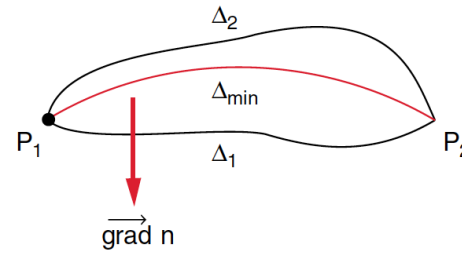


Ch. 9 geometrische Optik

- **Prinzip von Fermat**
- **Abbildungen**
- **Holspiegel**
- **Linsen**
- **Matrix-Optik**

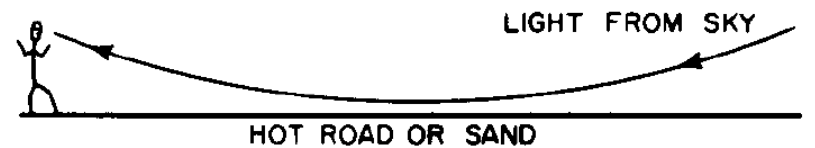
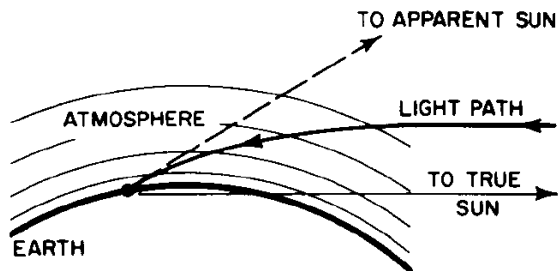
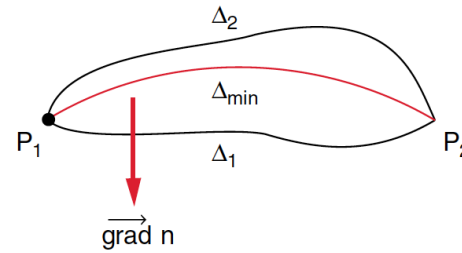
Prinzip von Fermat

$$\delta \int_{P_1}^{P_2} n(\mathbf{x}) d\mathbf{x}$$



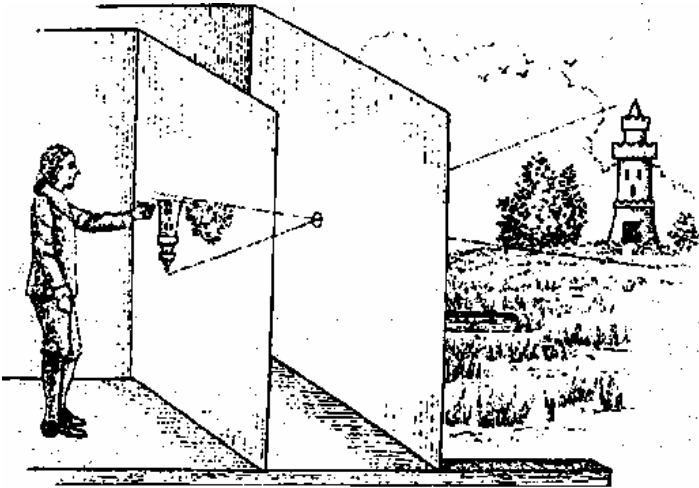
Prinzip von Fermat

$$\delta \int_{P_1}^{P_2} n(\mathbf{x}) d\mathbf{x}$$



Camera obscura

- Bekannt seit Aristoteles (c. 300 BC)
- Erste Nutzung: Leonardo da Vinci (1452-1519)



Camera Obscura @ University of Pretoria



Sténopé



1-2min Belichtung



Vergleich Sphärischer- und Parabolspiegel

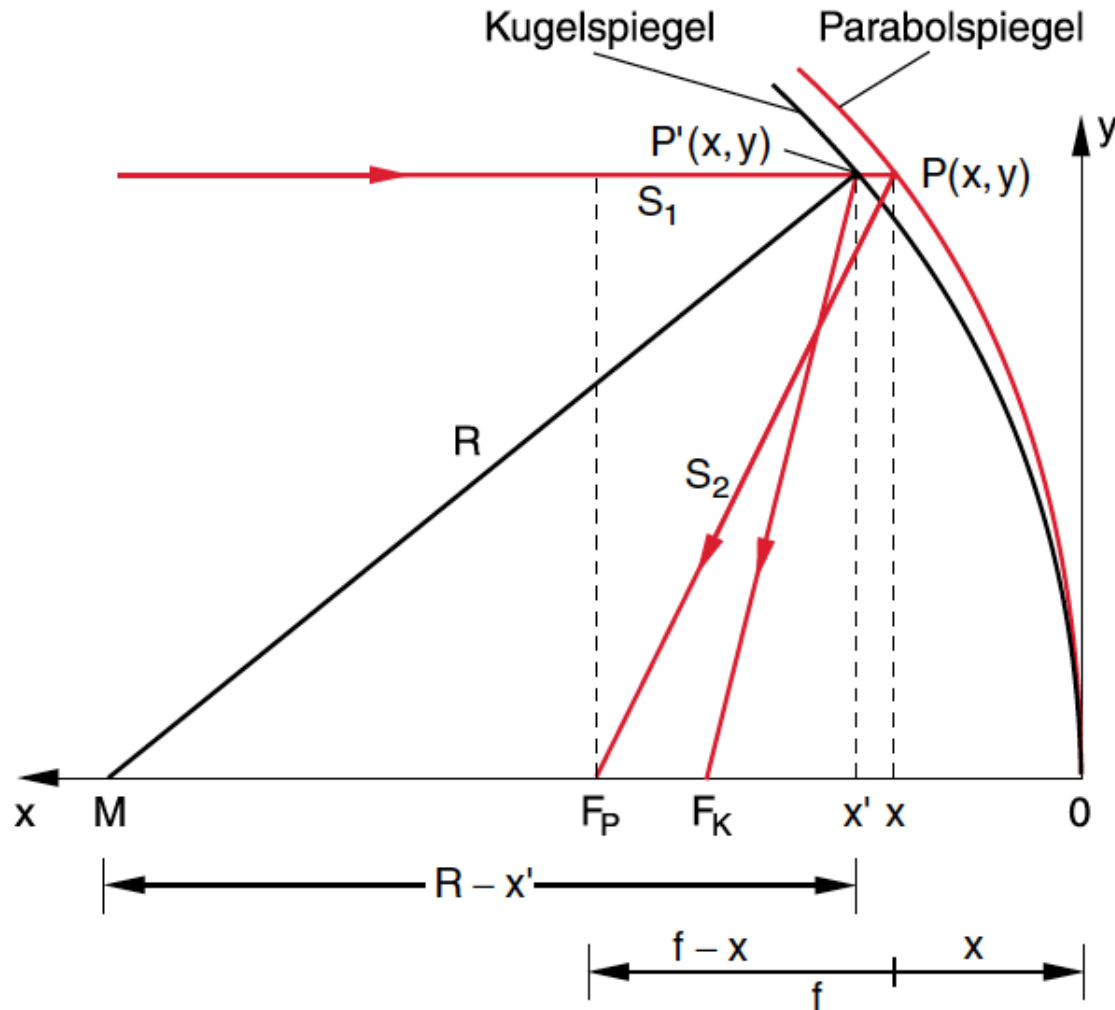
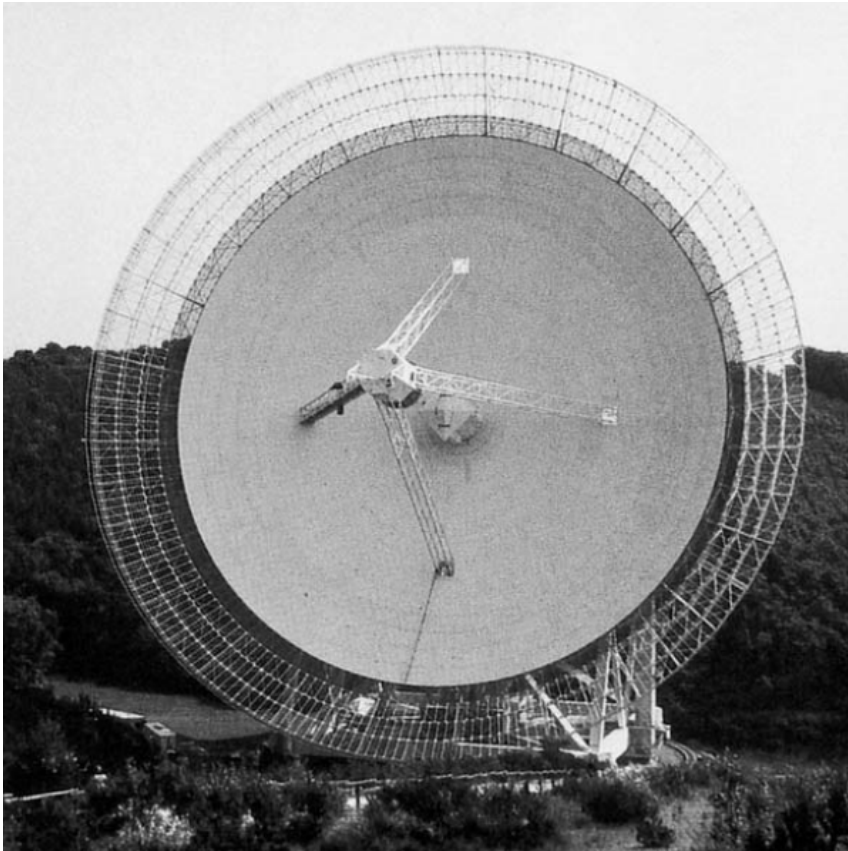


Abb. 9.17. Vergleich des Strahlenganges bei sphärischem Spiegel und Parabolspiegel mit Brennweite $f = R/2$. Für $y \ll R$ wandert F_K gegen F_P nach $x = R/2$

Parabolspiegel für Radio-Astronomie



Radioteleskop des Max-Planck-Instituts für Radioastronomie in Effelsberg, DE

Geometrische Konstruktion des Bildes eines achsennahen Punktes

3 Strahlen zeichnen

S1: parallel zur Achse

S2: durch Brennpunkt

S3: durch Kugelmittelpun.

