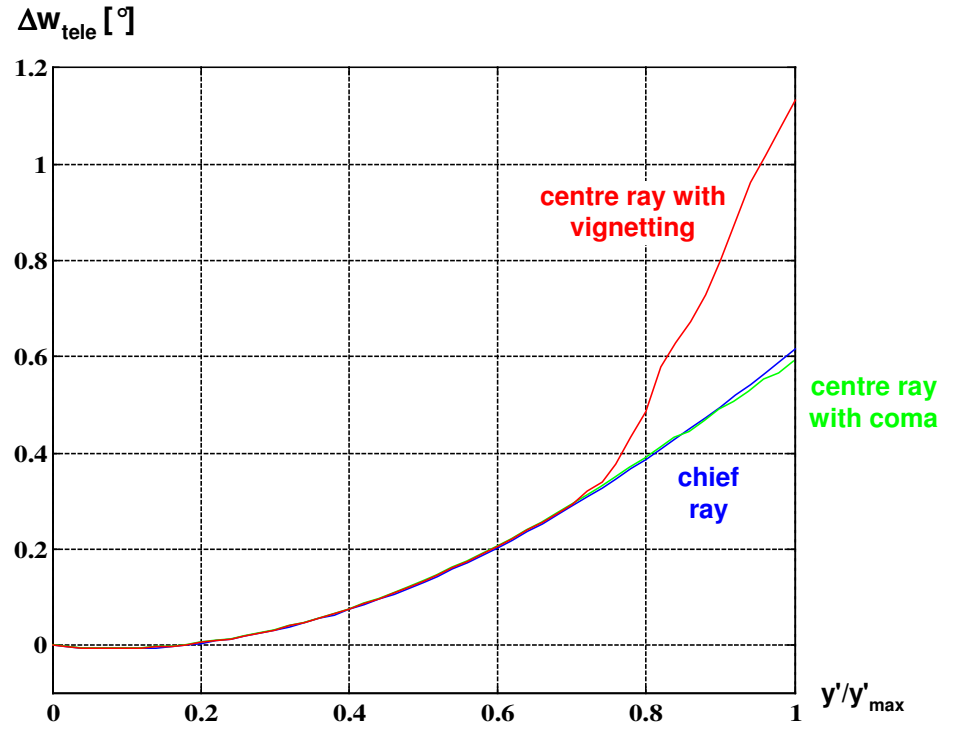
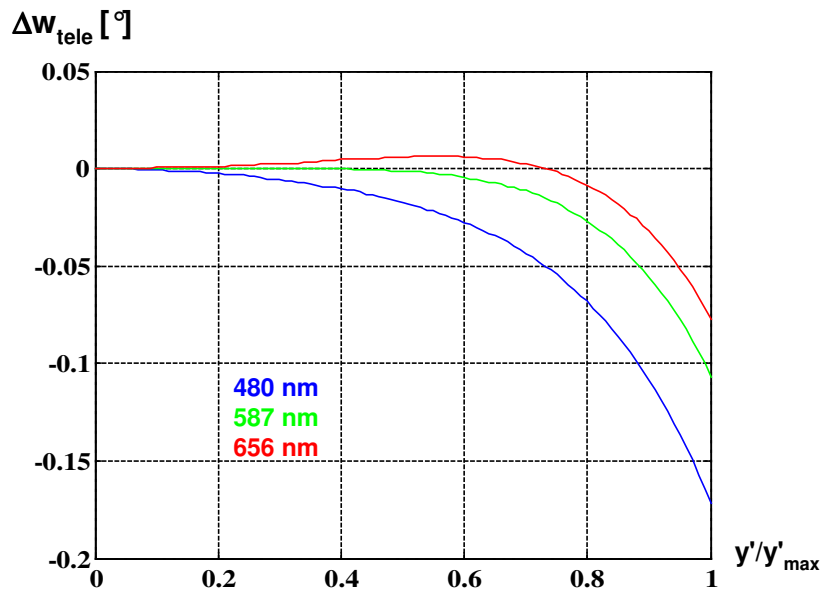
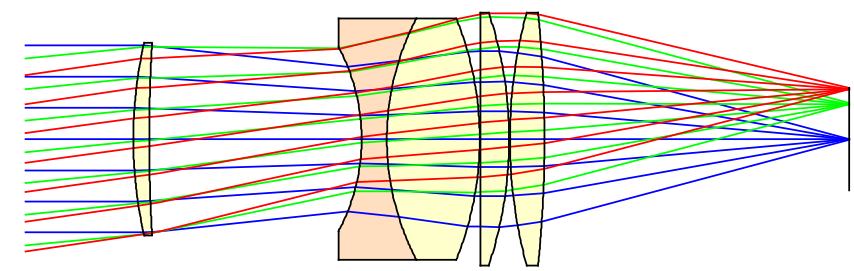
- Case 3



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Telecentric Systems

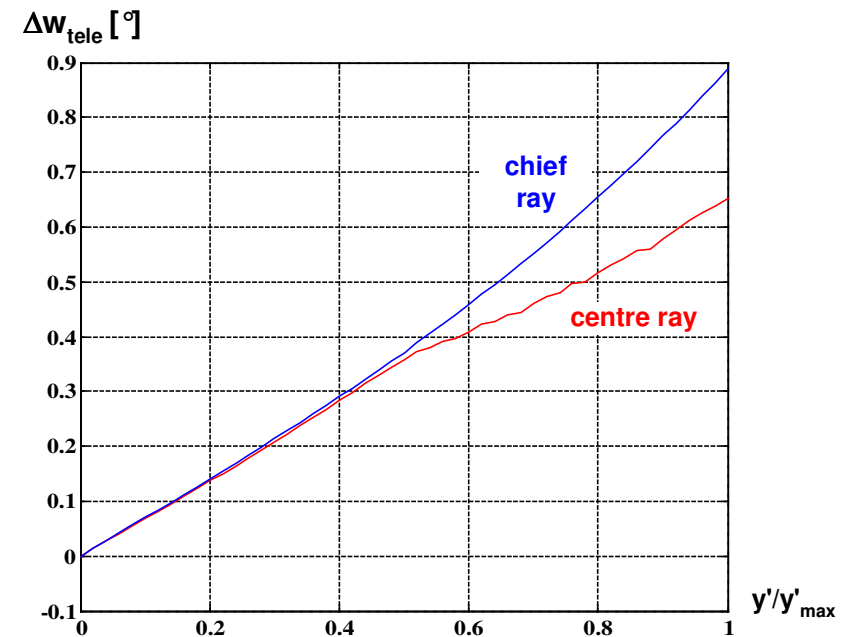
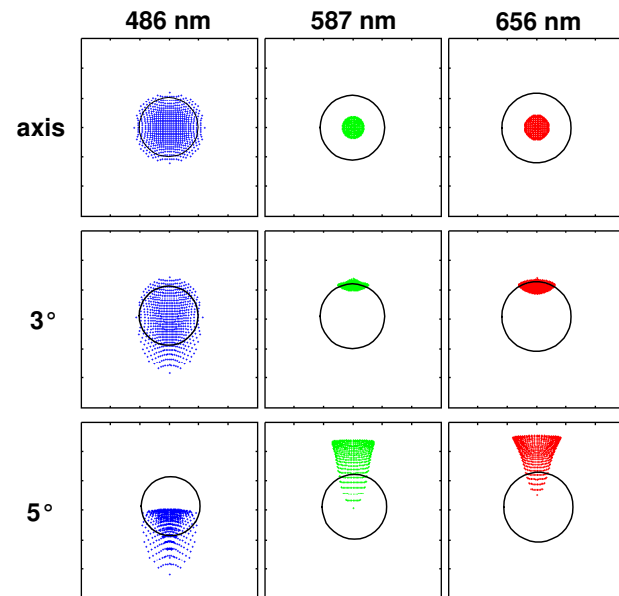
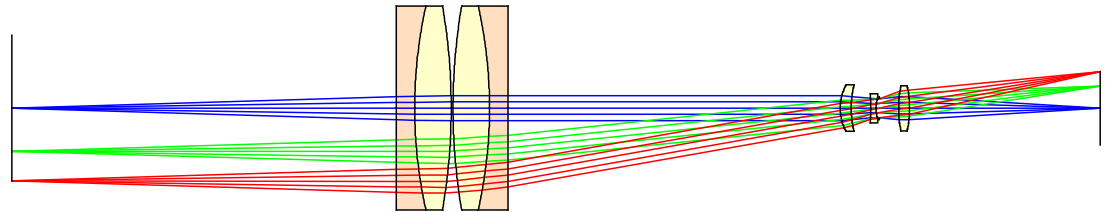
- Example system
- Problem : coma and vignetting disturbe telecentricity
- Definition of telecentricity deviation



