Institute of Applied Physics

Friedrich-Schiller-Universität Jena

Metrology and Sensing

Lecture 10-2: Measurement of basic system properties

2021-01-19

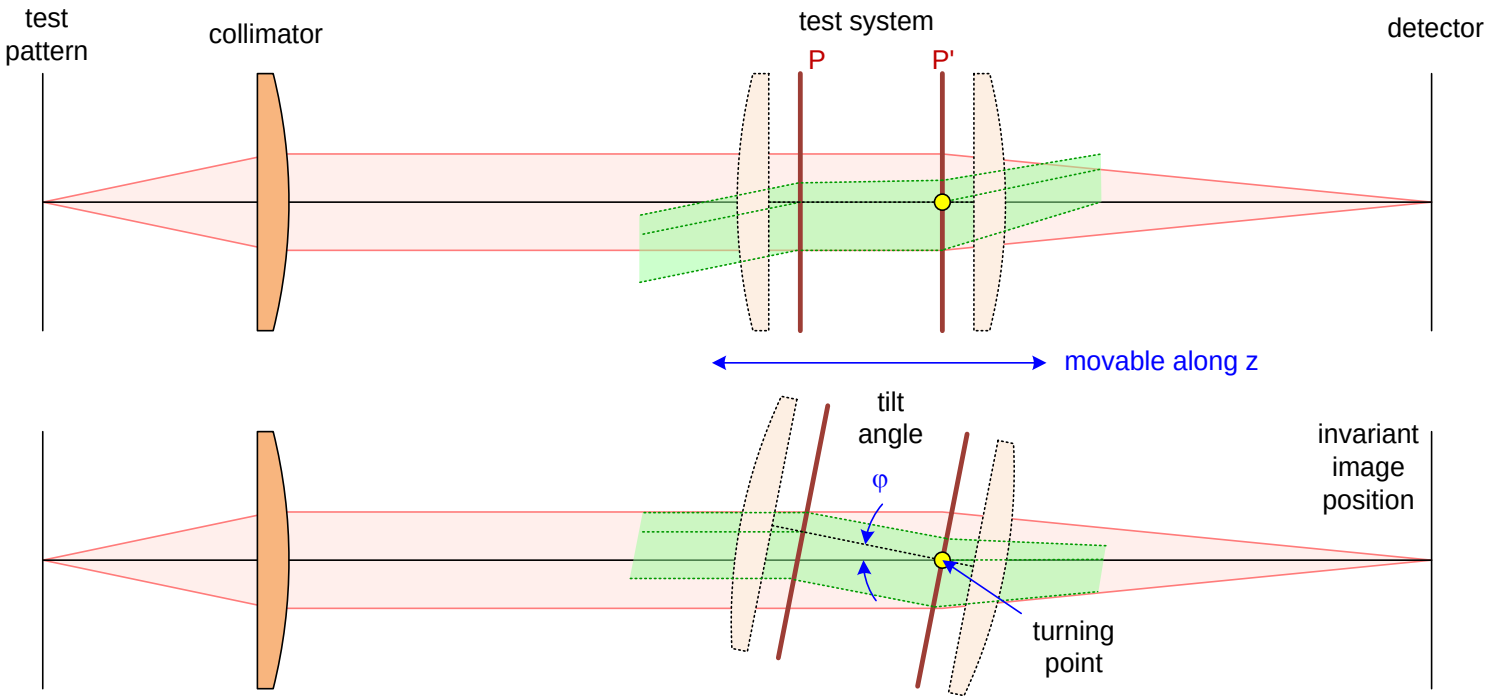
Herbert Gross

Content

- Principal planes
- Aperture
- Centering
- Assembly

Measurement of Principal Planes

- Measurement for systems in air via the nodal planes
- Imaging of a test pattern with a collimator onto a detector
- Invariant lateral image location for rotated system around the nodal point
- Critical: vignetting effects for large angles