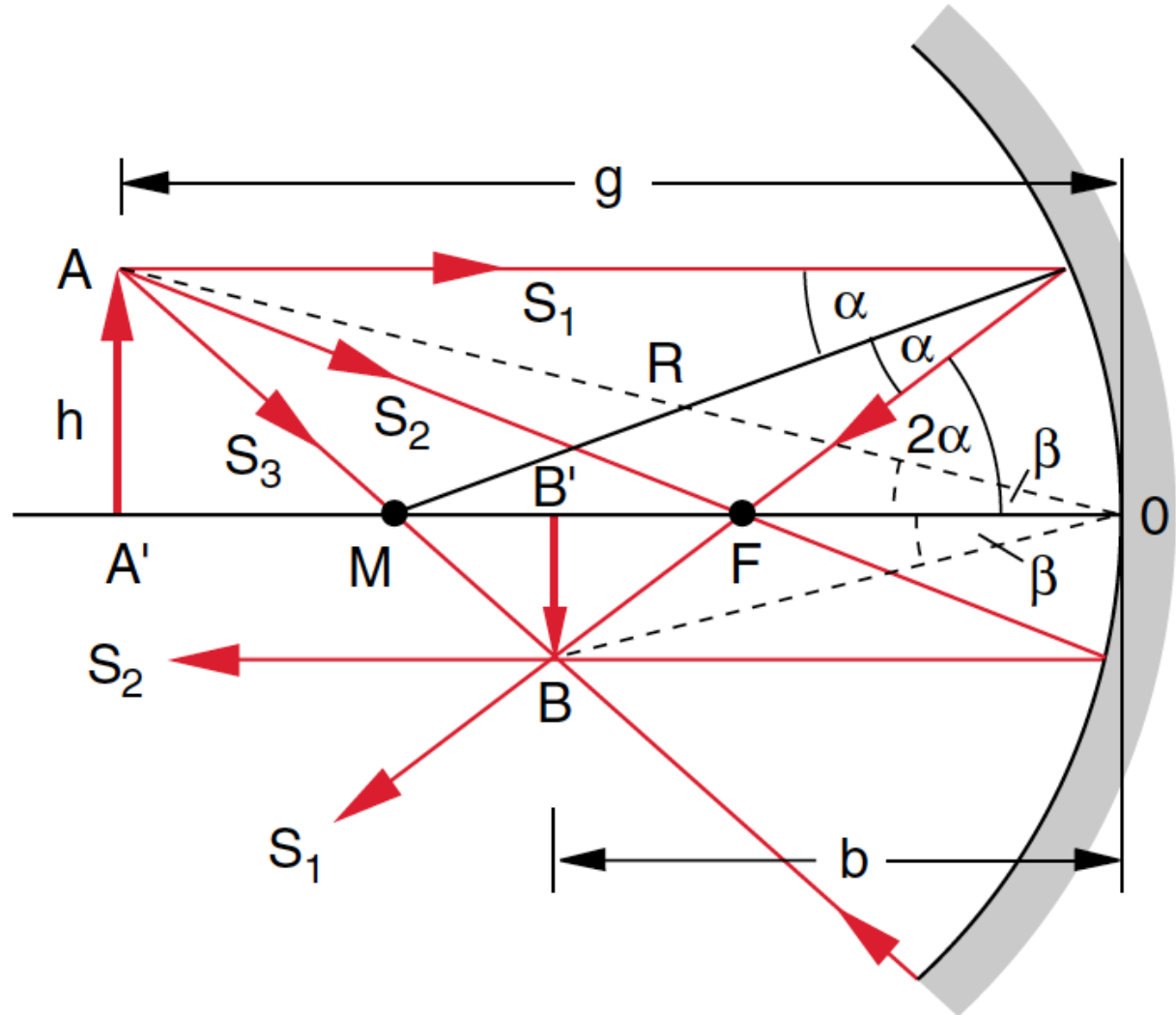


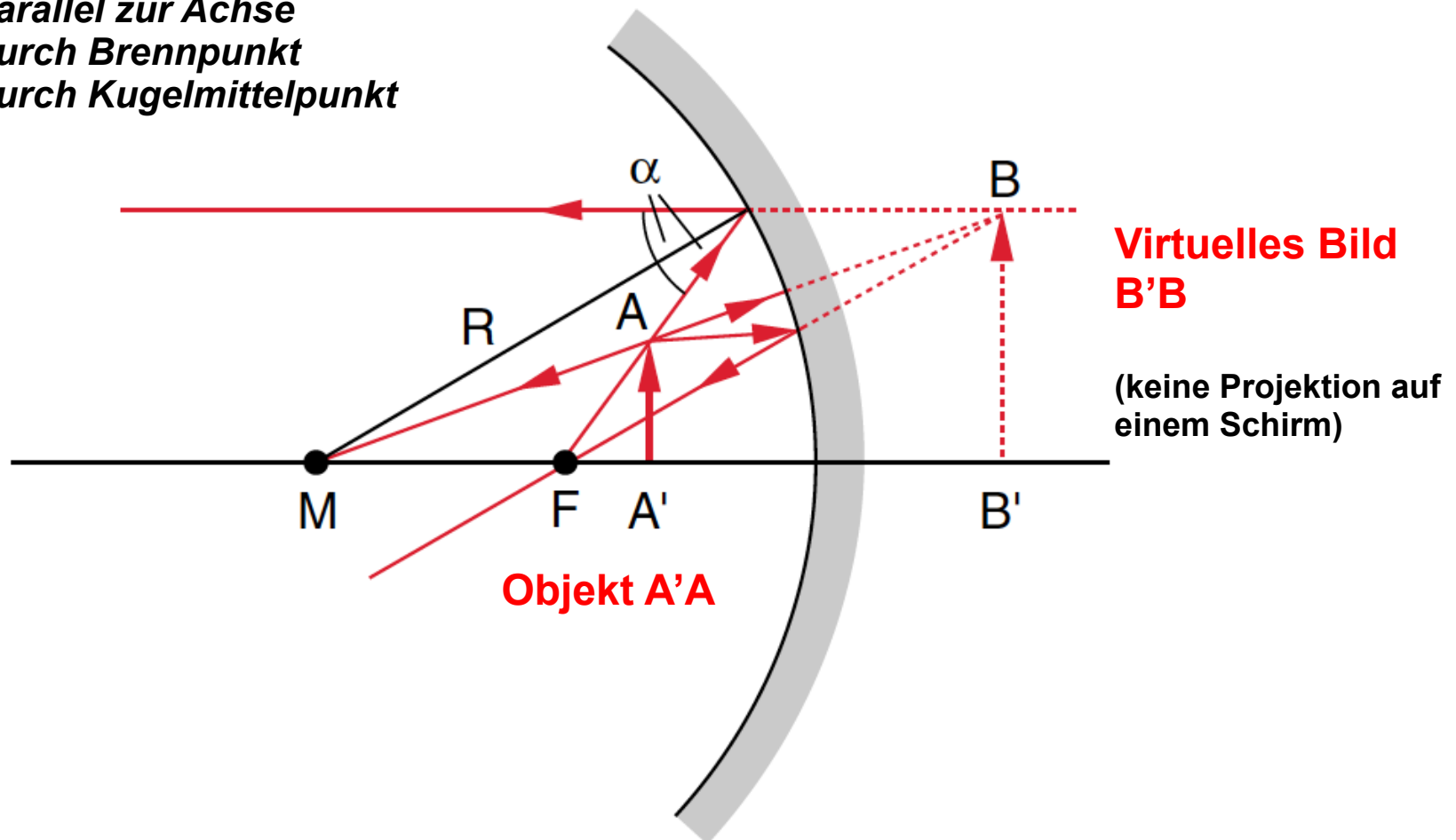
Abbildung Massstab

$$\frac{\overline{BB'}}{\overline{AA'}} = \frac{b}{g}$$

Entstehung eines virtuellen Bildes

Objekt (Schweinchen) zwischen Spiegel und Brennpunkt

3 Strahlen zeichnen
S1: parallel zur Achse
S2: durch Brennpunkt
S3: durch Kugelmittelpunkt



Konkaver und konvexer Spiegel

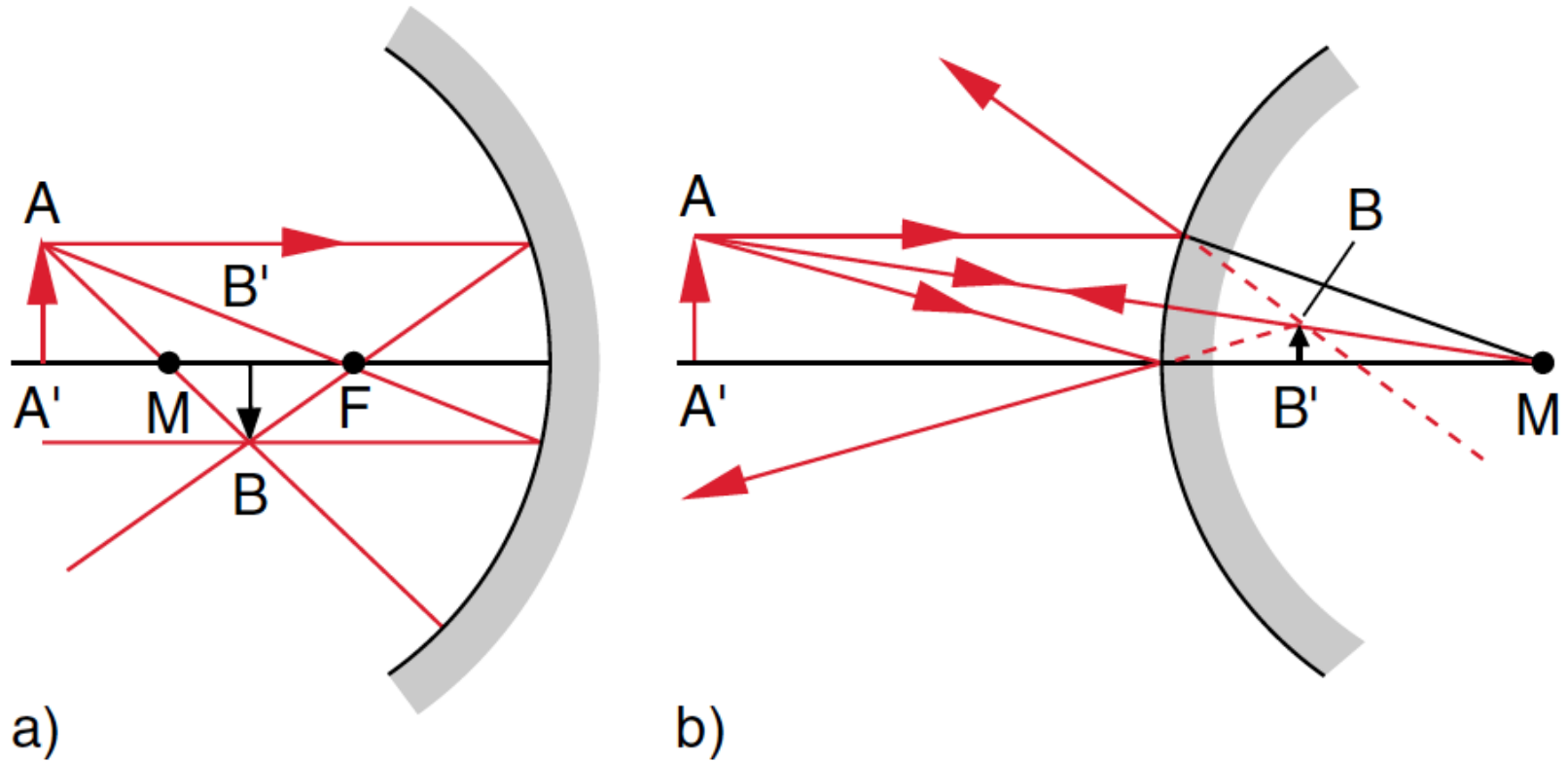
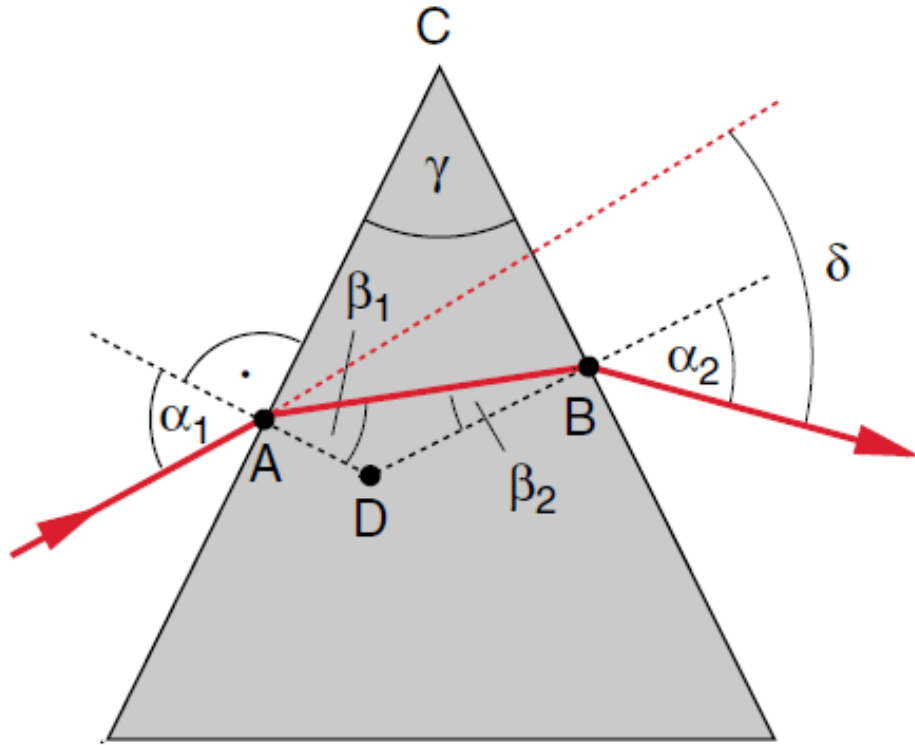


Abb. 9.14. (a) Konkaver und (b) konvexer Hohlspiegel

Prisma



δ : Ablenkung des Lichtstrahls

Für symmetrischen Strahlengang ($\alpha_1 = \alpha_2 = \alpha$)
ist δ minimal ($\delta = \delta_{\min}$):

$$\delta_{\min} = 2\alpha - \gamma$$

Dann gilt (für kleine Winkel):

$$\delta = \gamma(n - 1)$$



Dispersion!

Bildformation an dünner Linse

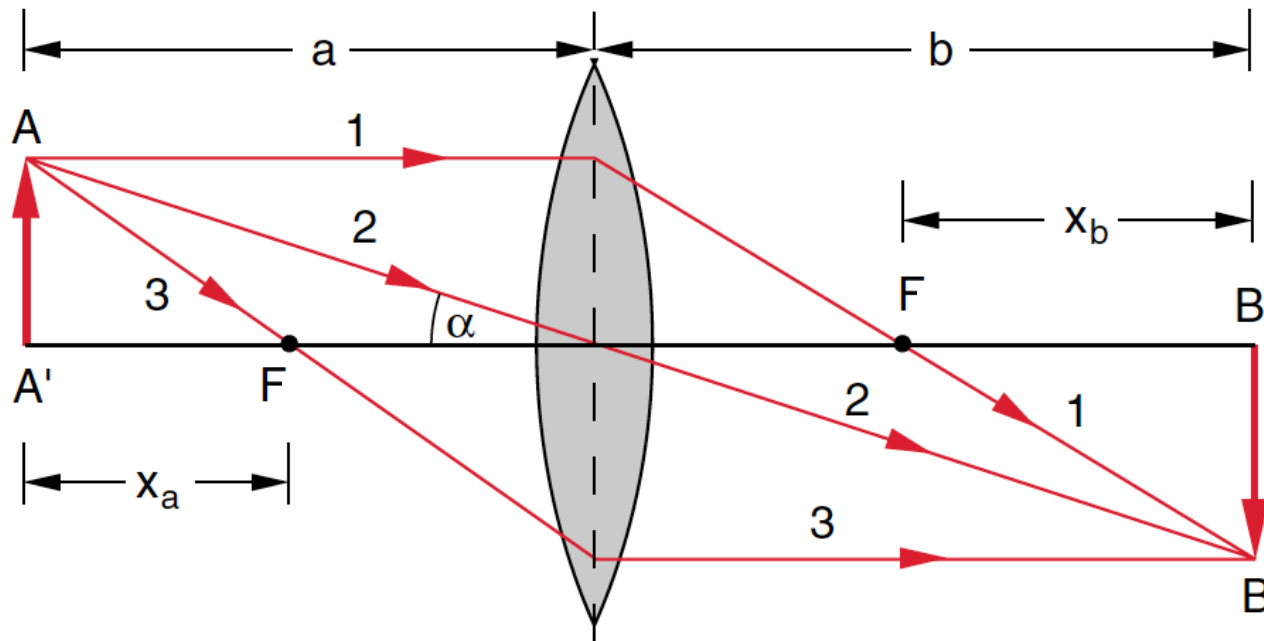


Abb. 9.27. Zeichnerische Konstruktion der Abbildung durch eine dünne Linse

Startend von Punkt A

1. **Parallel zur optischen Achse** (orthogonal und zentriert zur Linse)
2. **Durch Zentrum der Linse**, un-abgelenkt
3. **Durch Fokalpunkt F** (tritt parallel zur optischen Achse aus)