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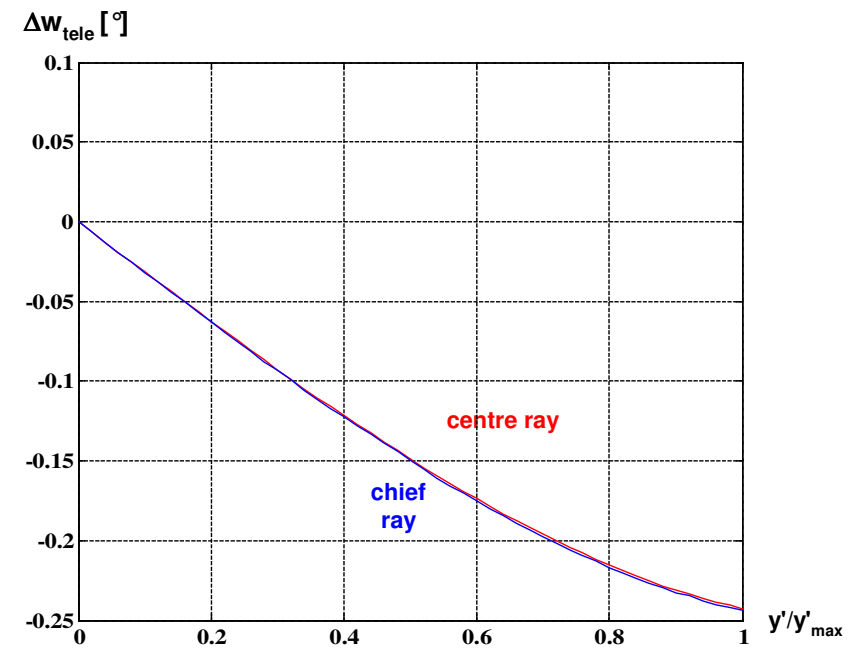
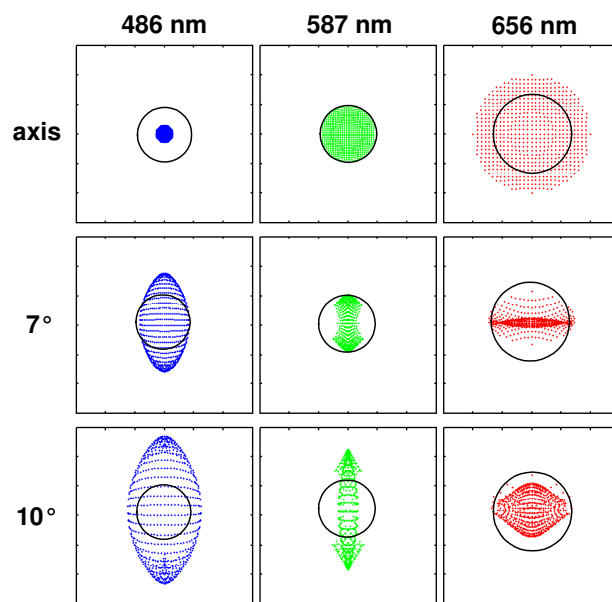
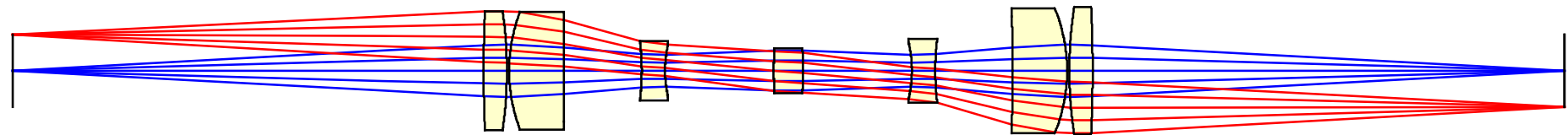
Telecentric Systems

- Typical :
System layout with two groups
- Error due to vignetting



Einfache Optiksyste Telecentric Systems

- Example :
Double sided no-vignetting system



Einfache Optiksysteme

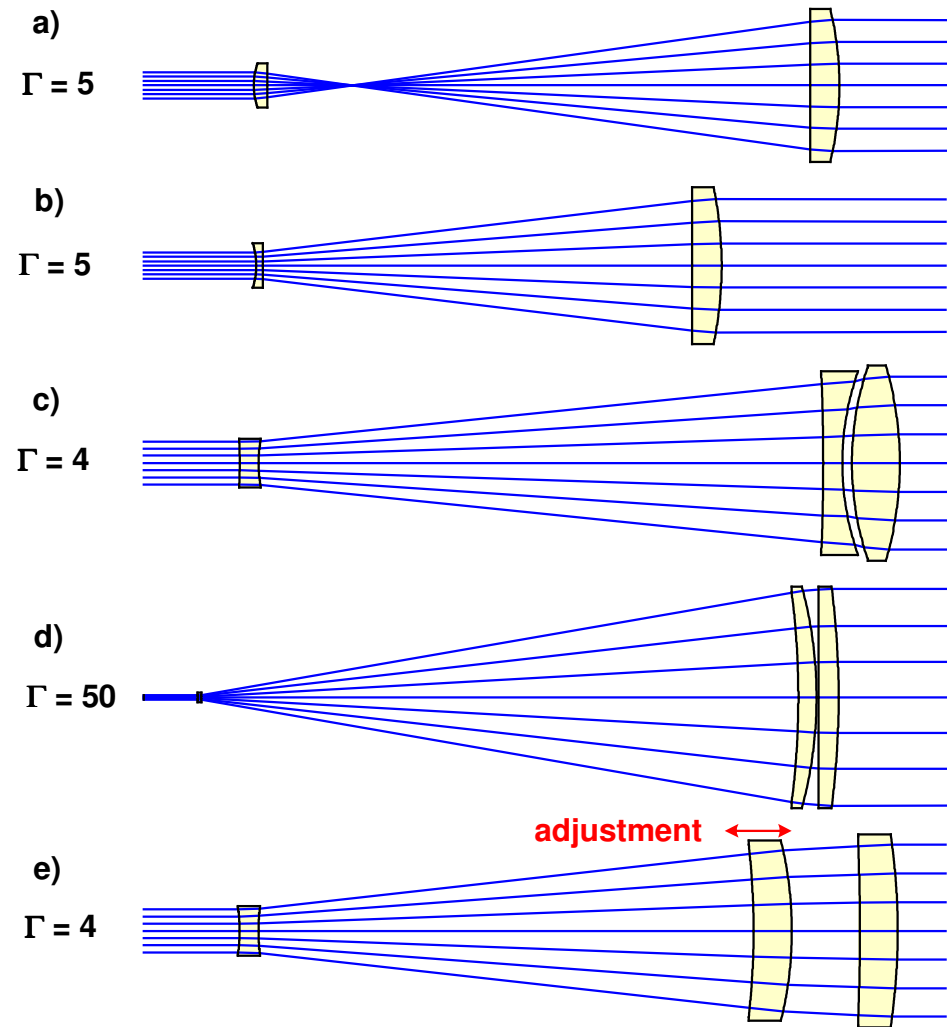
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Beam Guiding Systems

- Transport of laser light over large distances
- Adaptation of beam diameter
- Solutions :
Telescopes of Kepler or Galilei type



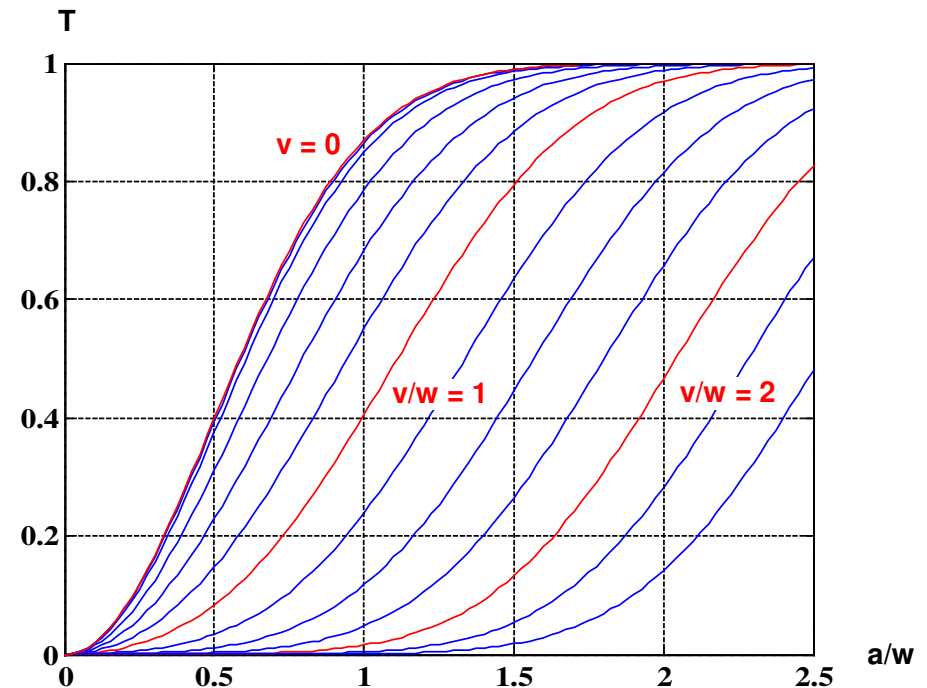
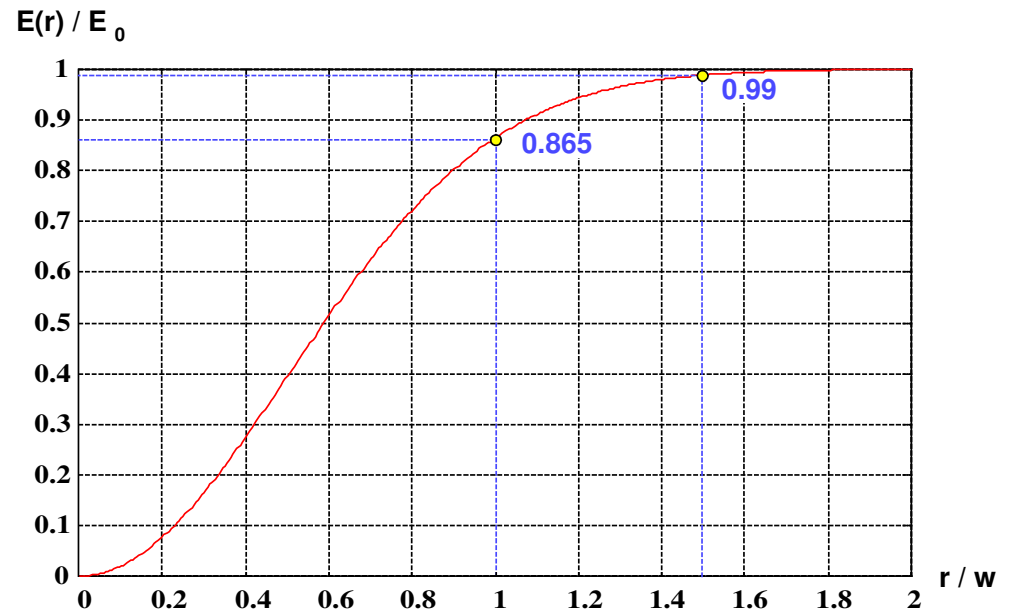
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Beam Transmission