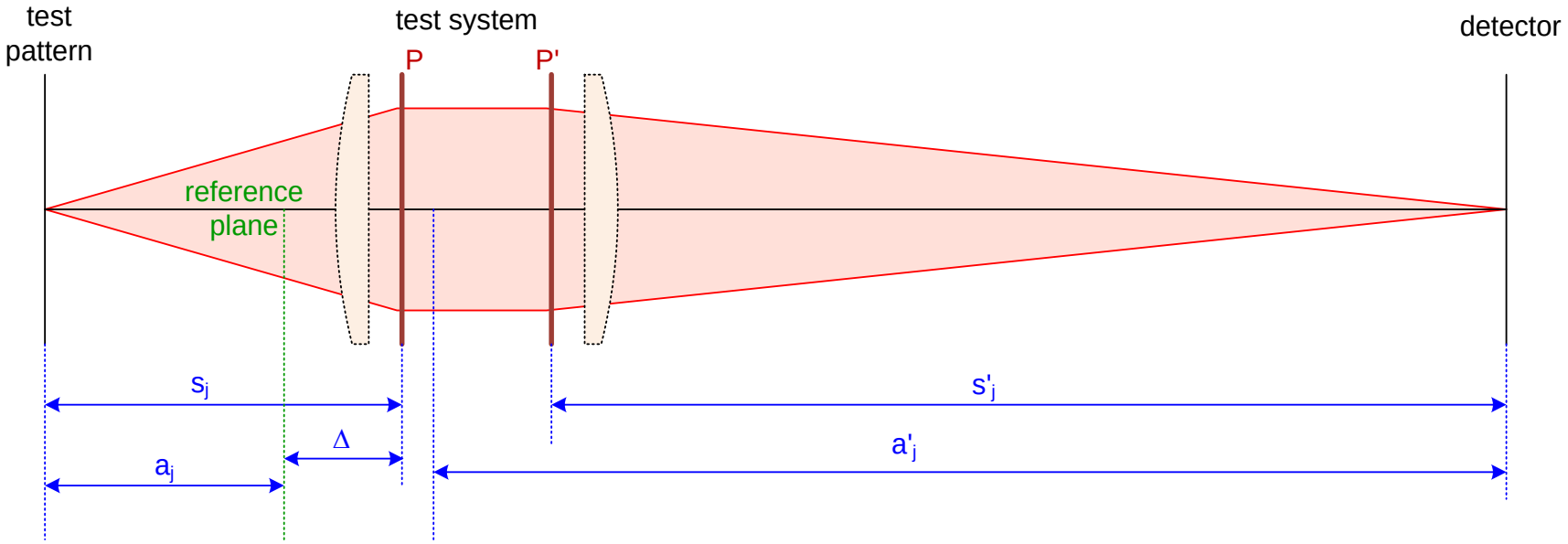
Measurement of Principal Planes

- Setup of the test lens with different object locations: axial shift Δ
- Analysis of the lens imaging formula

$$\frac{1}{a_j + \Delta} + \frac{1}{a'_j - \Delta} = \frac{1}{f}$$

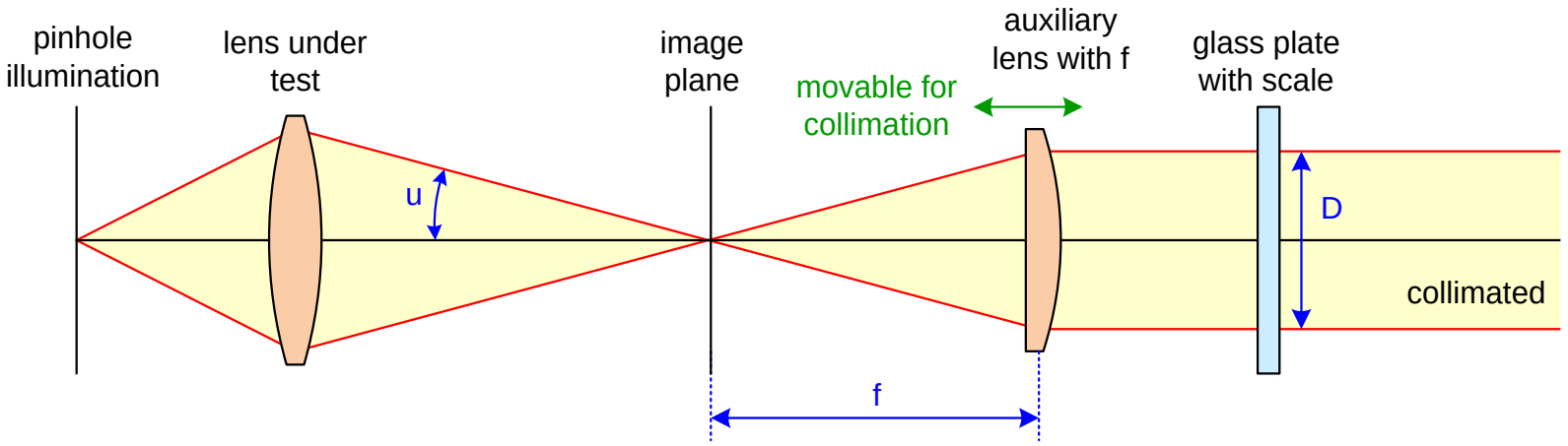
- Minimizing the error of several measurements j