Bildformation an zwei dünnen Linsen

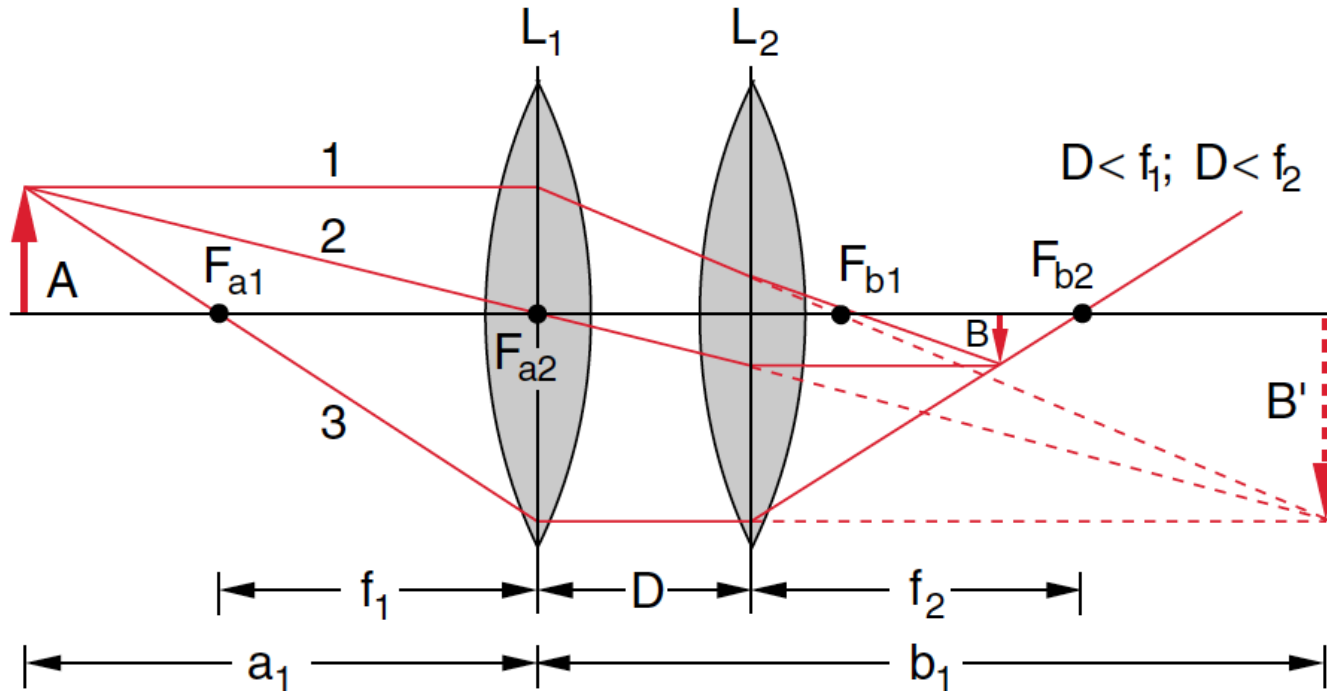


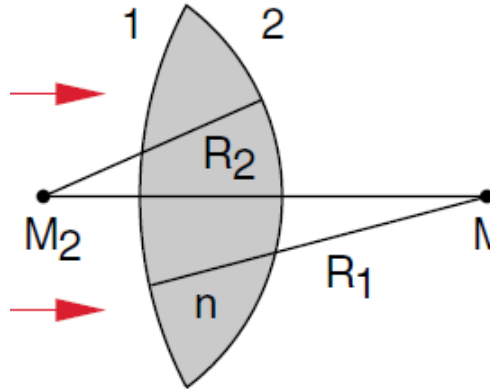
Abb. 9.33. Abbildung durch ein System zweier Linsen, deren Abstand D kleiner als jede ihrer Brennweiten f_i ist

Startend von Punkt A

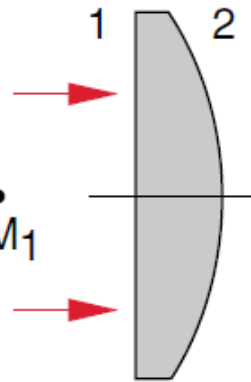
1. Benutze Prozedere für **einfache Linse** um **virtuelles Bild B'** zu erhalten
2. Durch **Zentrum der Linse**, un-abgelenkt
3. **Durch Fokalfpunkt F** (tritt parallel zur optischen Achse aus)

Linsen

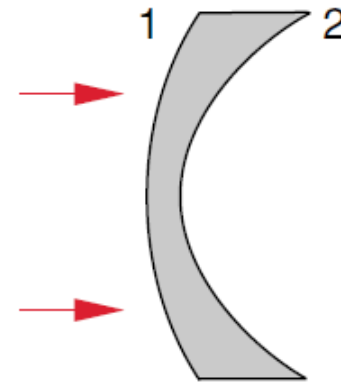
bikonvex



plan-konvex



konvex-konkav



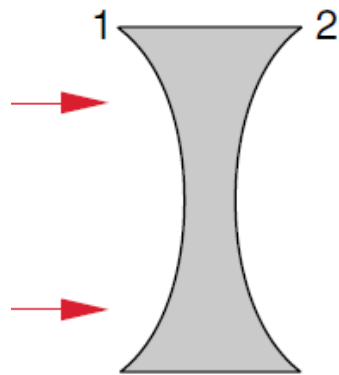
**Zeichen
Konvention**

a) $R_1 > 0$
 $R_2 < 0$

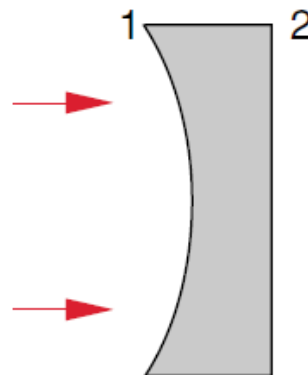
b) $R_1 = \infty$
 $R_2 < 0$

c) $R_1 > 0$
 $R_1 \neq R_2 > 0$

bikonkav



plan-konkav



Kugel-**asphärisch**
fläche



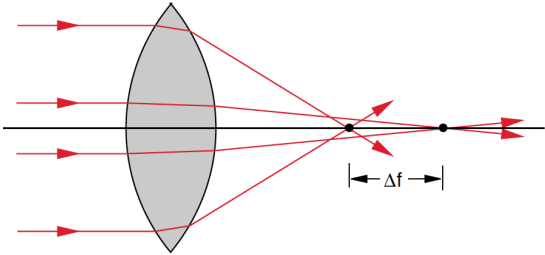
d) $R_1 < 0$
 $R_2 > 0$

e) $R_1 < 0$
 $R_2 = \infty$

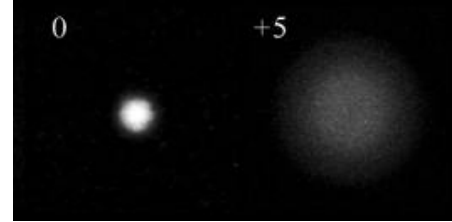
f) nicht-
sphärisch

Linsen-Fehler

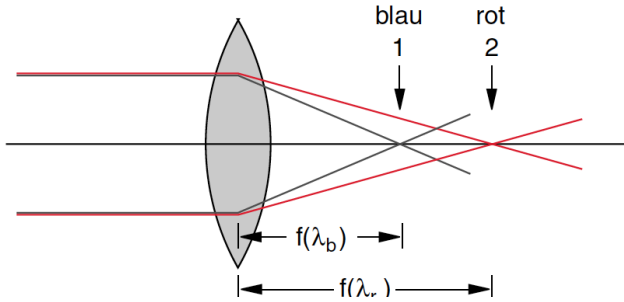
sphärische
Aberration



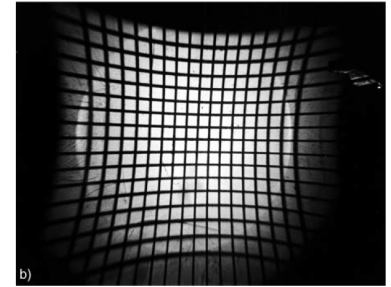
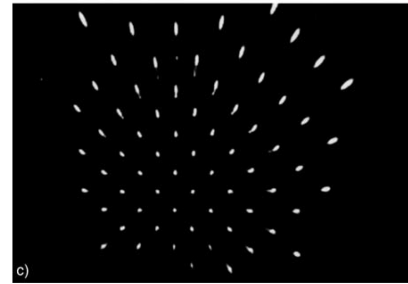
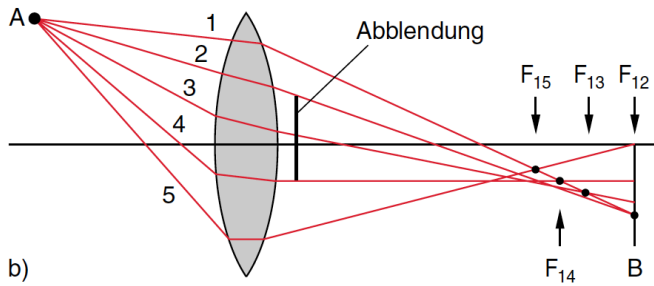
Blende: klein gross



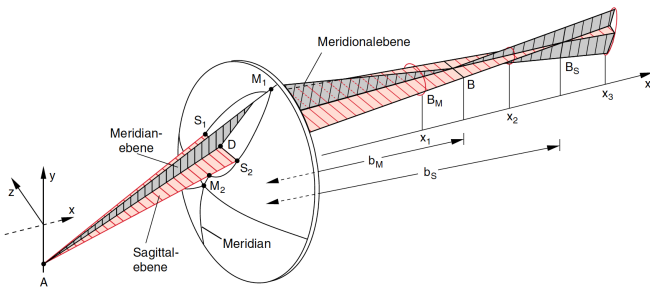
chromatische
Aberration



Koma



Astigmatismus

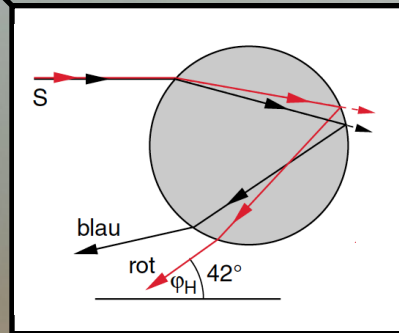
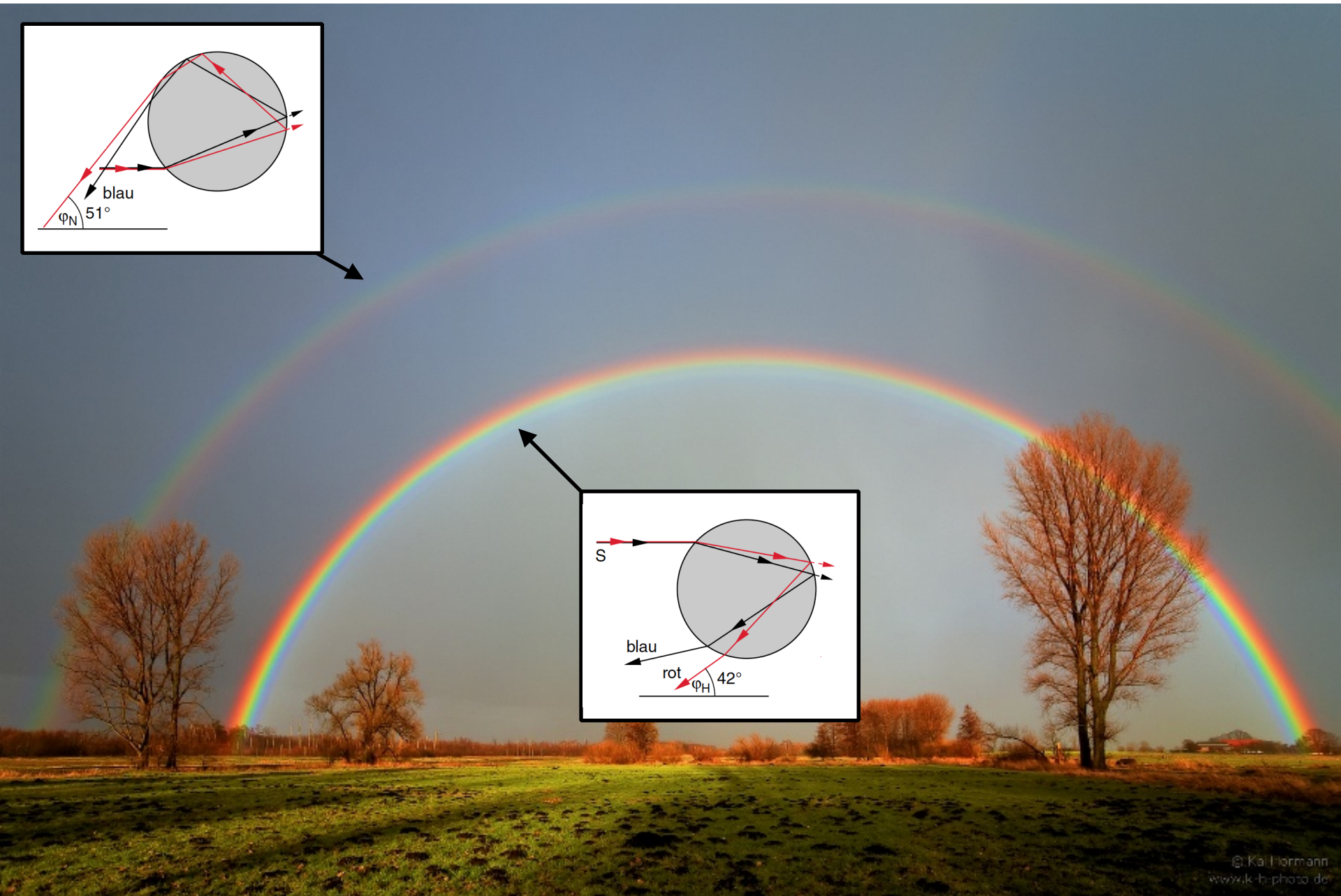
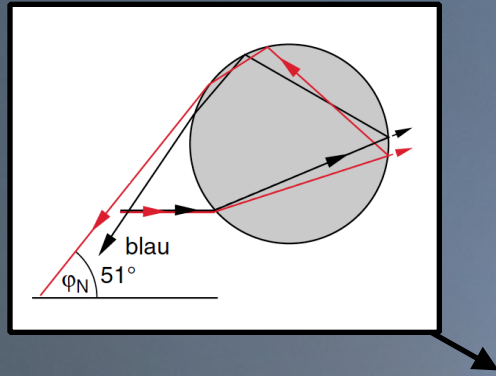