- Encircled energy of a Gaussian beam

$$E(r) = \frac{\int_0^r I(r') 2\pi r' dr'}{\int_0^\infty I(r') 2\pi r' dr'} = 1 - e^{-2\left(\frac{r}{w}\right)^2}$$

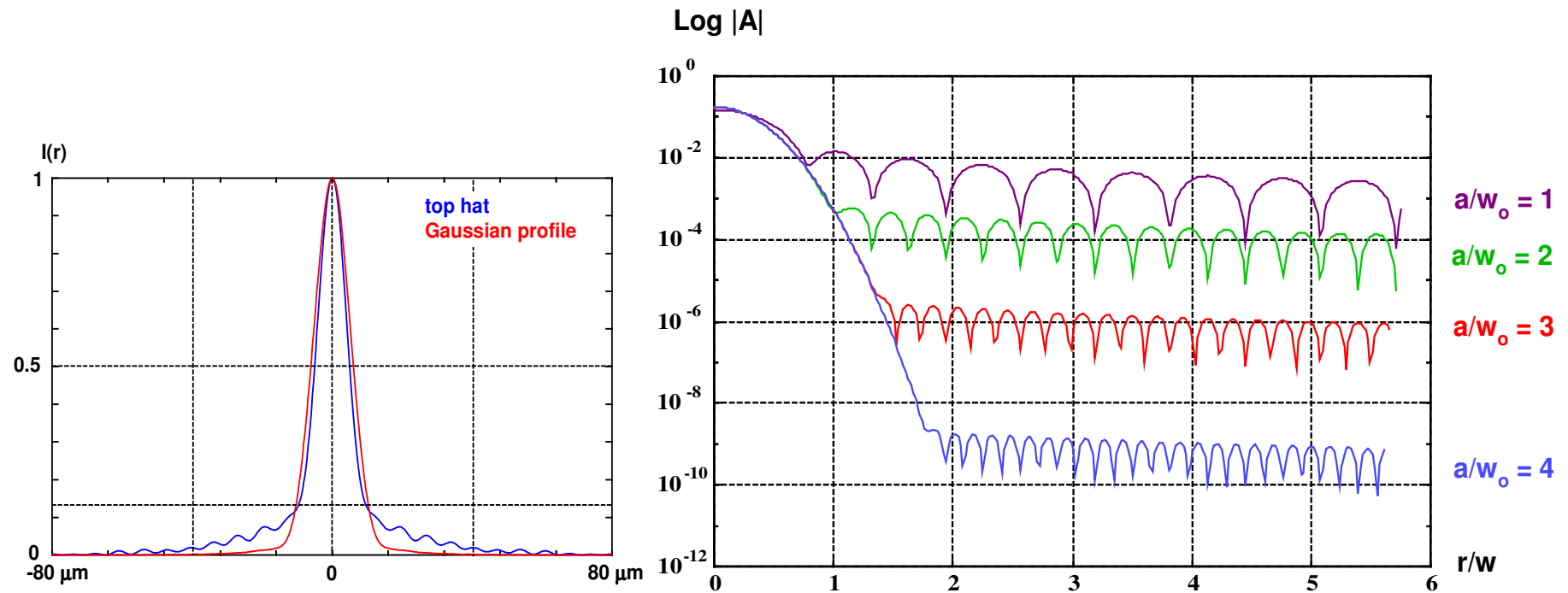
- Transmission through a circular aperture numerical



Einfache Optiksyste

Edge-Diffraction of Gaussian Beams

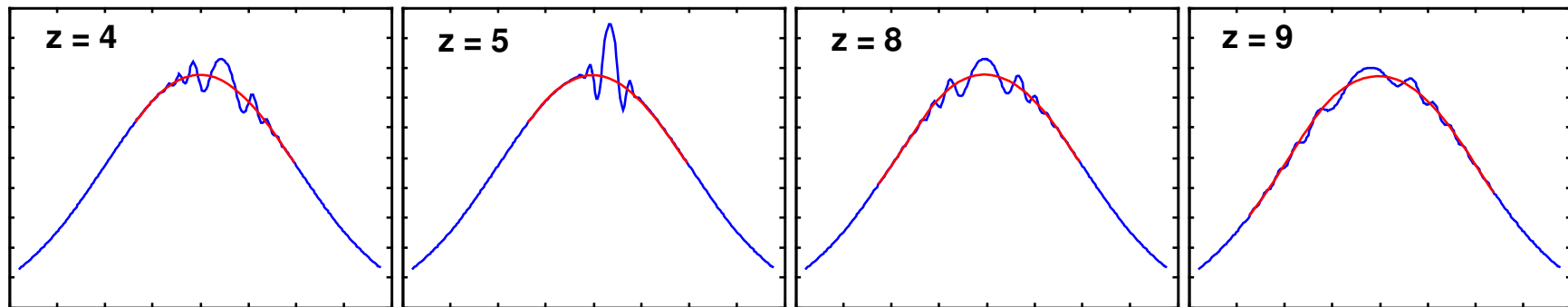
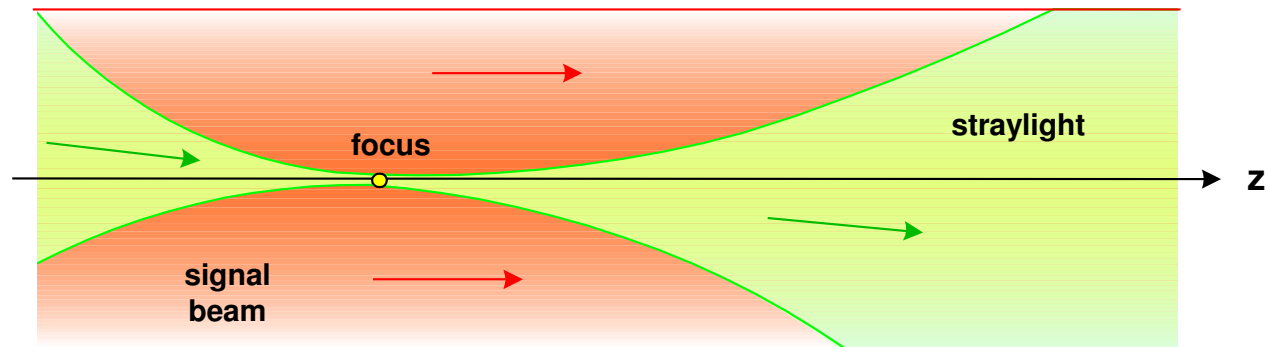
- Truncation of a coherent Gaussian beam at a circular aperture:
Edge-diffraction
- Low-level intensity at the boundary: small effect in focus