$$\delta = f \cdot \left(a_j + a'_j\right) + \Delta \cdot \left(a_j - a'_j\right) - a_j a'_j + \Delta^2$$

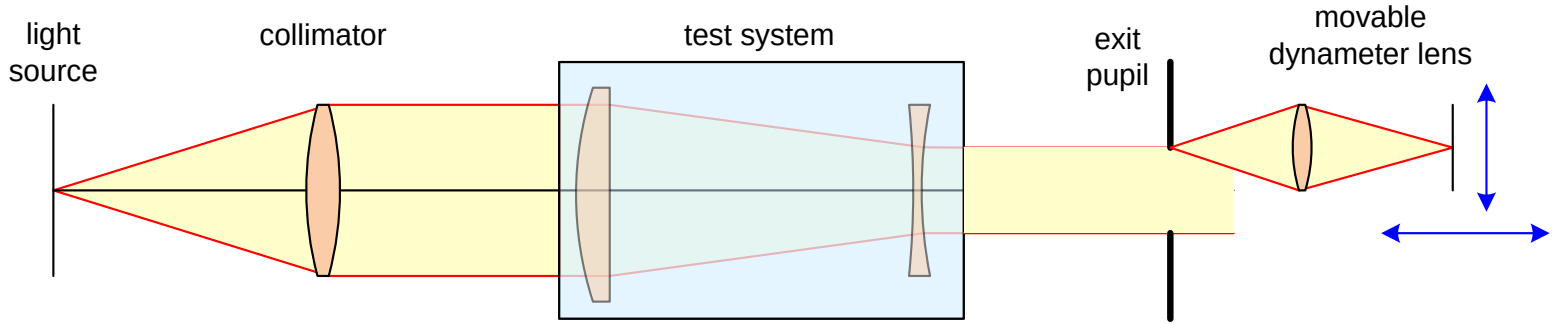


Measurement of Pupil Size

- Setup with collimating auxiliary lens $\tan u = \frac{D}{2f}$



- Determination with measuring microscope (dynameter)