ABCD ABCD

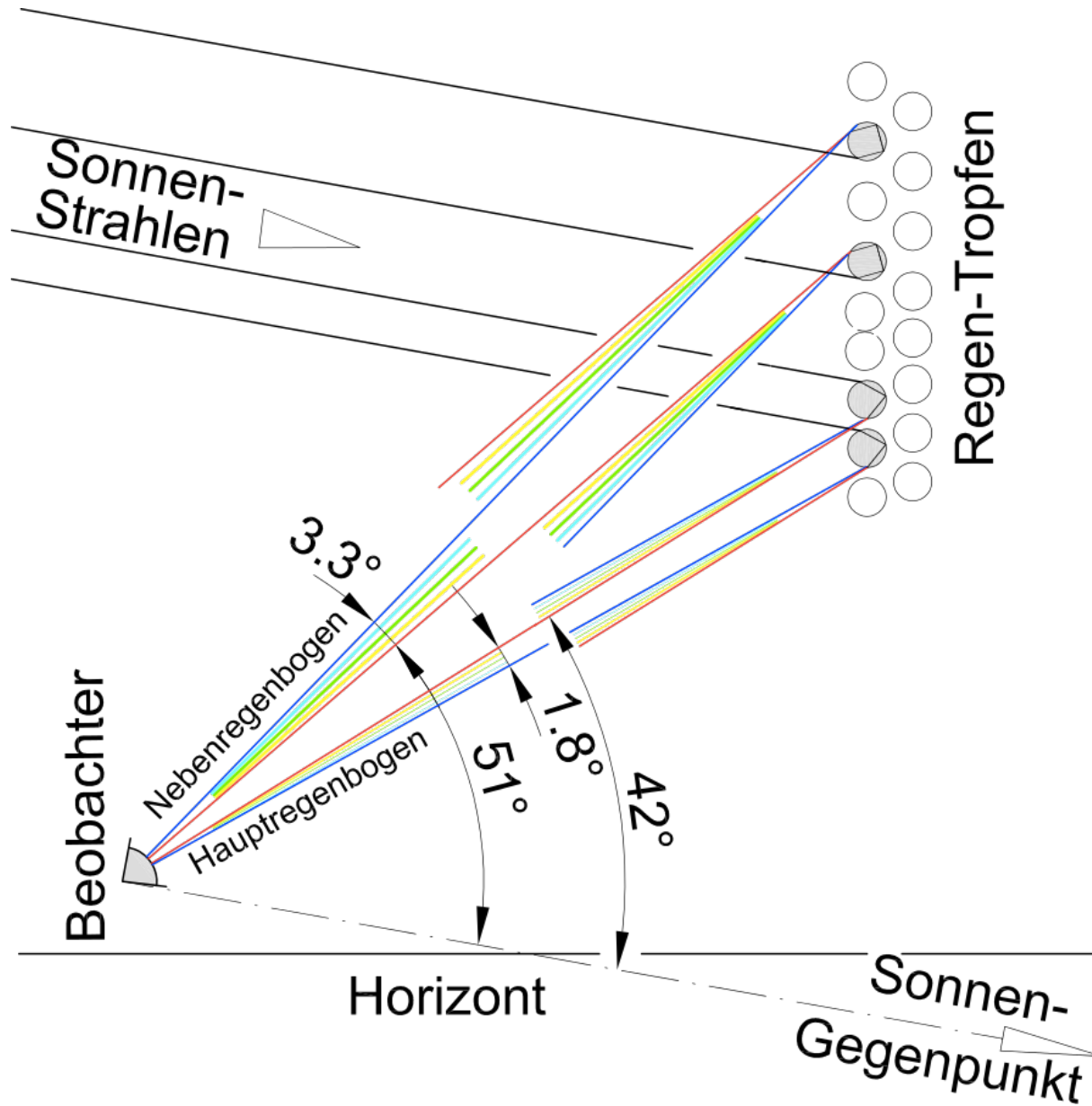
Regenbogen



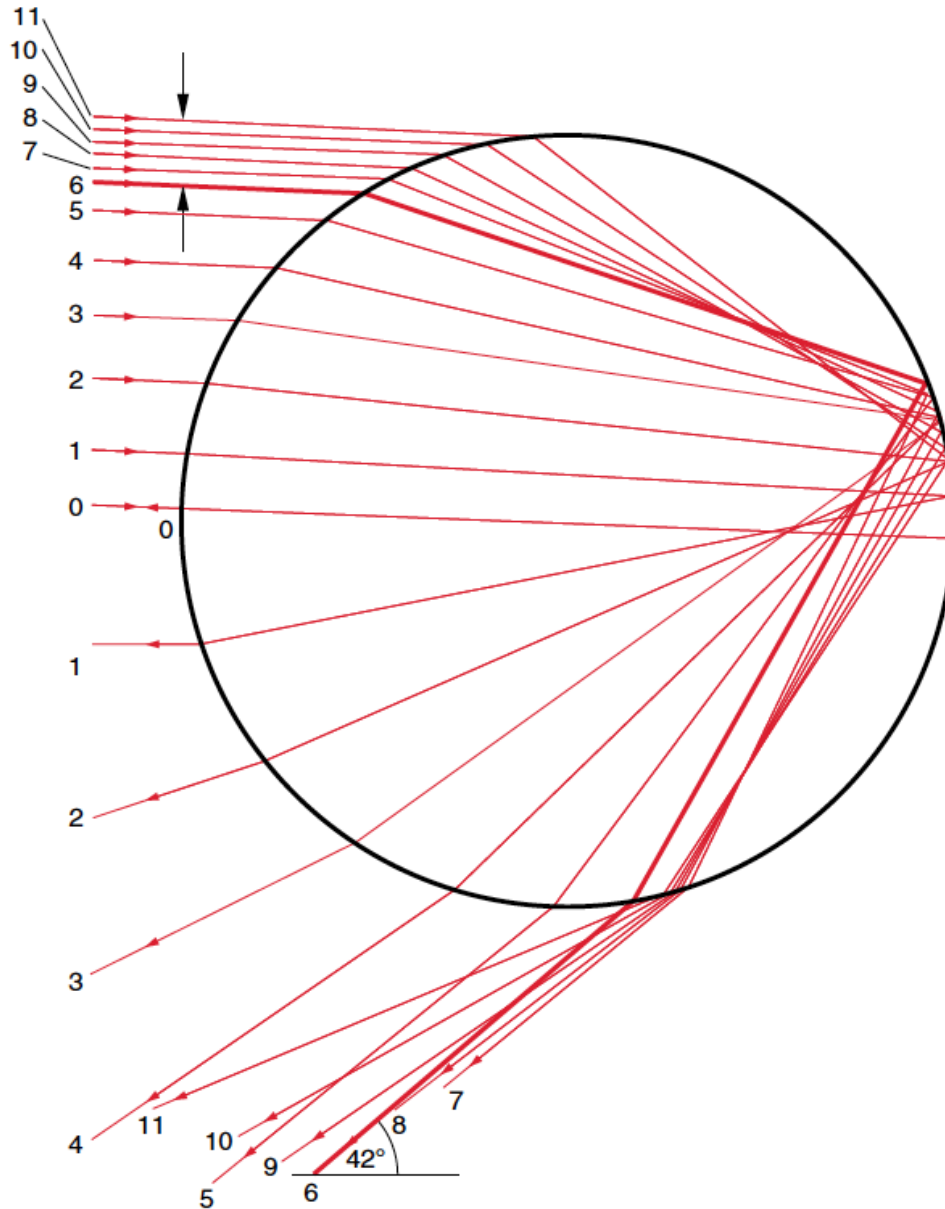
Regenbogen



Regenbogen



Regenbogen



Regenbogen

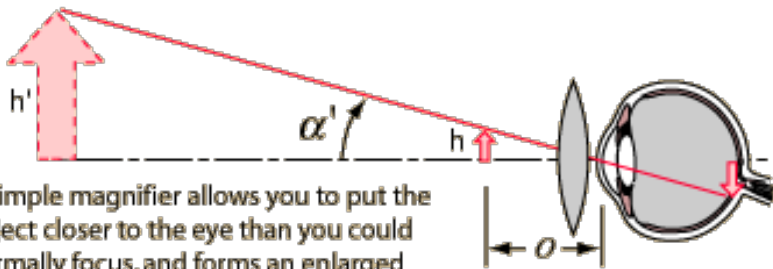
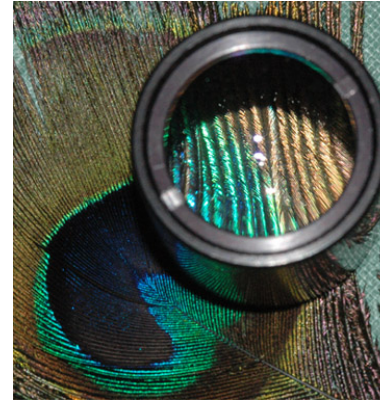
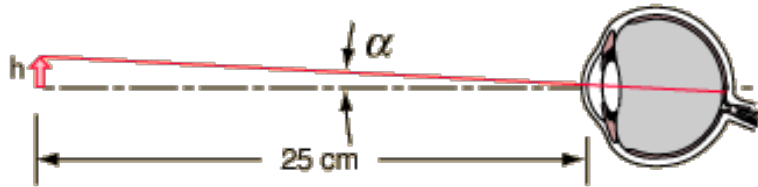


Regenbogen

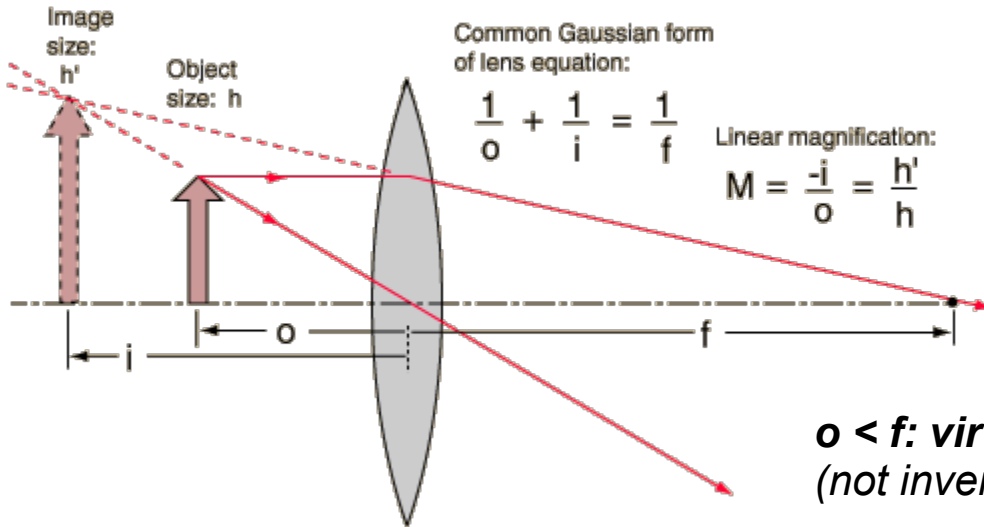
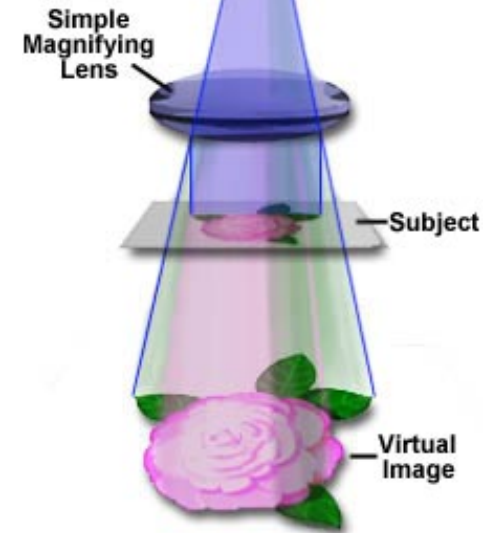
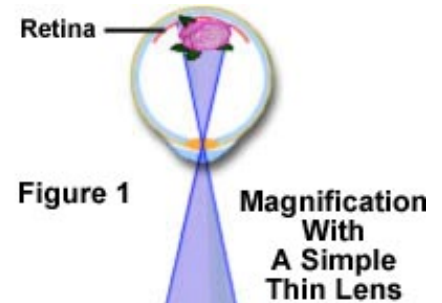


Nicht alle Beobachtungen erklärbar mit geometrischer Optik
⇒ Beugung und Interferenz (Kap. 10)

Lupe



A simple magnifier allows you to put the object closer to the eye than you could normally focus, and forms an enlarged virtual image.