Einfache Optiksysteme

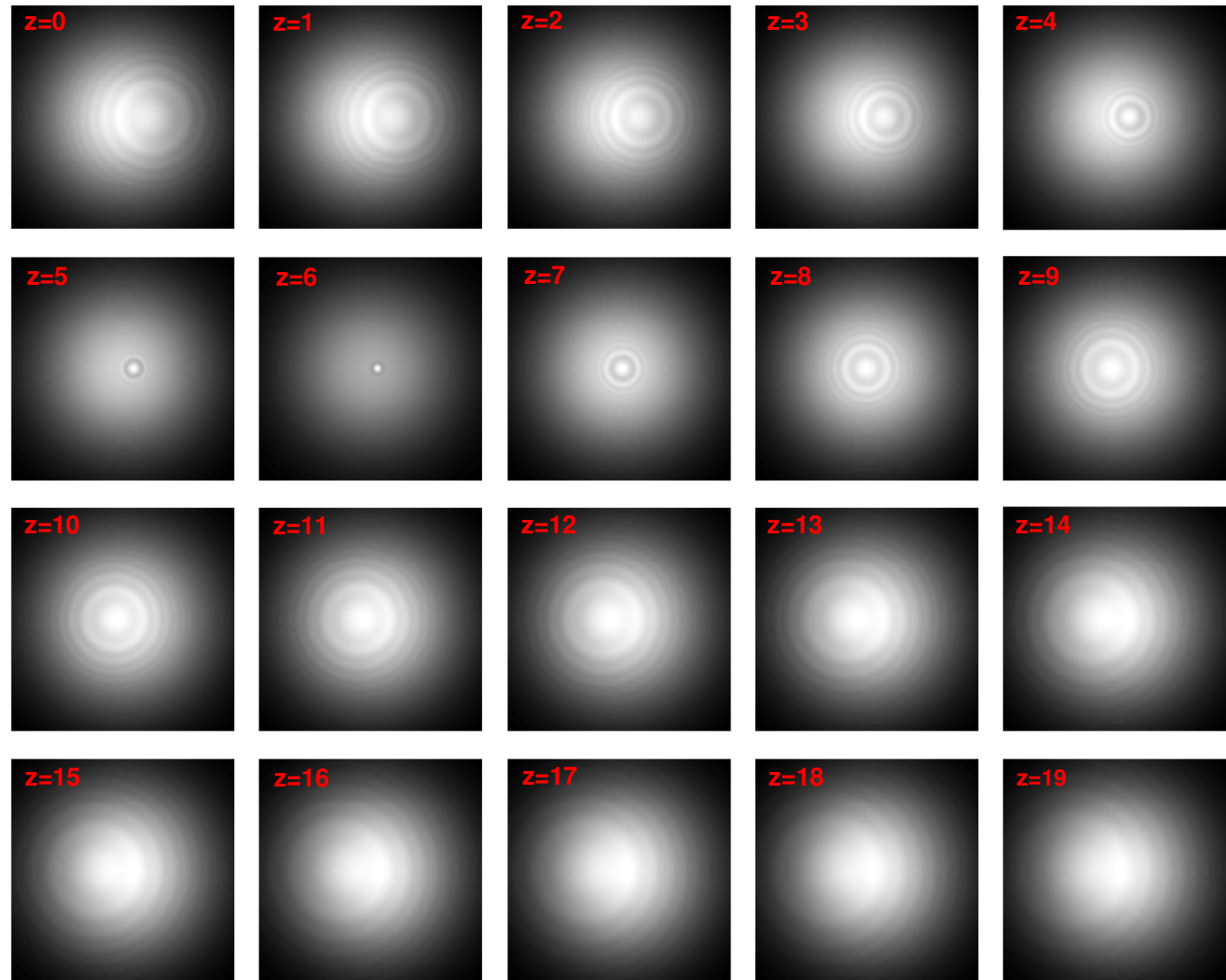
Coherent Straylight

- Example : coherent straylight with 1% of signal energy
Focused straylight : significant interference fringes



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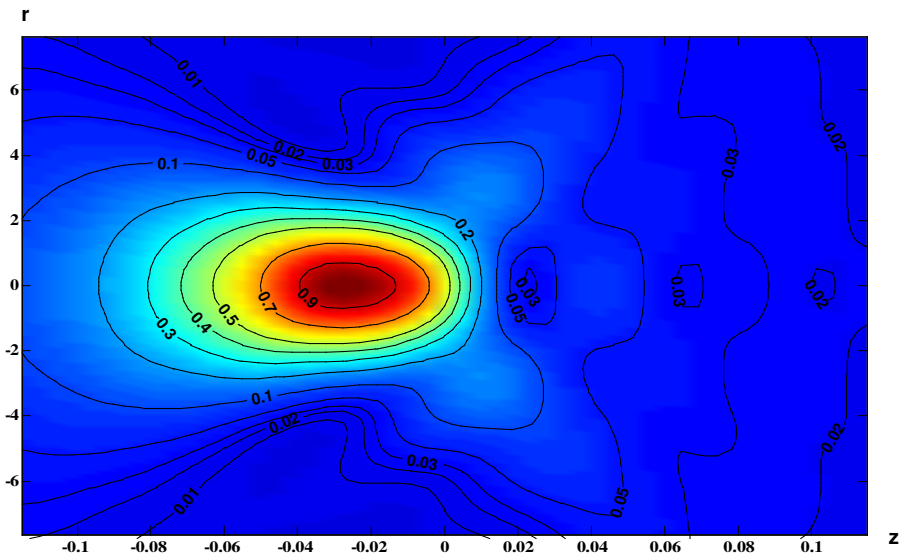
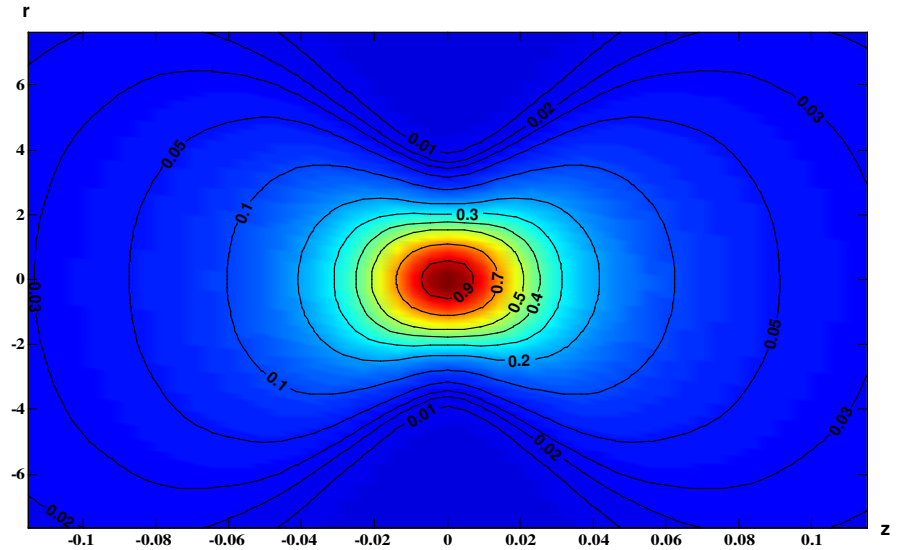
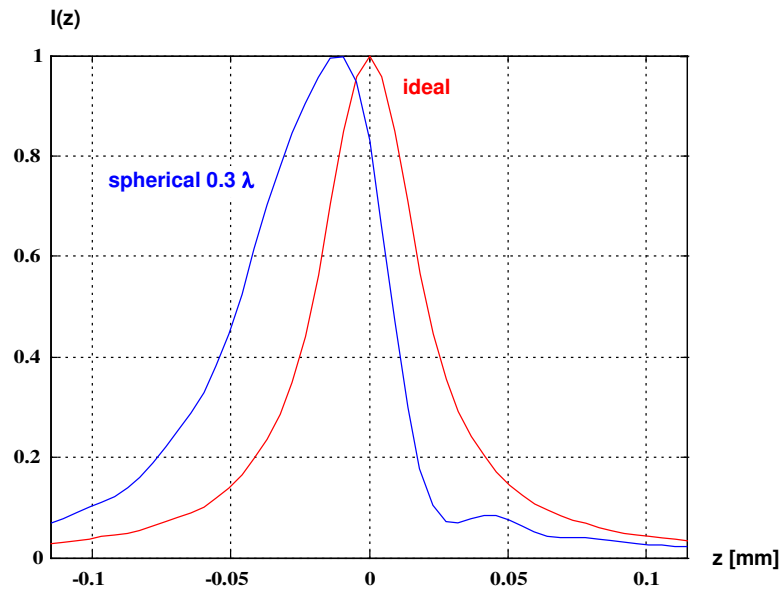
Coherent Straylight



Einfache Optiksyste_me

Gaussian Beams with Aberrations

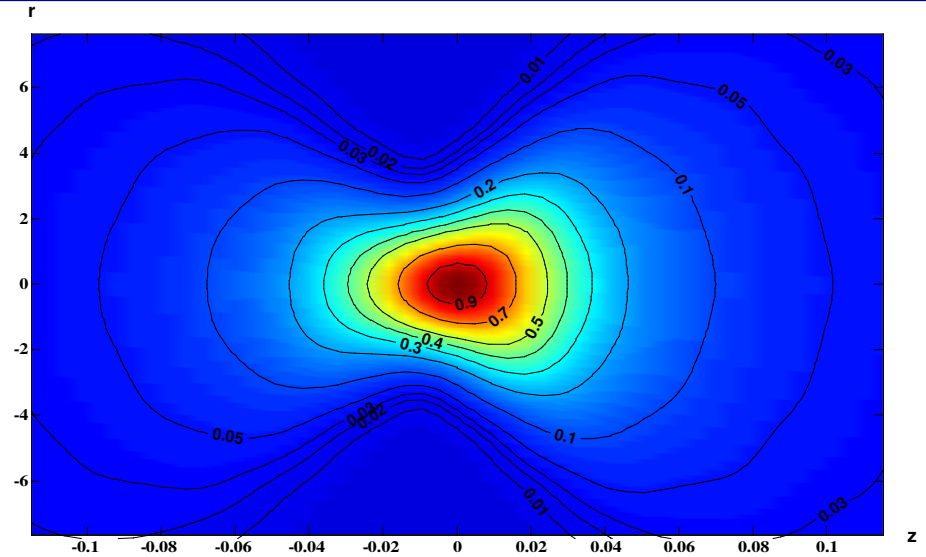
- Ideal intensity $I(r,z)$
- Spherical aberration $c_{40} = 0.3 \lambda$
Asymmetry and focal shift



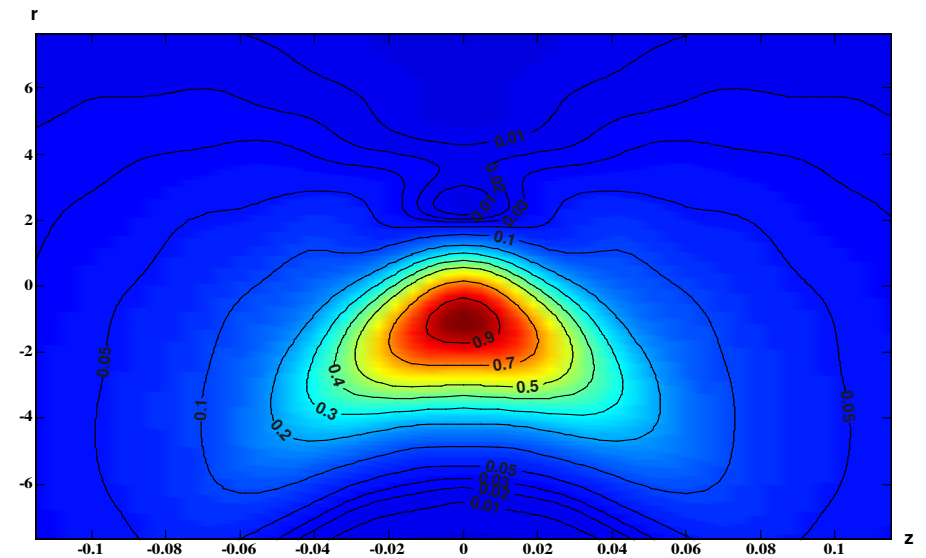
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Gaussian Beams with Aberrations