Measurement of Pupil Size

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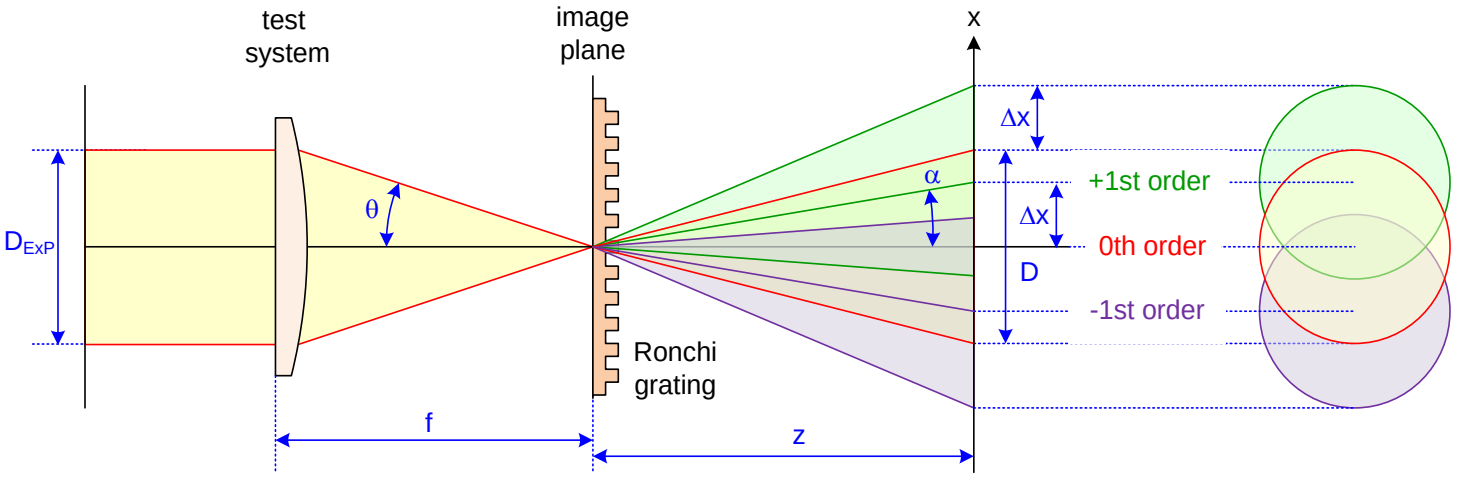
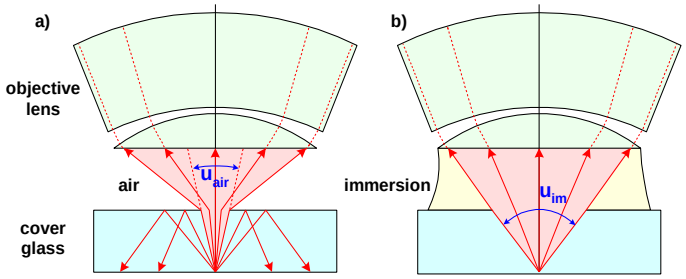
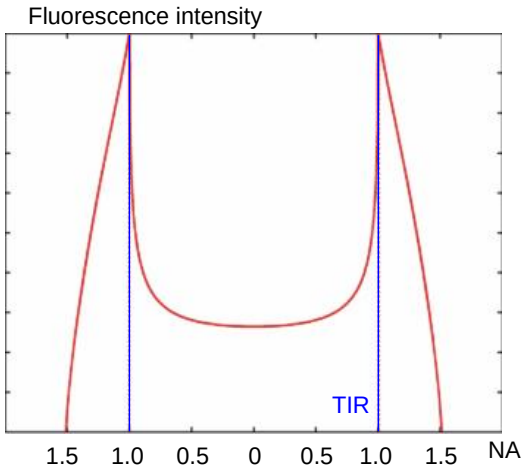
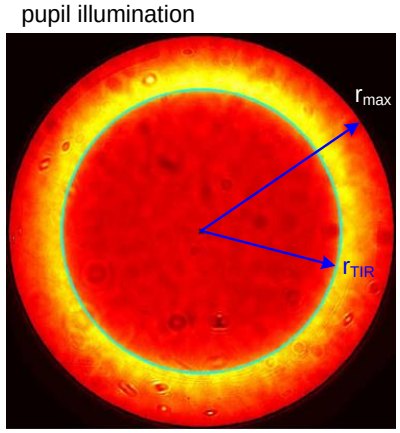
- Setup with Ronchi grating
- Measurement of the lateral shift of higher diffraction orders at distance z



- High-NA in microscopy: NA>1
  Measurement of total internal reflection of fluorescence light