Common Gaussian form of lens equation:

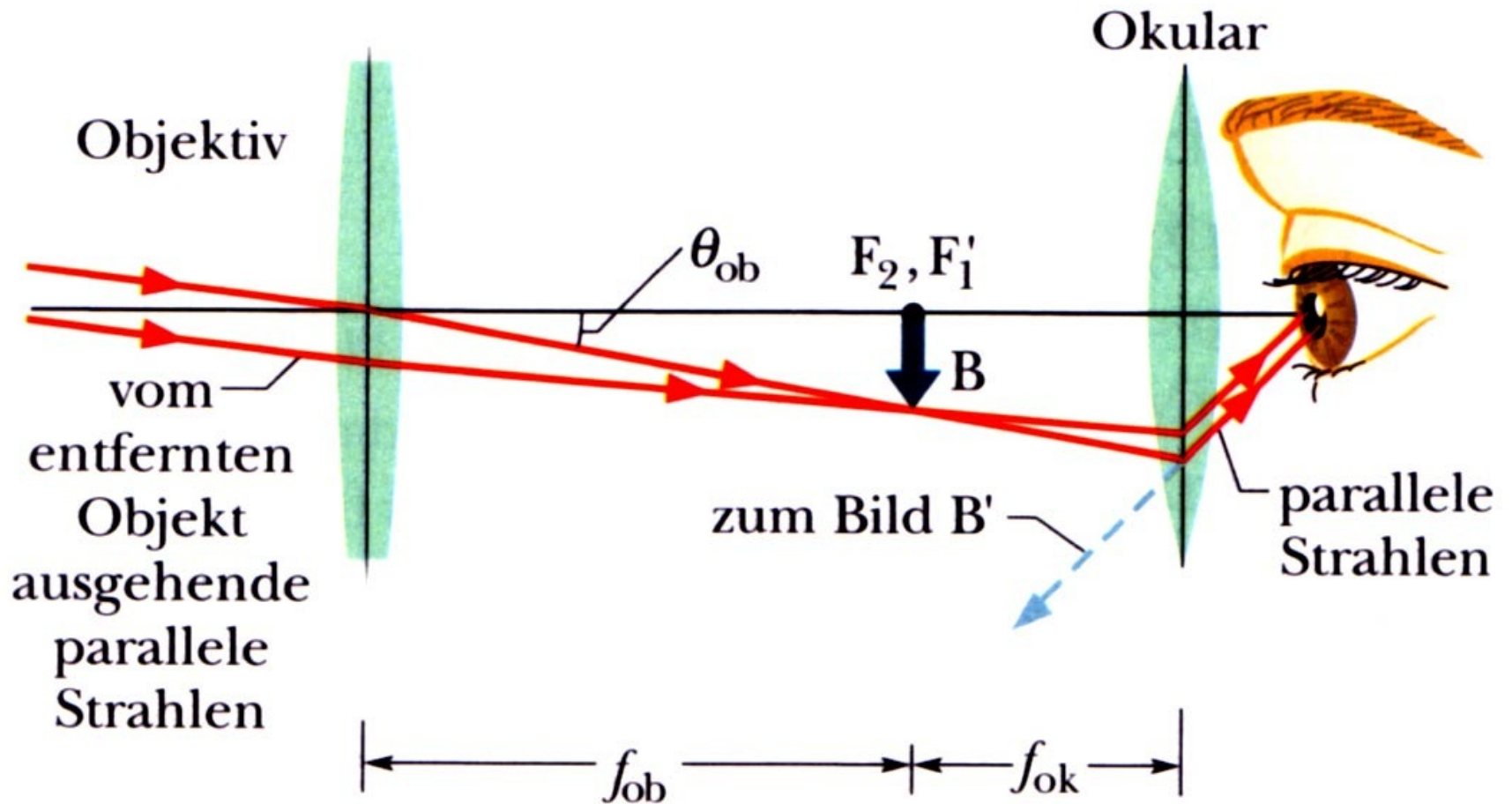
$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

Linear magnification:

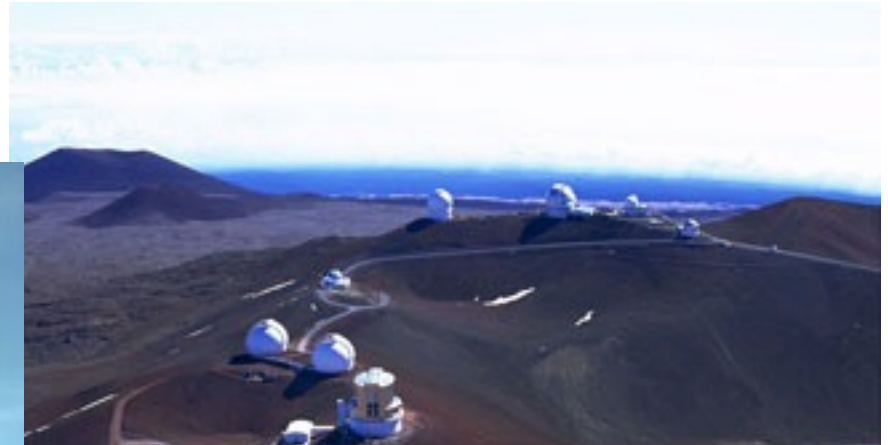
$$M = \frac{-i}{o} = \frac{h'}{h}$$

$o < f$: virtual image (not inverted)

Fernrohr / Teleskop



Kek Teleskope (10 Meter)



ESO La Silla (NTT)



3.58m Durchmesser (1989)



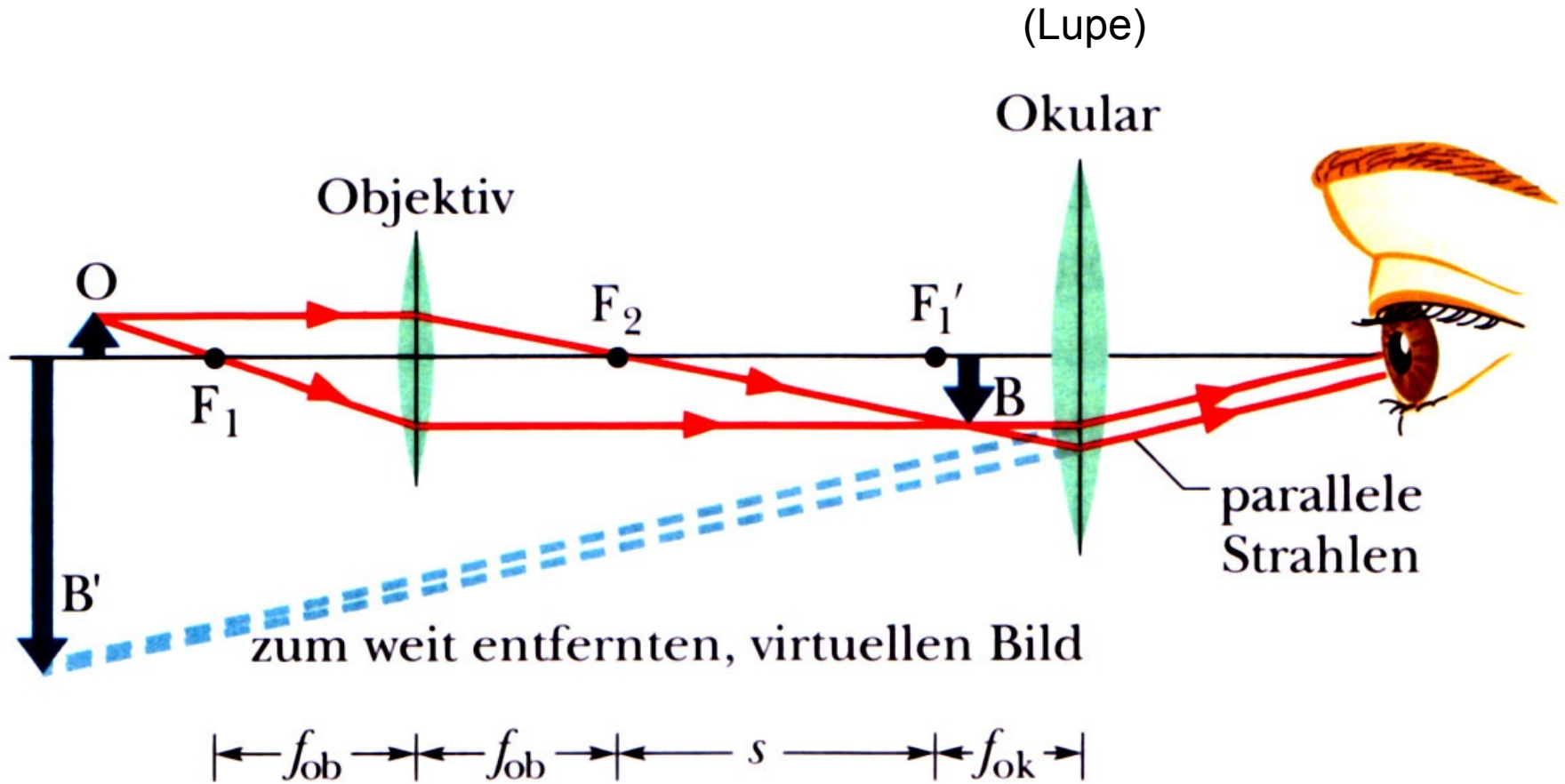
"flexibel" Spiegel: 78 Kontrol Aktuatoren (*active optics*)

ESO Paranal (VLT)



4 x 8.2m (17.5cm thick!), adaptive optics (laser star calibration) + auxiliary telescopes, interferometric operation

Mikroskop



Mikroskoptypen



Reflected Light Microscope Tube Length

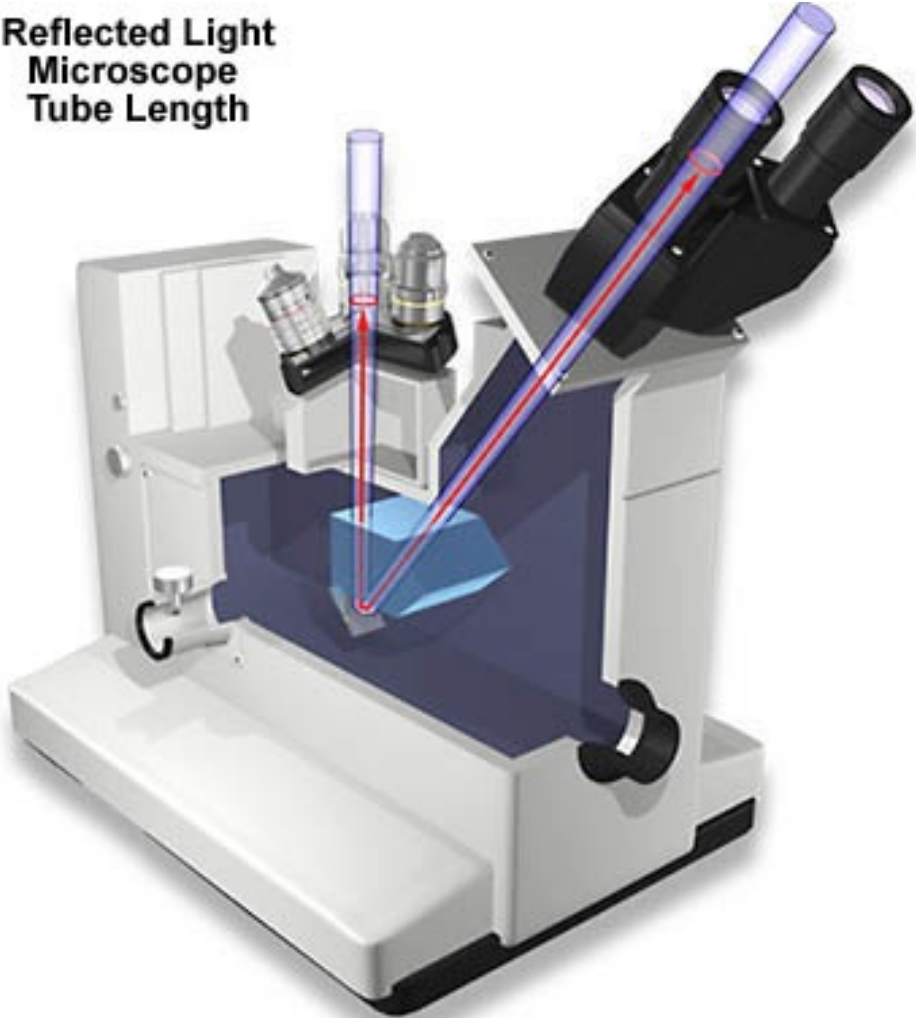


Figure 2

Zoom Linsensystem (Variabel Vergrößerung M)