■ Astigmatism $c_{22} = 0.3 \lambda$



■ Coma $c_{31} = 0.3 \lambda$



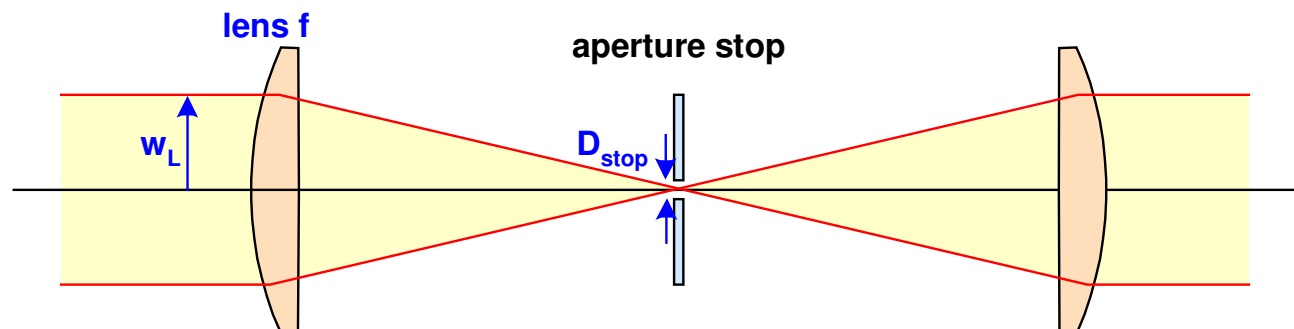
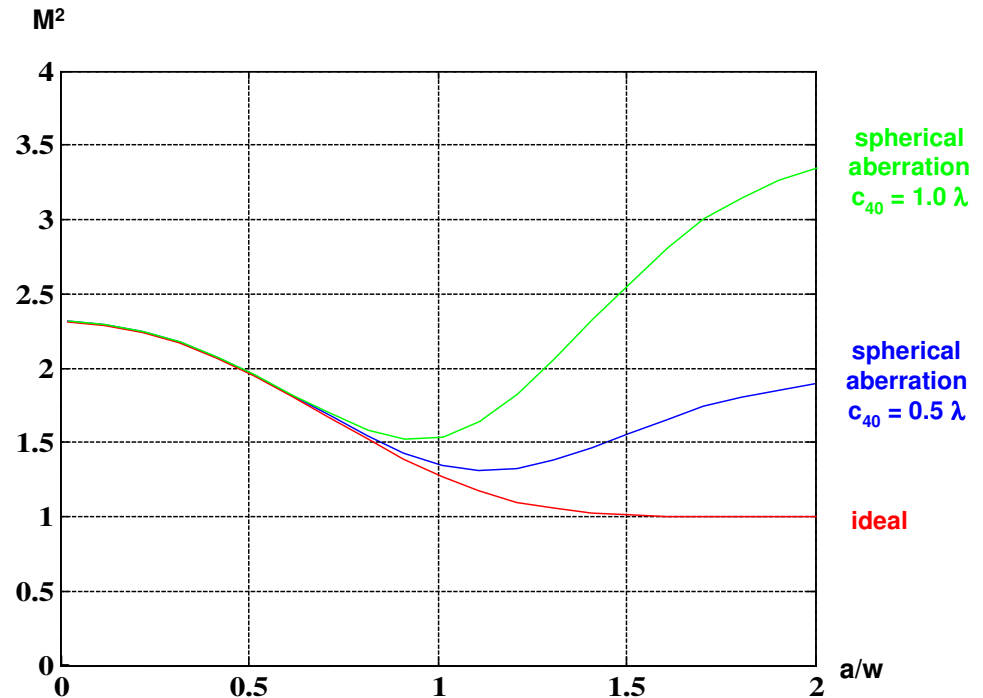
Einfache Optiksysteme

Beam-Clean-up-System

- Filtering of higher order modes in a non-fundamental beam
- Kepler telescope with stop in or near the focal location
- Typical diameter:

$$D_{stop} = \frac{2\lambda f}{\pi w_L} = 0.637 \cdot \frac{\lambda f}{w_L}$$

- Optimization of filtering and diffraction effects



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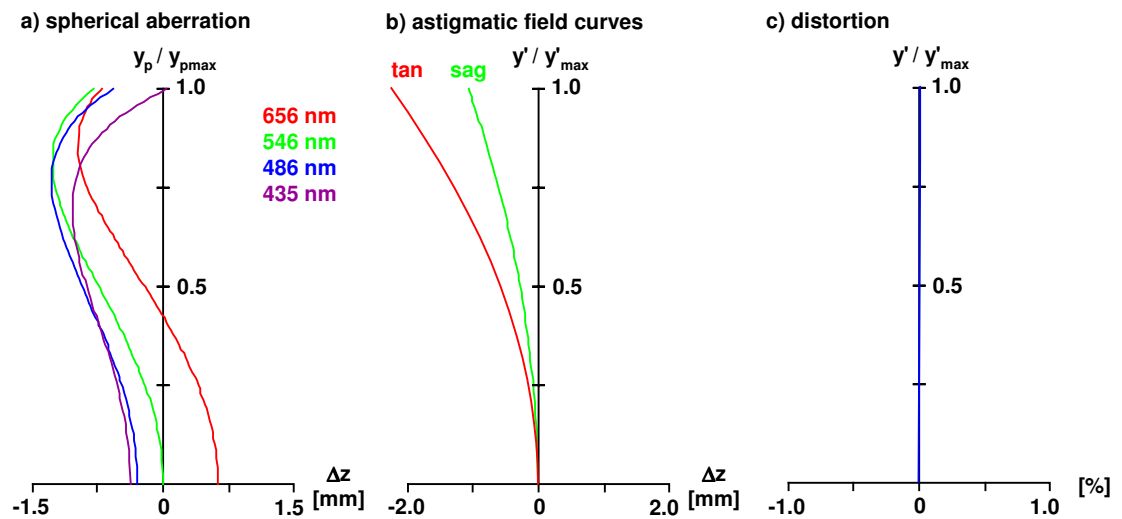
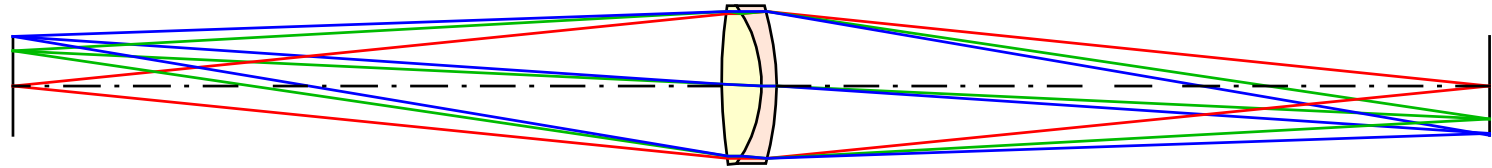
Inhalt:

1. Überblick
2. Achromate
3. Disk-Objektive
4. Kollimatoren
5. Telezentrische Systeme
6. Laser-Strahlführungen
7. Relay-Systeme
8. Scanner-Systeme

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Relay Systems: Achromate

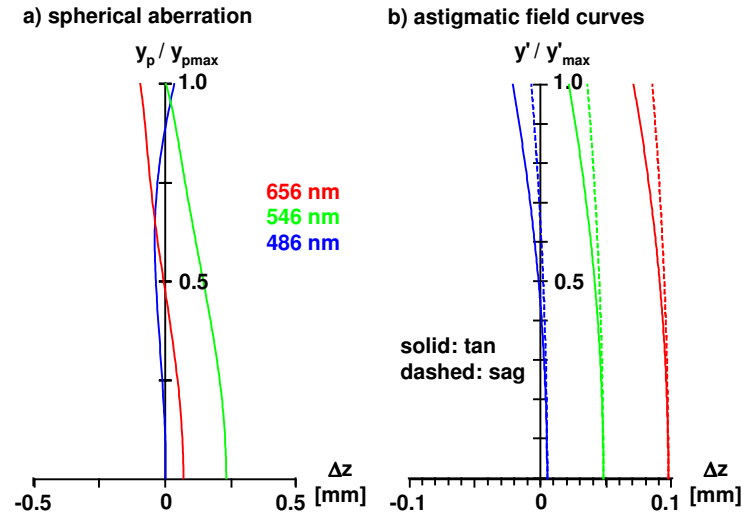
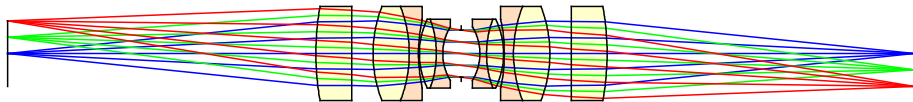
- Large residual aberrations:
 1. Astigmatism
 2. Field curvature