Measurement of Telecentricity

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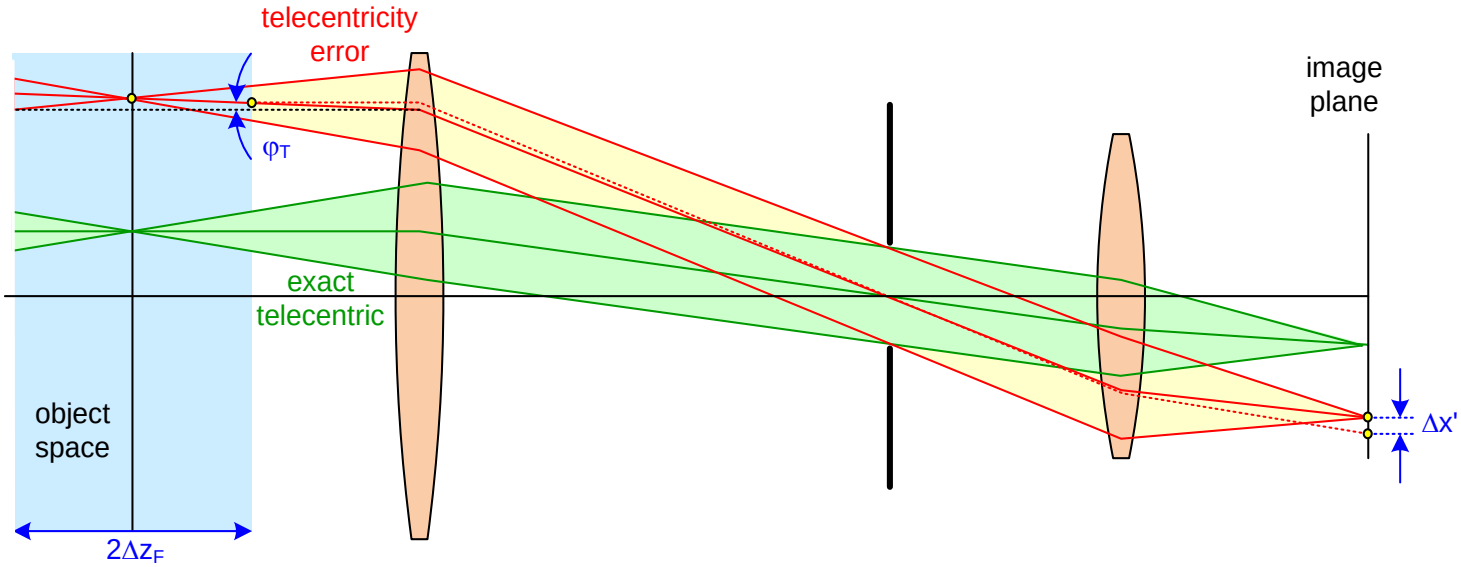
- Measurement of object sided telecentricity errors by lateral shift of image location during defocussing



- High accuracy measurement by interferometry and measurement of Zernike coefficients $c_{2/3}$.