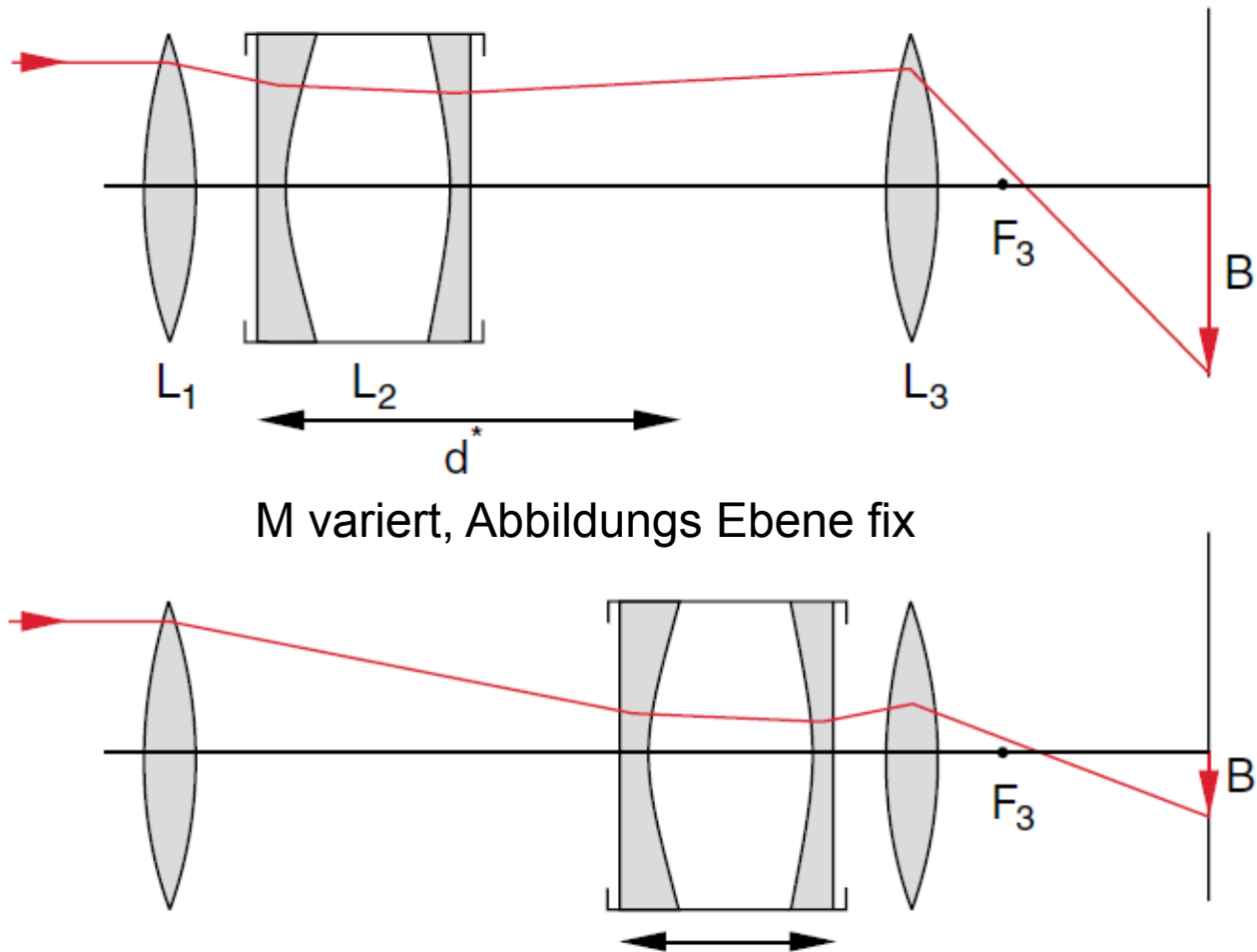


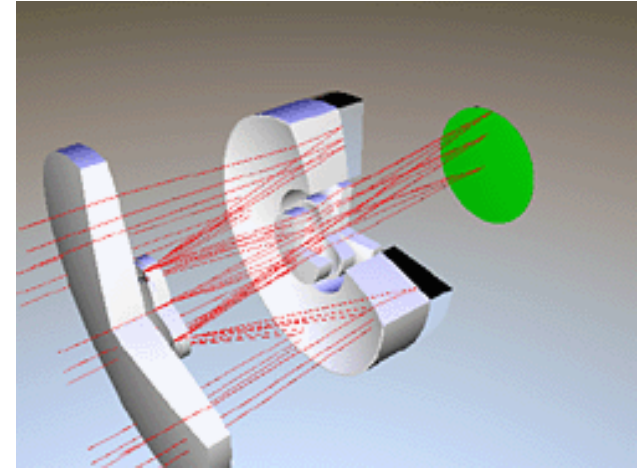
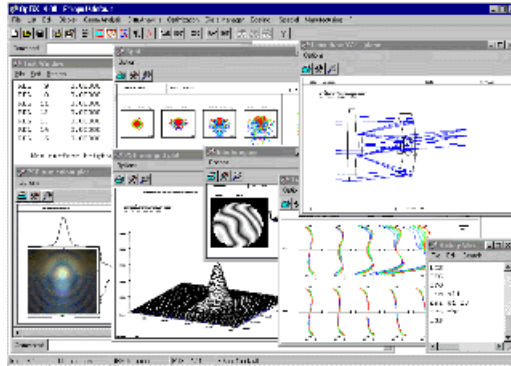
Abb. 9.35. Veränderung der Vergrößerung M eines Zoom-Linsensystems durch Verschieben des Linsenpaares L_2 innerhalb der Strecke d^*

ray tracing

computer ray tracing

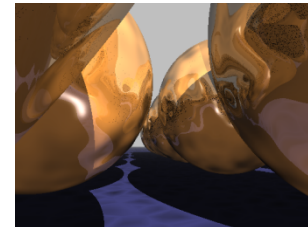
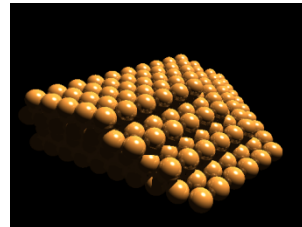
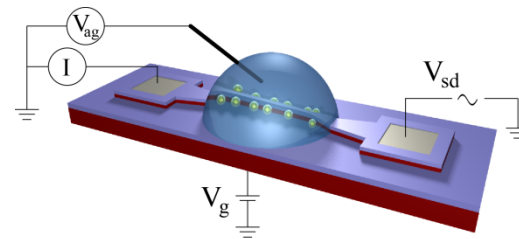
- *lens design and optimization*

e.g.: *OpTaliX*



- *image rendering*

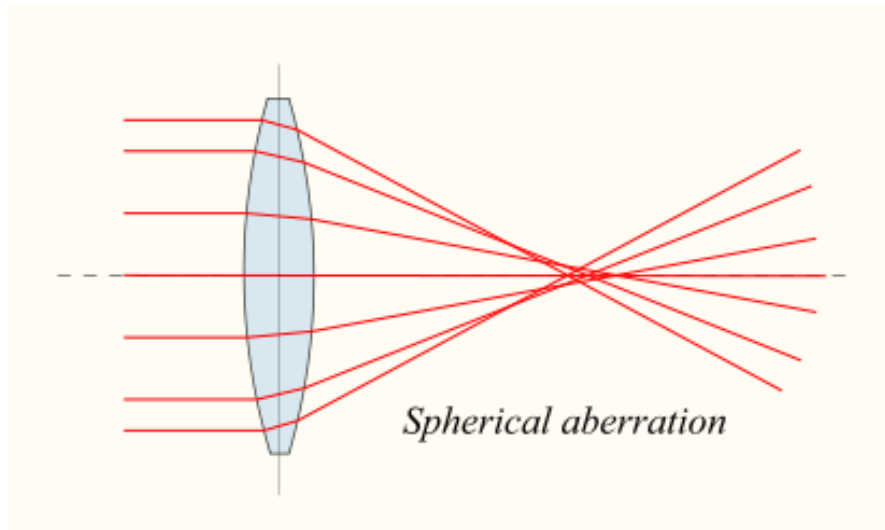
e.g.: pov ray



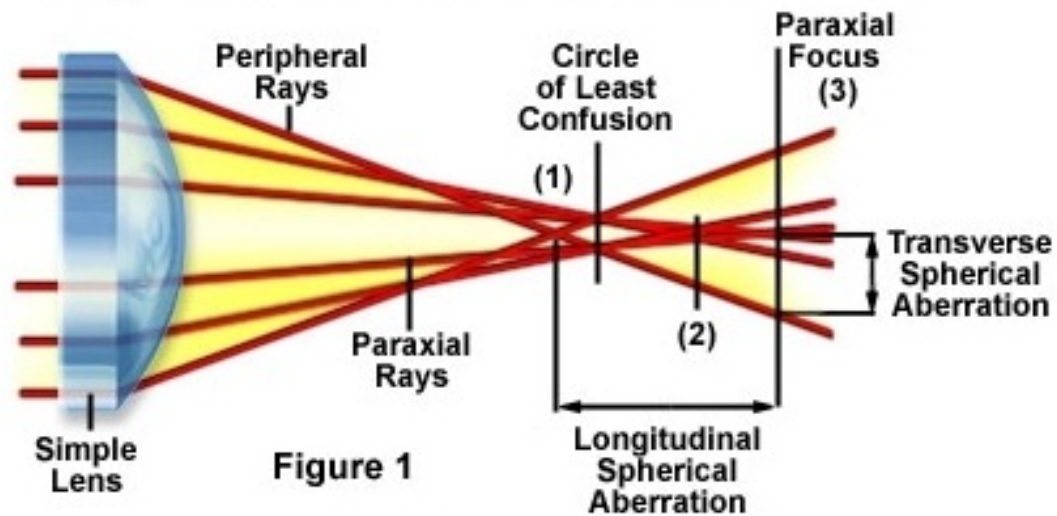
ray tracing



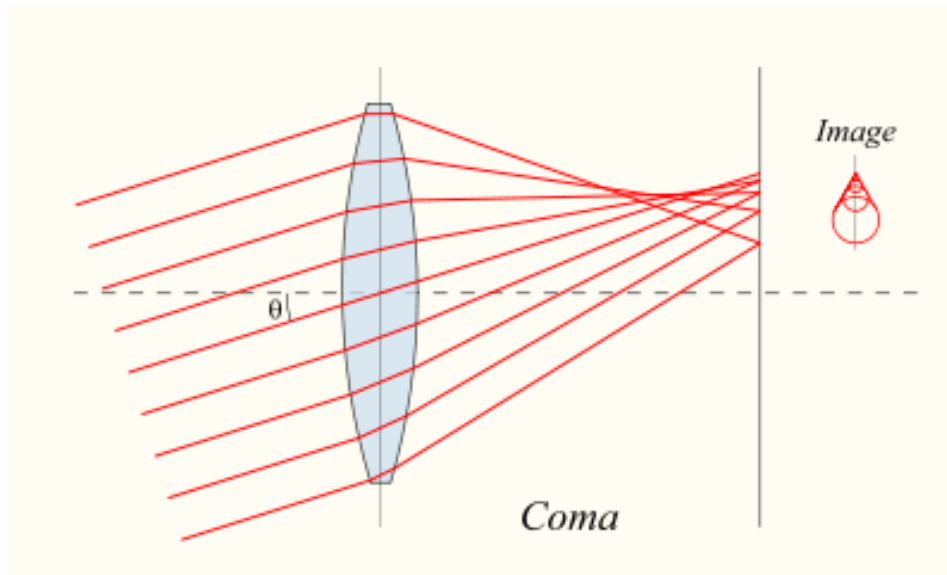
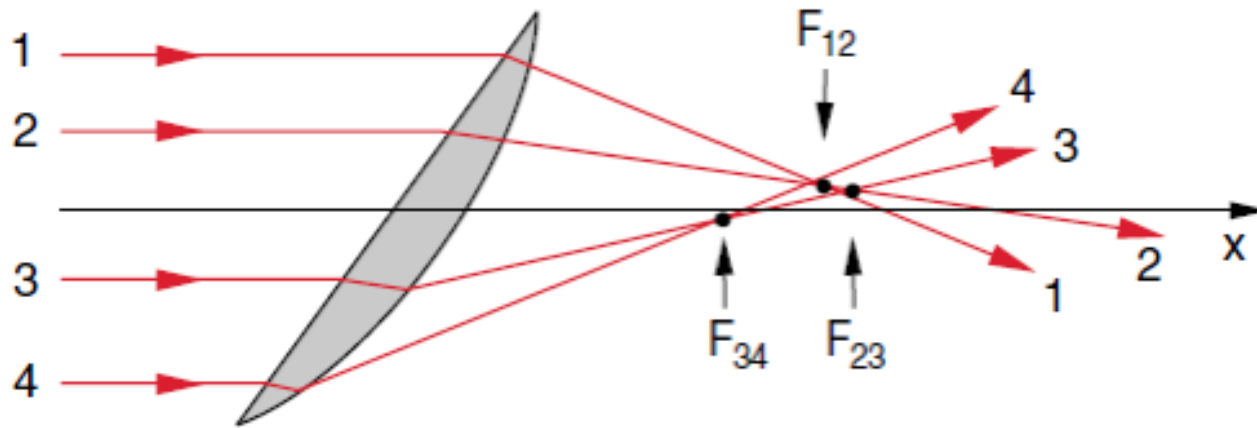
sphärische Aberration