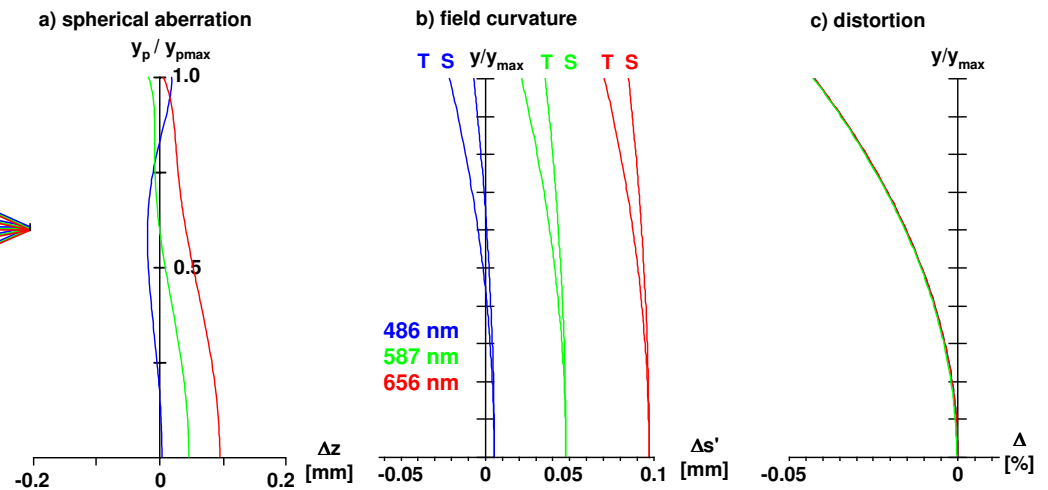
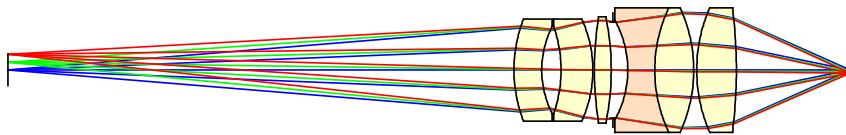
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Relay Systems: More Complicated Systems

- Improved performance with more lenses
- In particular better color correction

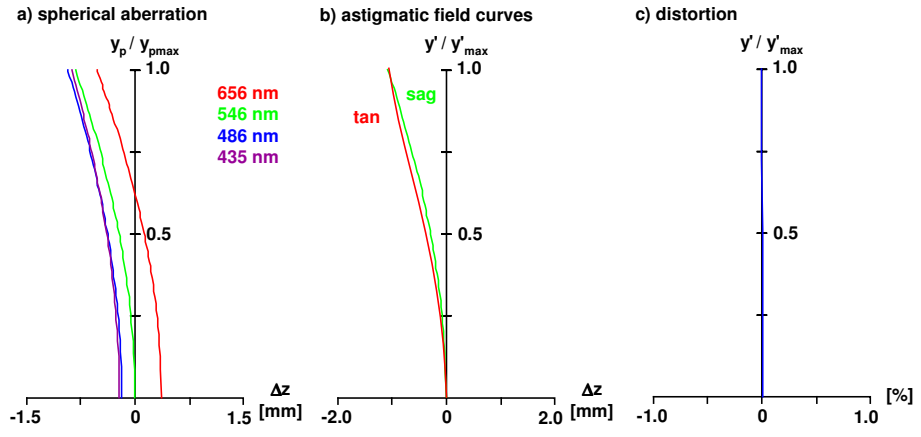
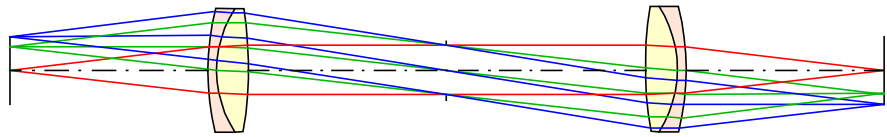


- Magnification $m = 0.2$

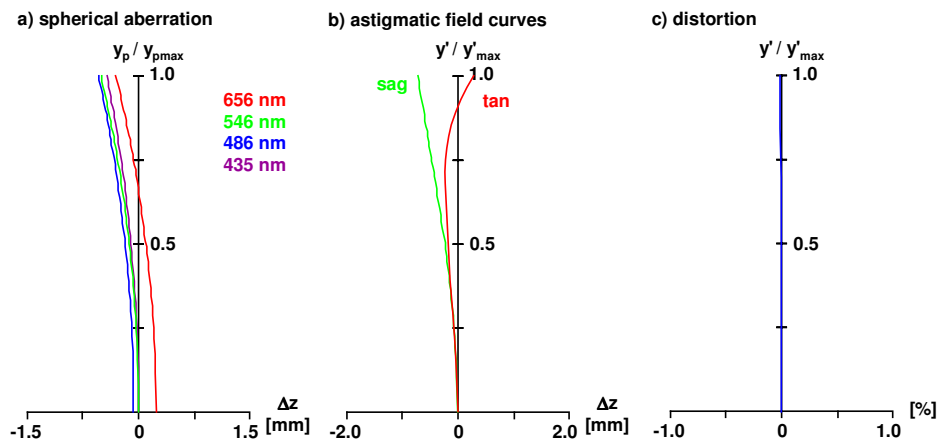
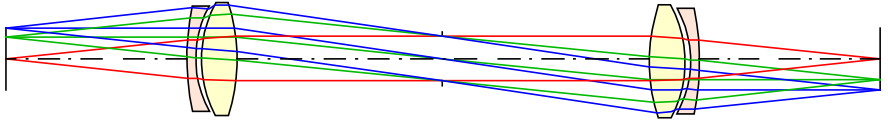


Einfache Optiksyste Relay Systems: 4f-Systems

- Basic system with achromates

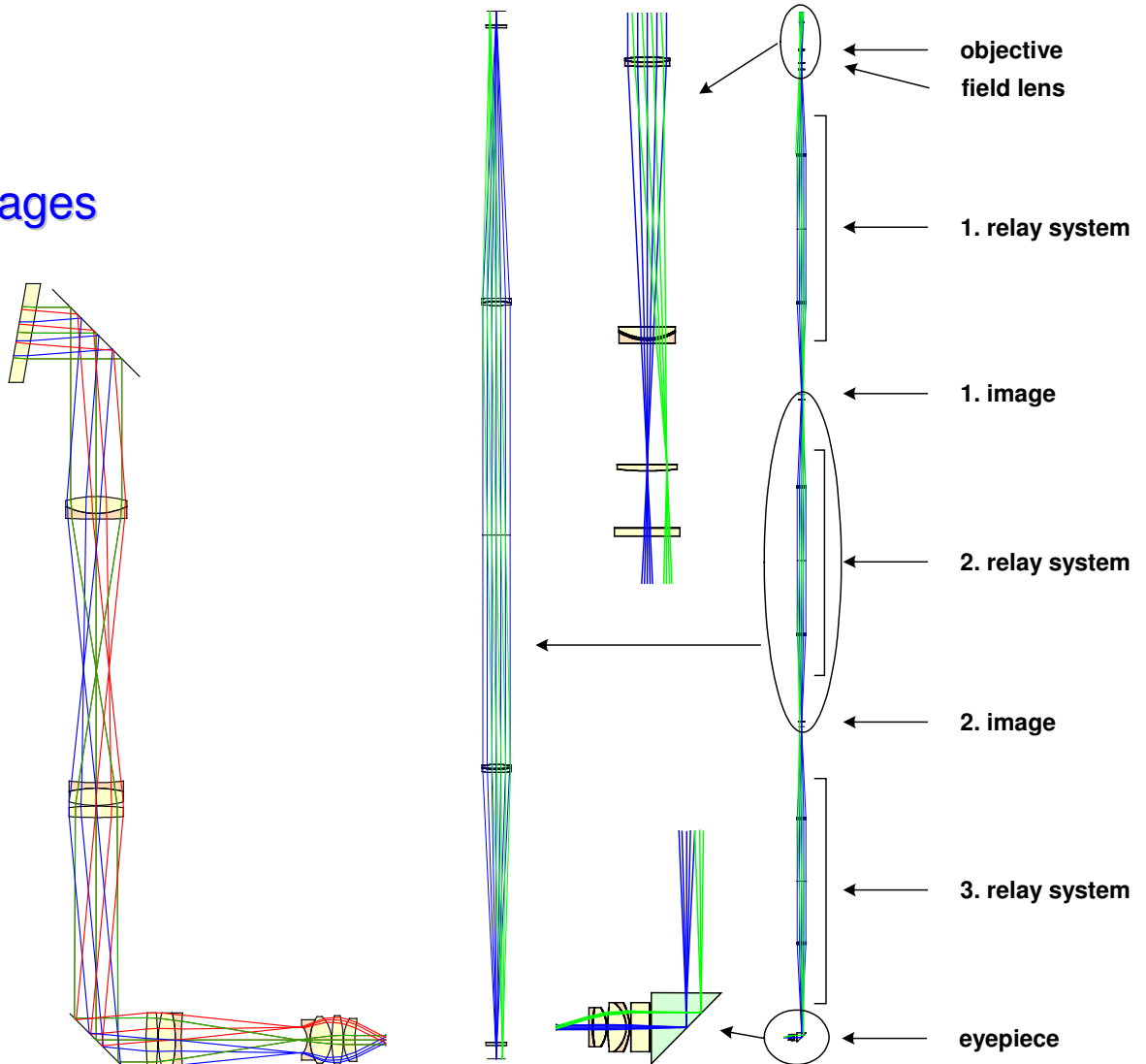


- Split achromates



Einfache Optiksyste Relay Systems: Periscope

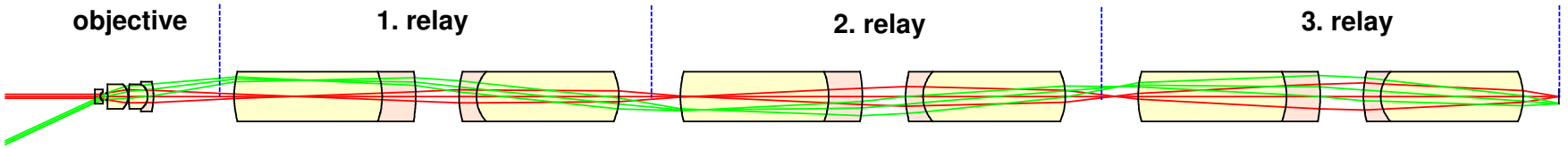
- Major parts:
 1. Eyepiece
 2. Relay system, several stages
 3. Objective
 4. Turnable prism