Longitudinal and Transverse Spherical Aberration

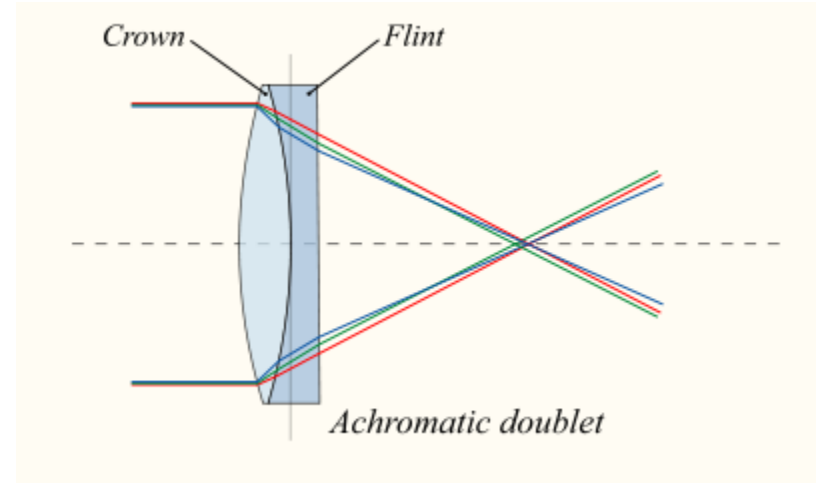
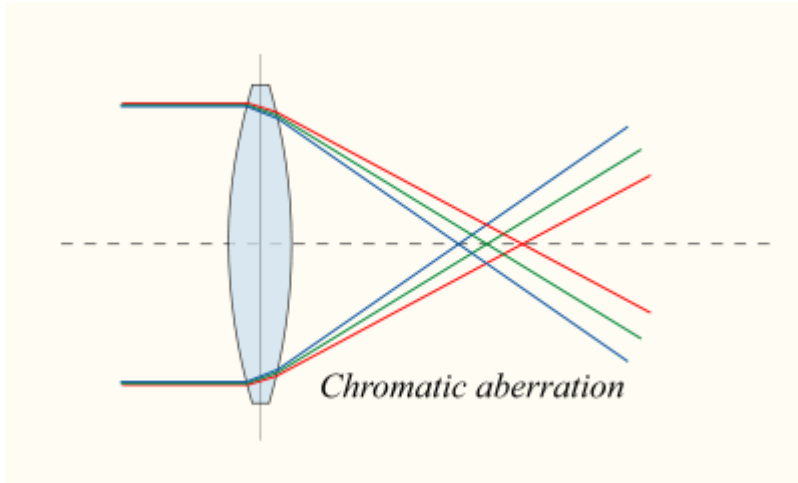


Koma



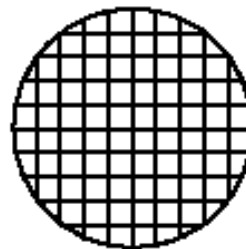
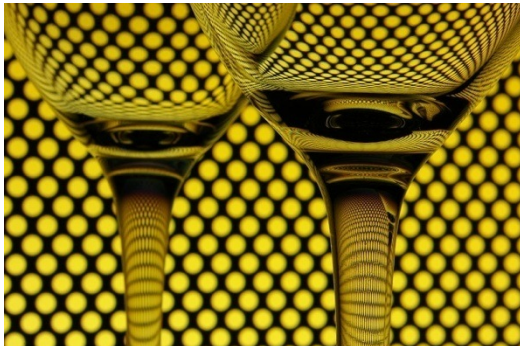
principal plane \neq plane

chromatische Aberration

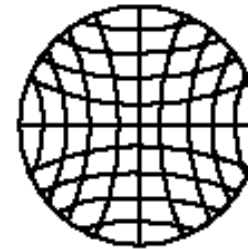


distortions

(geometry of lens; lens imperfections)



**Undistorted
Image**

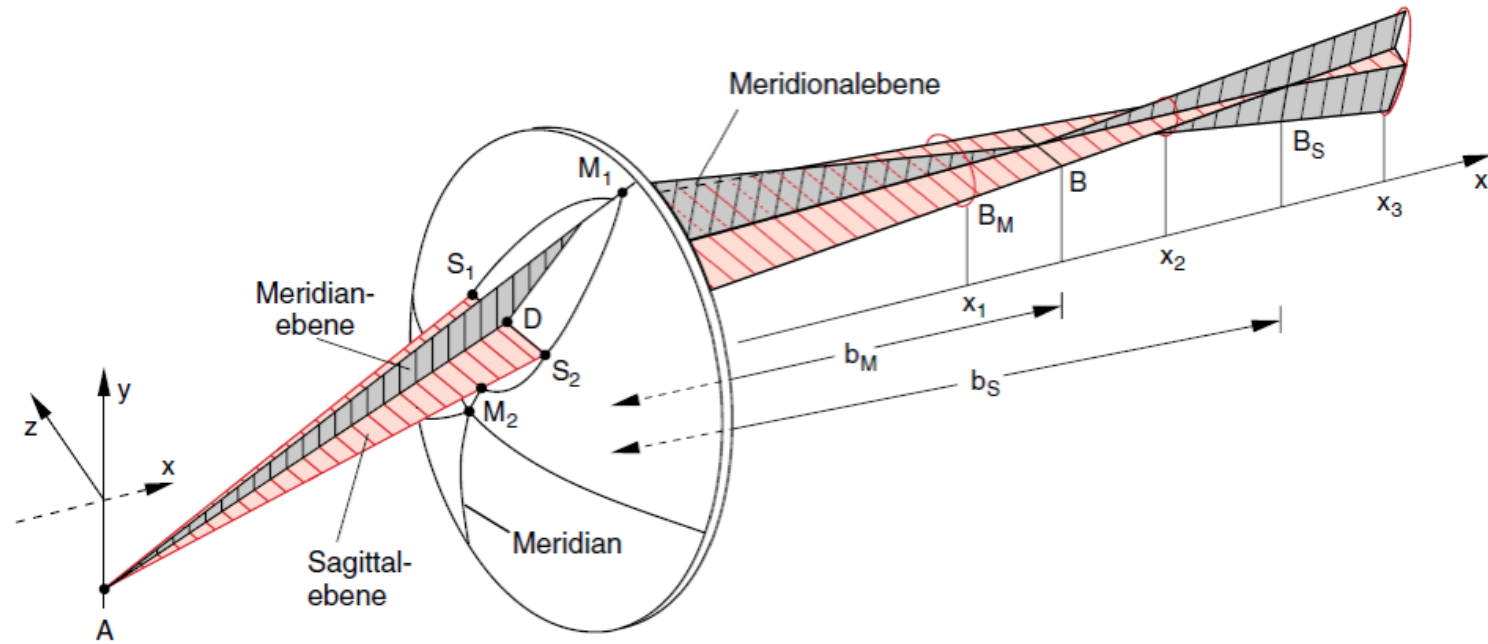


**Pincushion
Distortion**

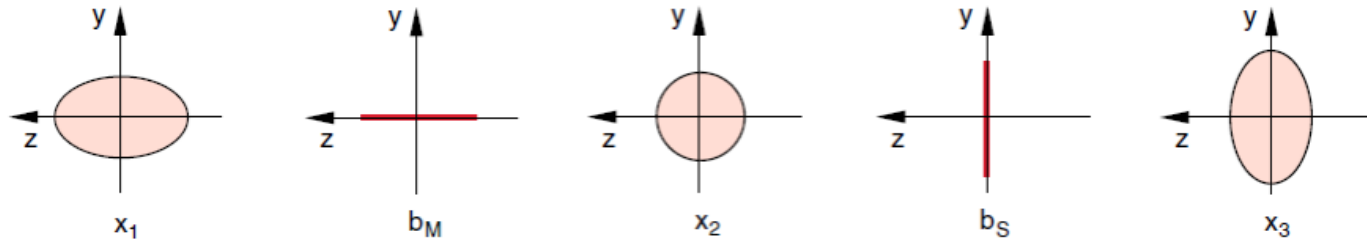


**Barrel
Distortion**

Astigmatismus



a)



b)

Abb. 9.45a,b. Astigmatismus bei der Abbildung eines schrägen Lichtbündels. (a) Perspektivische Ansicht; (b) Lichtbündelquerschnitt in den Ebenen im Abstand x_1 , b_M , x_2 , b_S , x_3

eye image formation

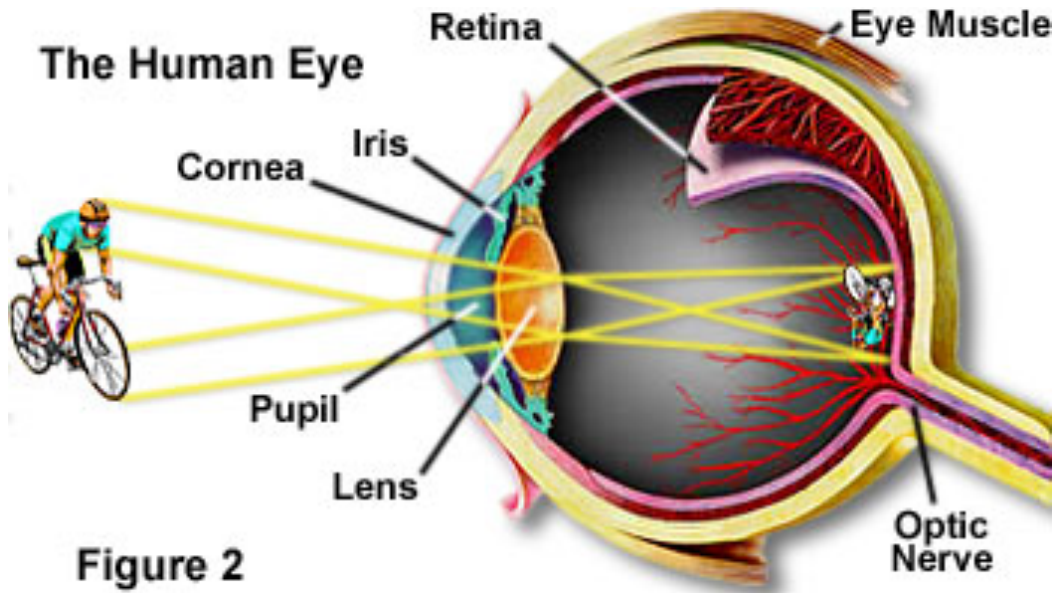
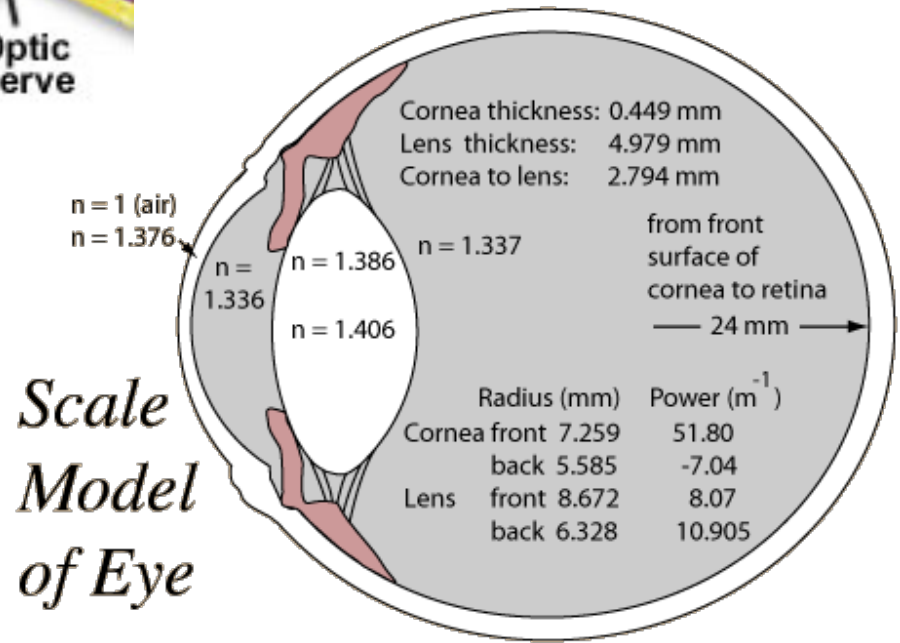
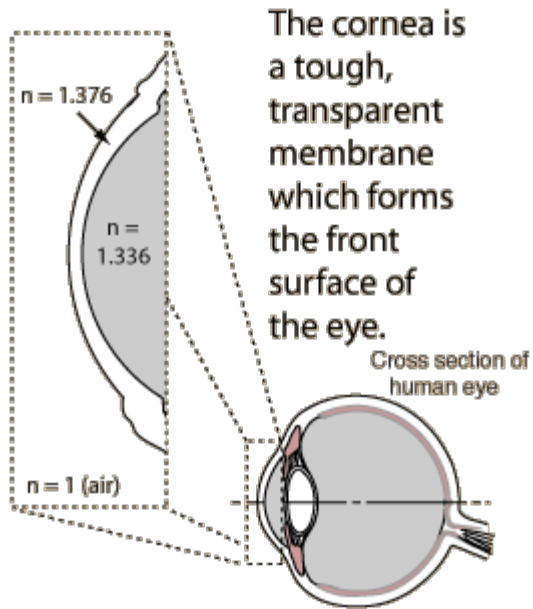