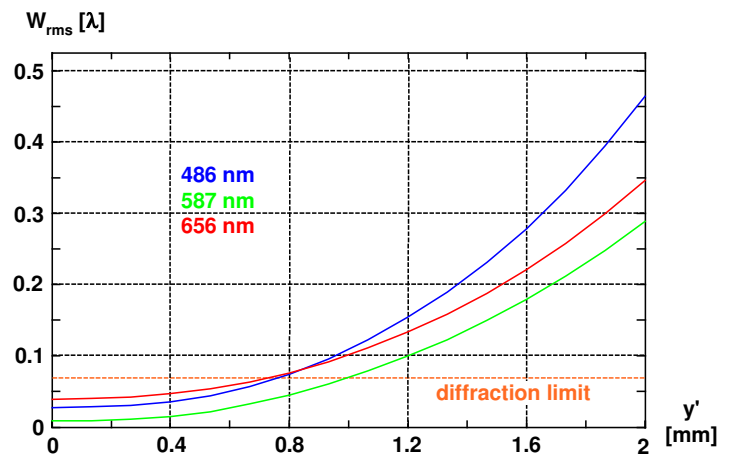
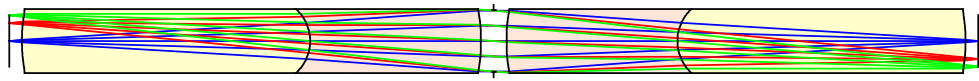
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Relay Systems: Endoscopes

- Transport over large distances
- Combination of several relay subsystems
- Large field-angle objective lens
- Applications: Technical or medical



- Different subsystems:



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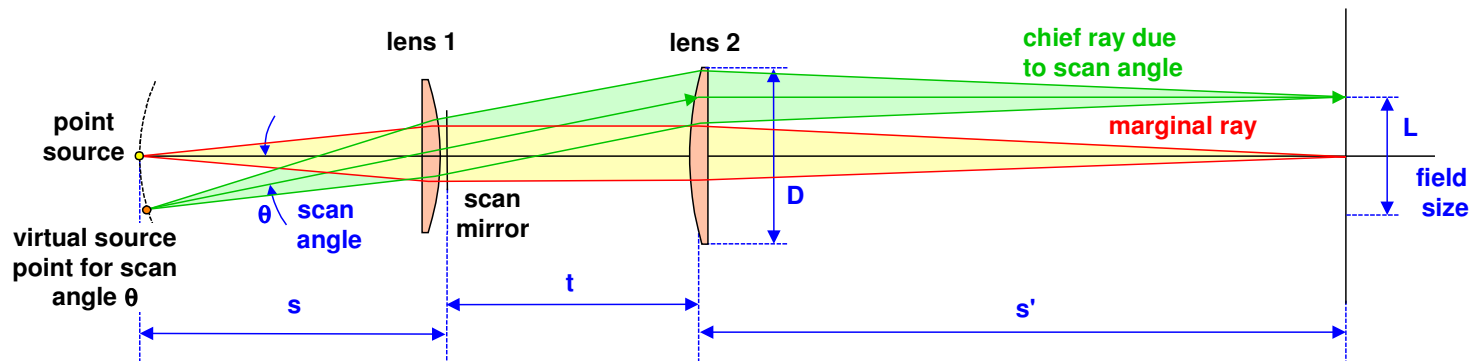
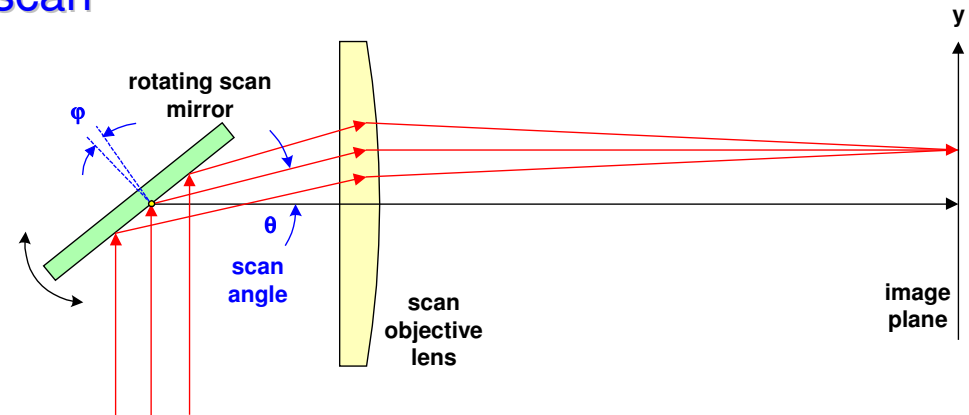
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Scan Systems: Introduction

- Changing components allows a field scan
- Mostly rotating mirrors
- Pre- and post-objective scanning possible
- Scan-magnification $m = 1 \dots 2$

$$m = \frac{d\phi}{d\theta}$$

- Basic setup

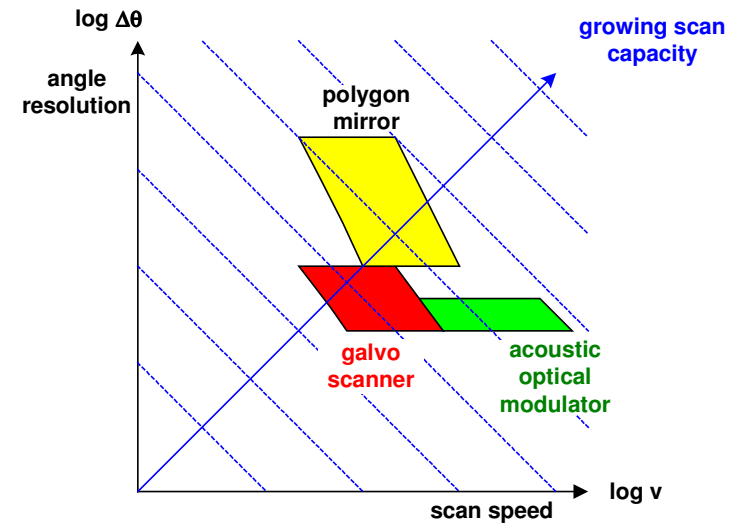
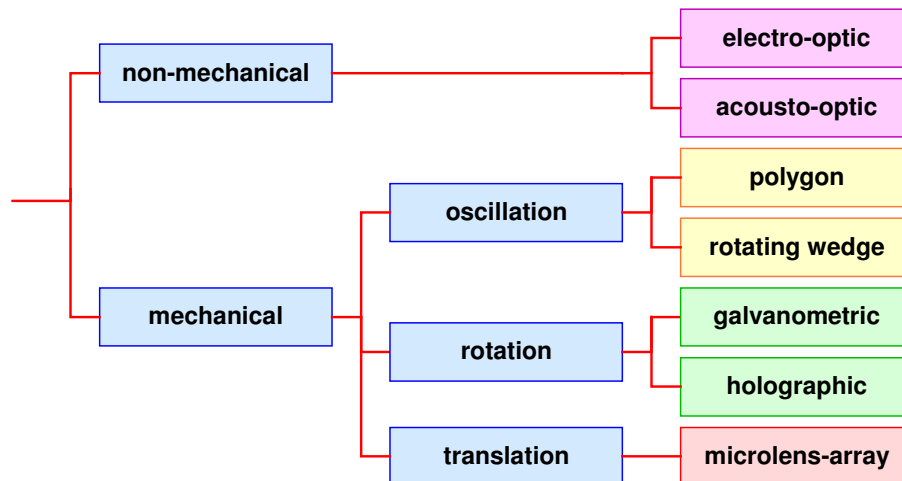


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Scan Systems: Introduction

- Scan resolution:
Number of resolvable points in the field of view
- Information capacity:
 1. Resolvable points
 2. Speed of scanning
- Types of variable components

$$N = \frac{L}{D_{Airy}} = \frac{2 \cdot D_{Exp} \cdot \theta_{max}}{\lambda}$$

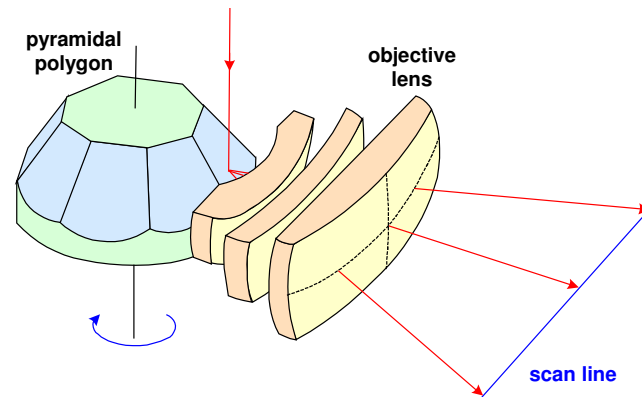


Einfache Optiksyste

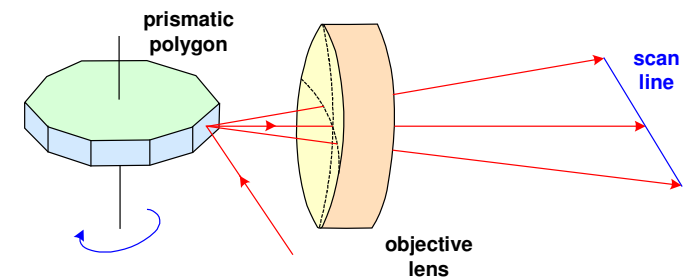
Scan Systems: Varying Components, Polygon Mirrors

- Rotating mirror with facets
- Two types:
 - Pyramidal
 - Prismatic
- Acousto-optical deflector
- Rotating wedges

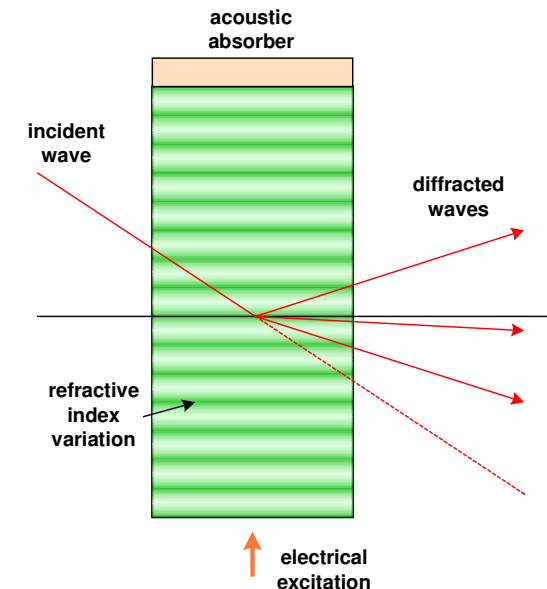
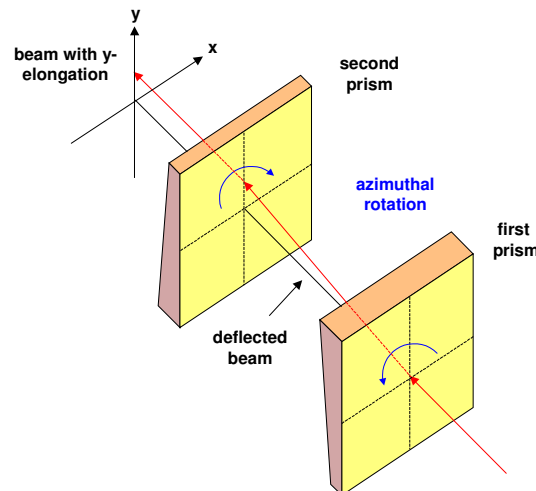
a) pyramidal polygonal mirror



b) prismatic polygonal mirror



a) prism setup



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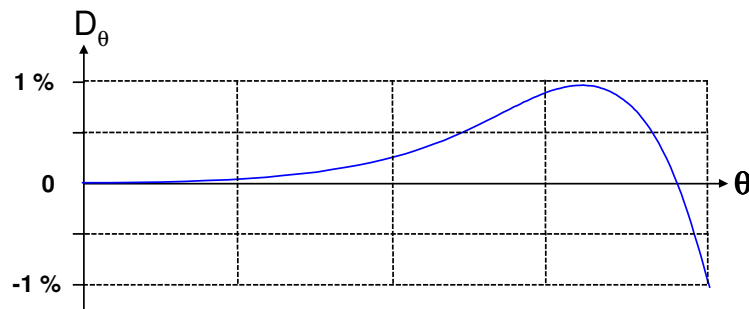
Scan Systems: F- θ -Scan Lenses

- Paraxial image height
- Desired in scan systems:
linearity of image position to angle size
- Solution : special distortion

$$D = \frac{\theta}{\tan \theta}$$

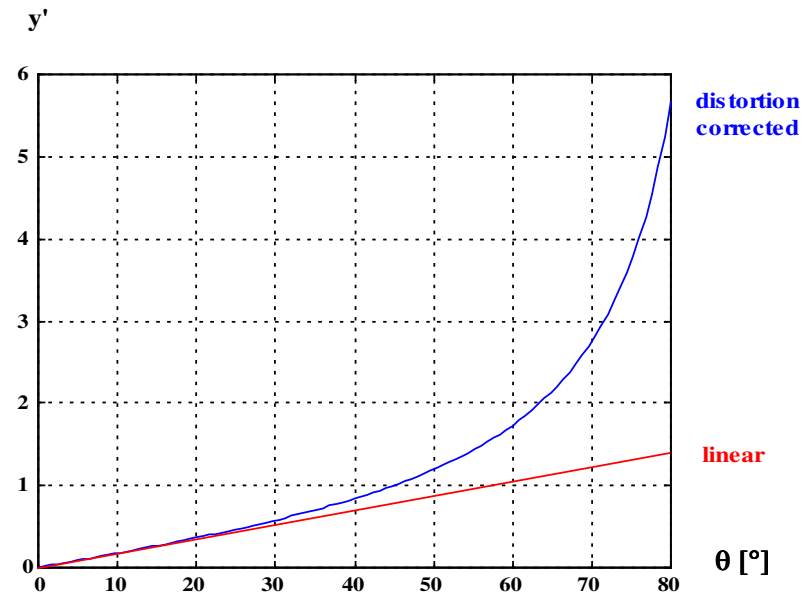
- Definition of deviation as aberration

$$D_{\theta} = \frac{y'}{f \cdot \theta} - 1$$



$$y' = f \cdot \tan \theta$$

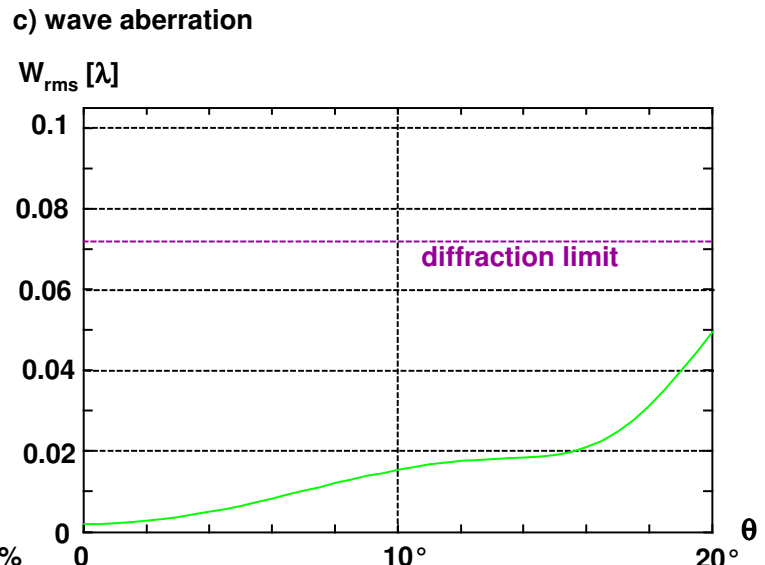
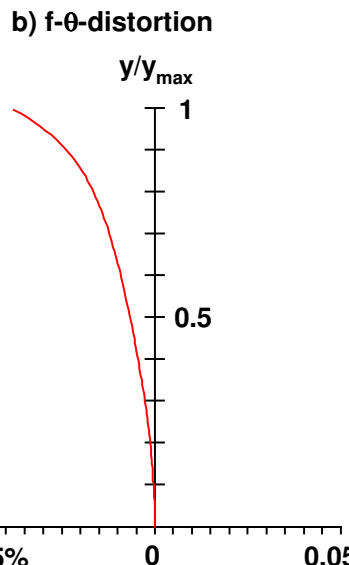
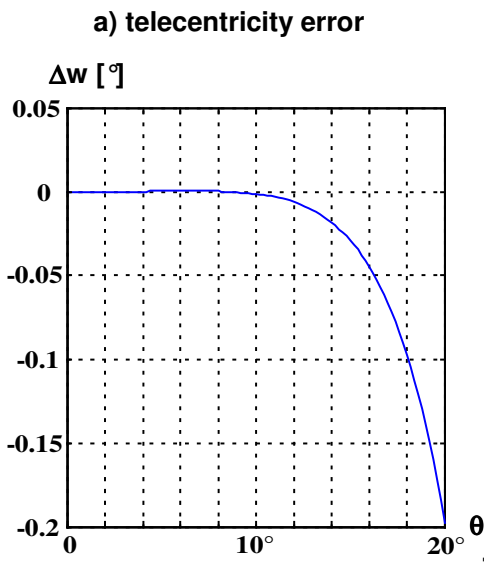
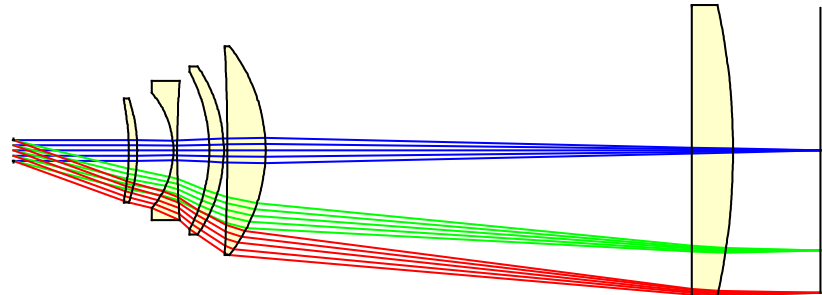
$$L = 2 \cdot f \cdot \theta$$



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Scan Systems: Example 1

- Monochromatic
- Scan field 2x20°
- Numerical apertur 0.025
- Telecentric
- F- θ -correction
- With field lens



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Scan Systems: Example 2

- Non-telecentric
- Scan angle $2 \times 30^\circ$
- Monochromatic
- F- θ -corrected