Figure 2



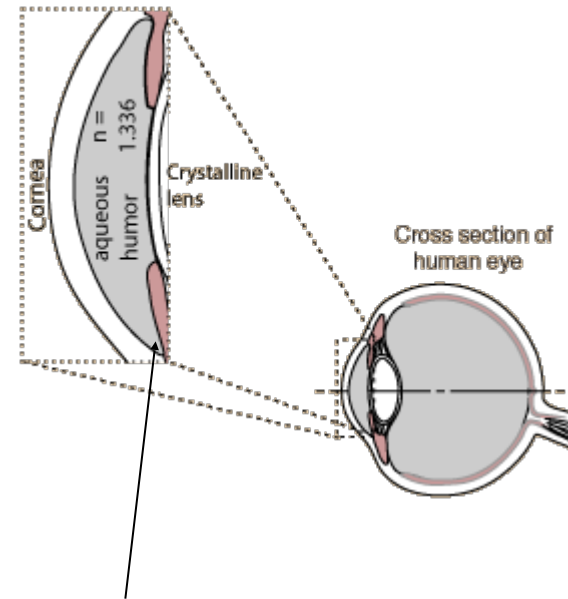
eye image formation

cornea



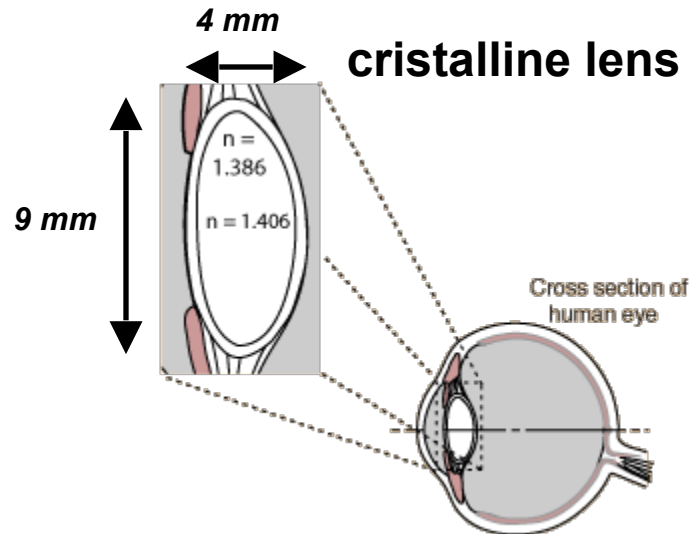
strong refraction
($n \sim 1.376$)

aqueous humor

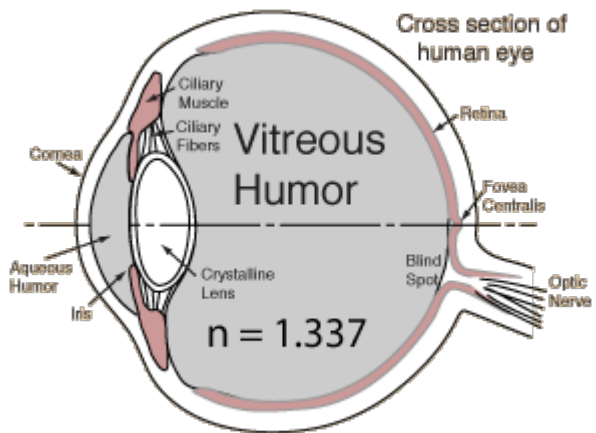
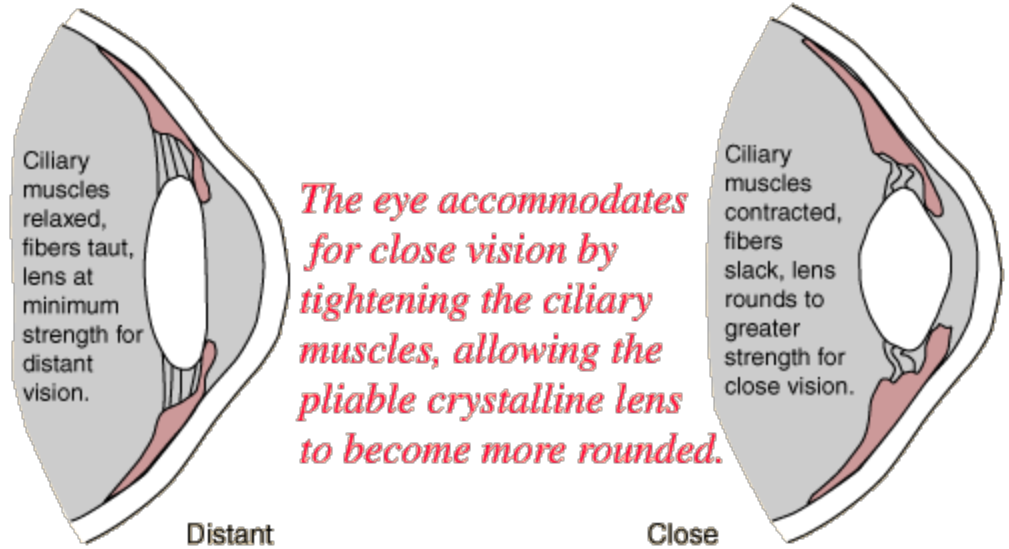


iris (diaphragm)

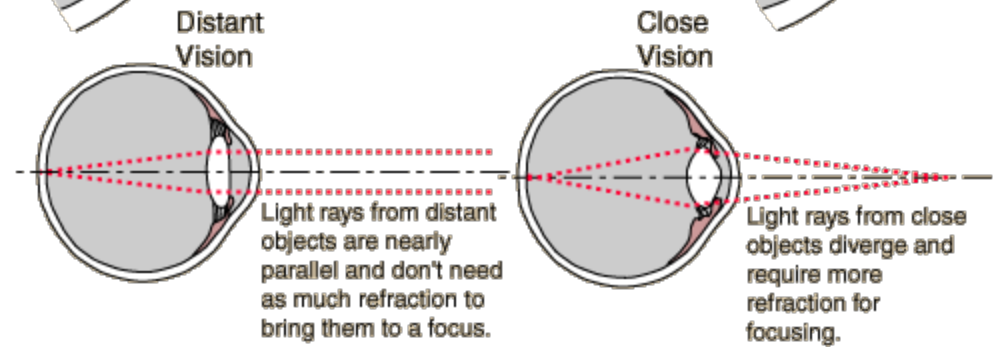
eye image formation



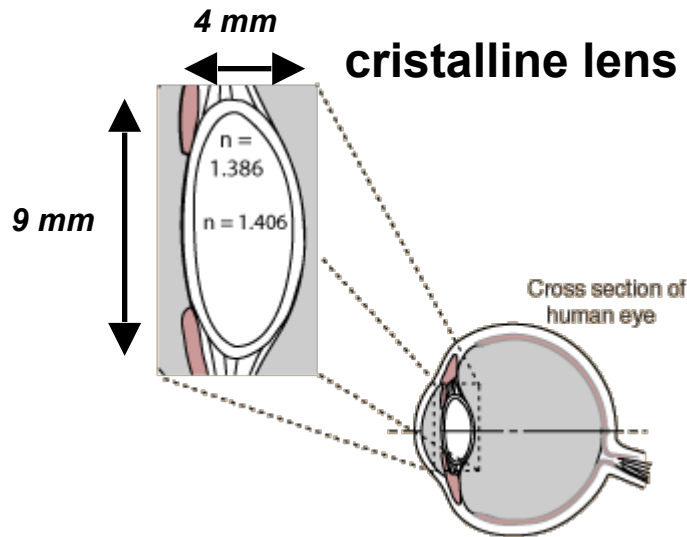
wie fokussiert die Auge?



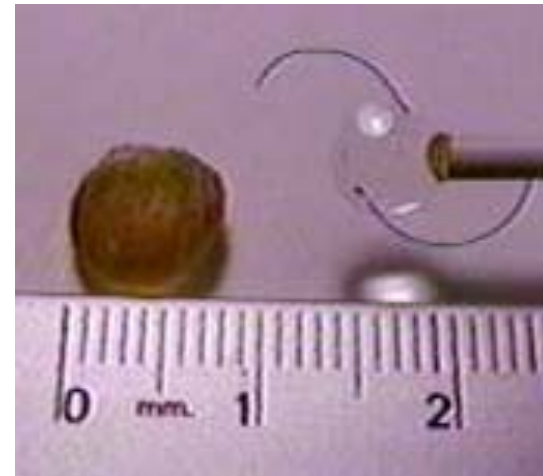
water: n ~1.33



eye image formation

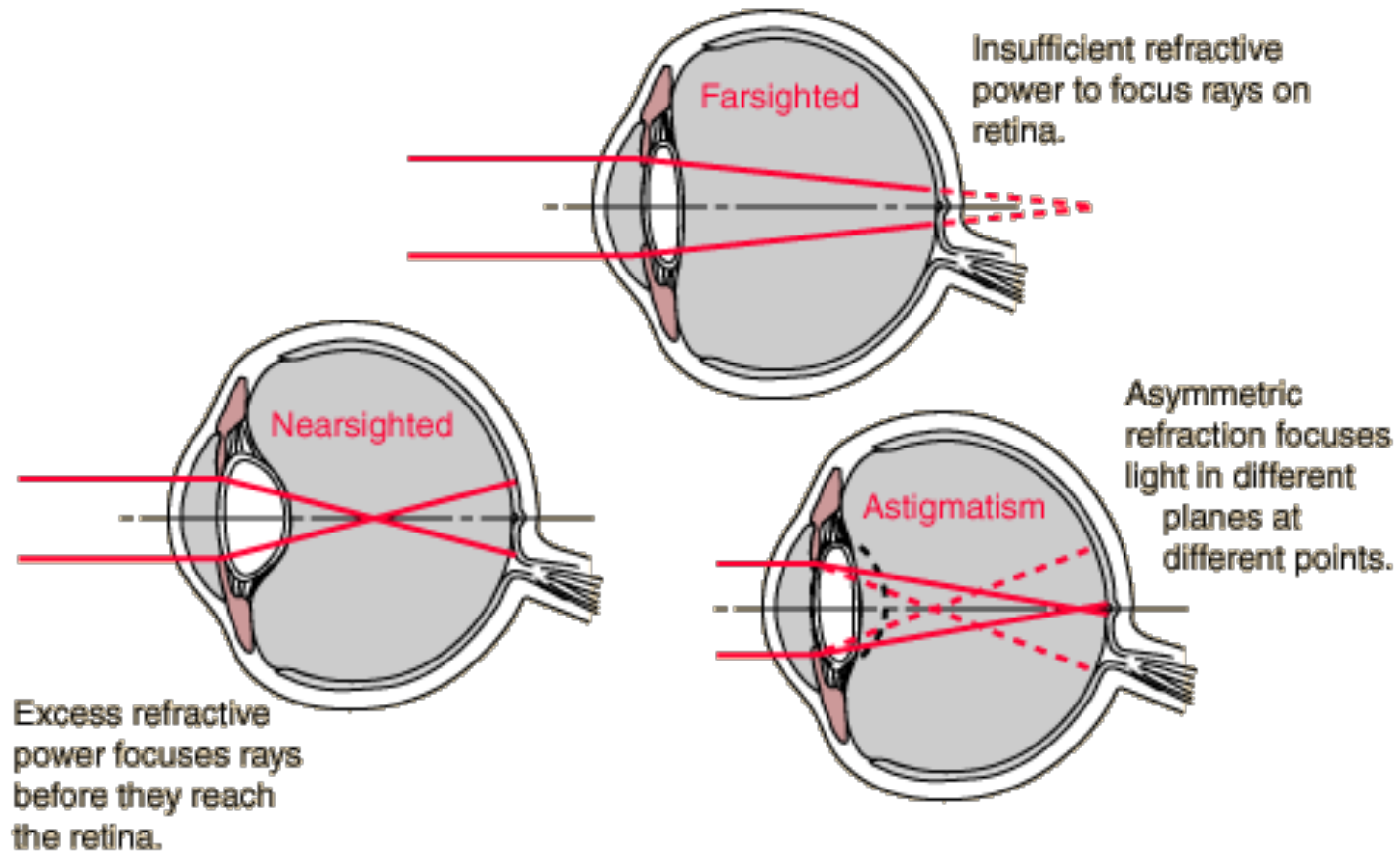


cataracts: opacification of lens



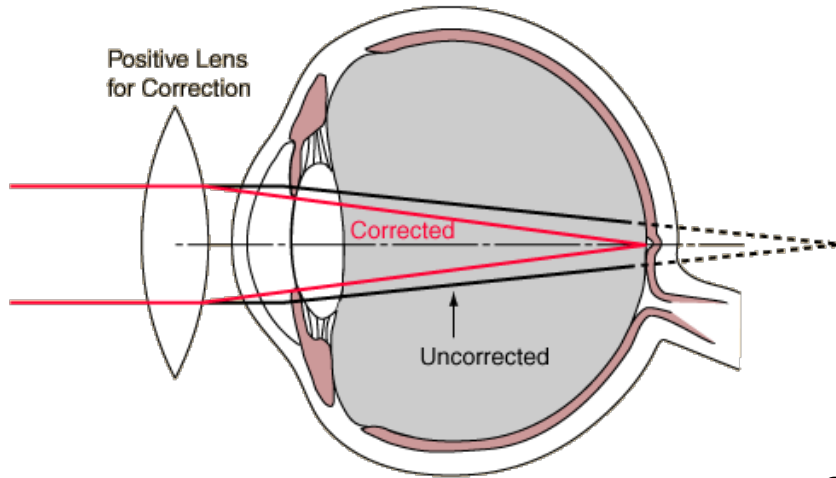
*glaucoma: aqueous humor degradation
pressure increase, perturbation of "optical" system*

vision defects

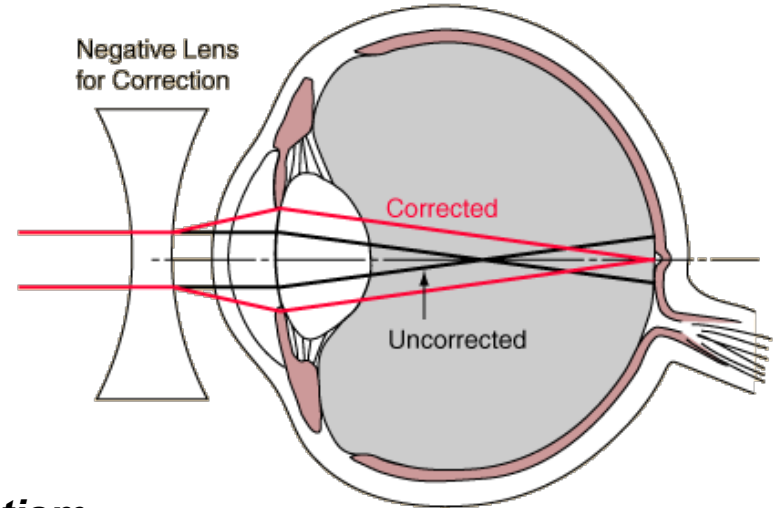


vision defects

hyperopia (farsighted)



myopia (nearsighted)



astigmatism