Measurement of Lens Position

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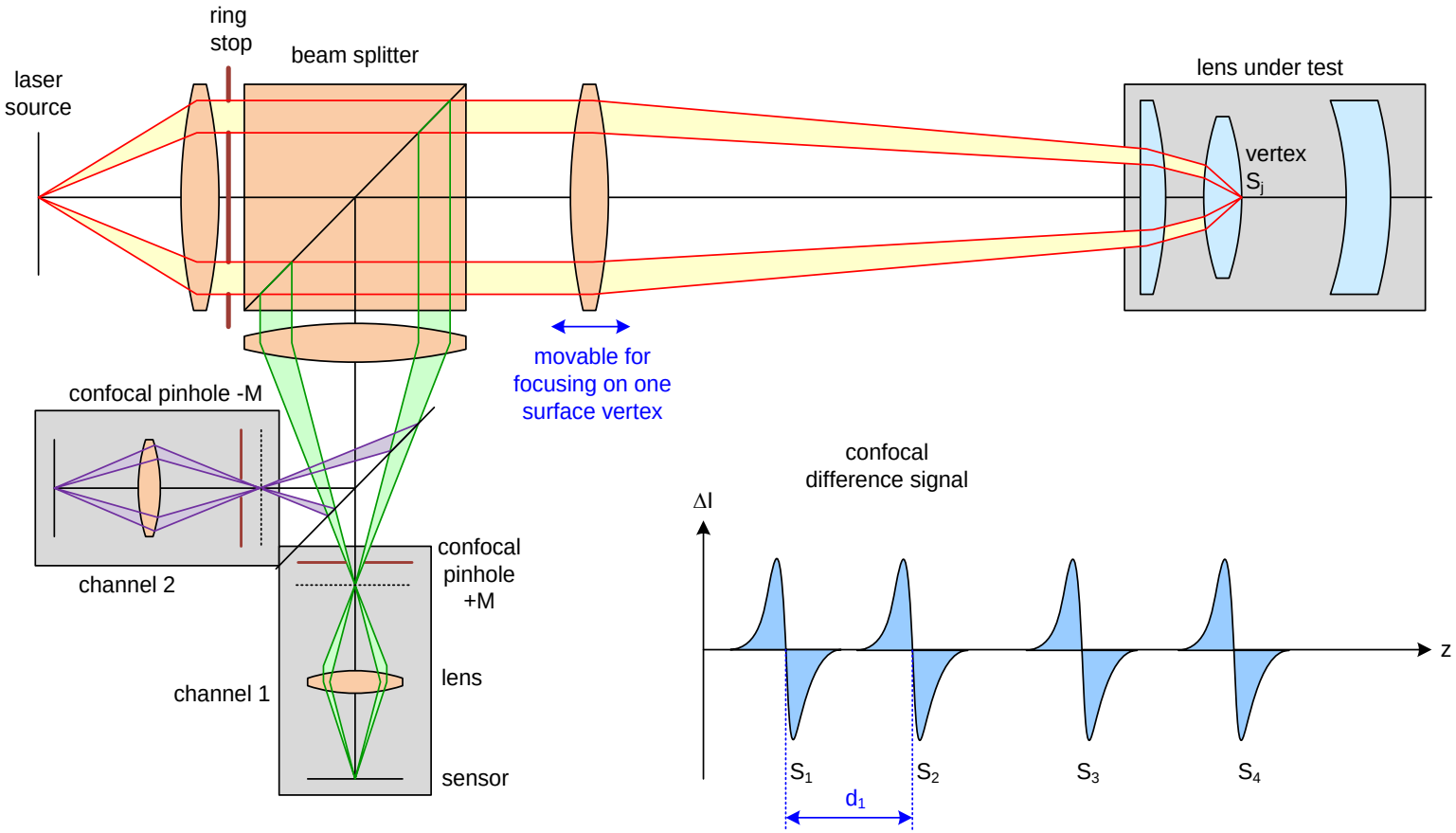
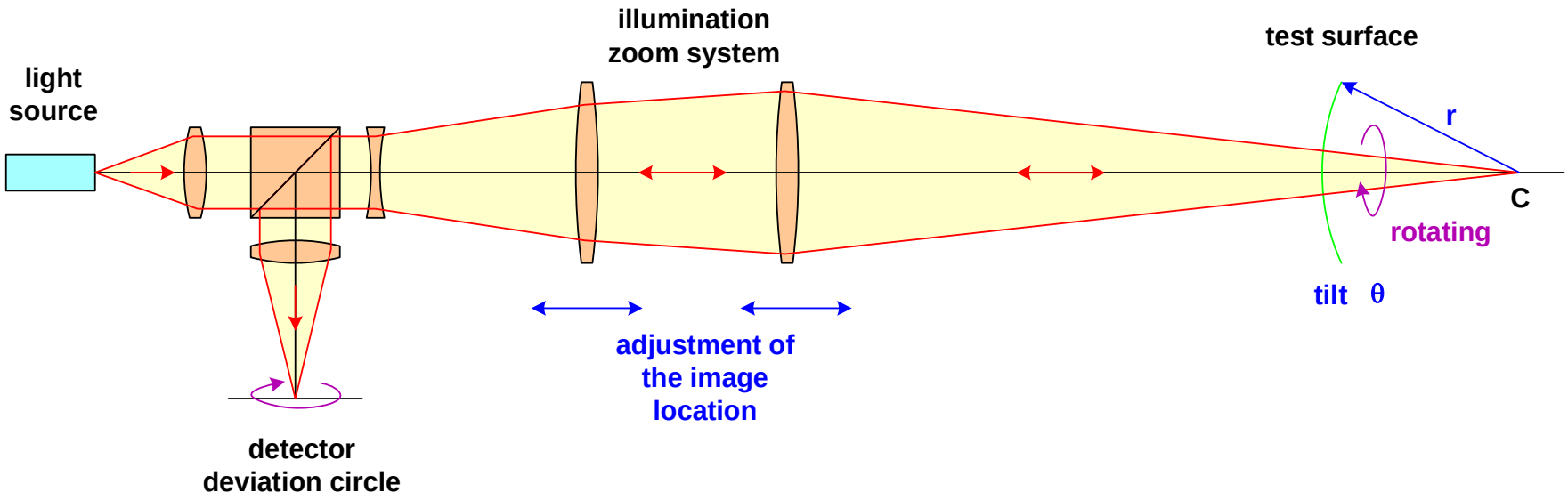
- Measurement of reflexes at lens vertex points
- Analysis of confocal signal in autocollimation
- Avoiding spherical aberration induced errors by ring illumination



Measurement of Centering Errors by Reflected Light

- Projection of test marker
- Autocollimation of sharp image, focal point coincides with center of curvature of surface with radius r
- Rotation of test system: tilt of surface induces a lateral shift of the image, magnification m
- Problems with inner surfaces

$$v = m \cdot v_M = 2 \cdot m \cdot r \cdot \theta$$



Wedge Angle of a Thin Lens

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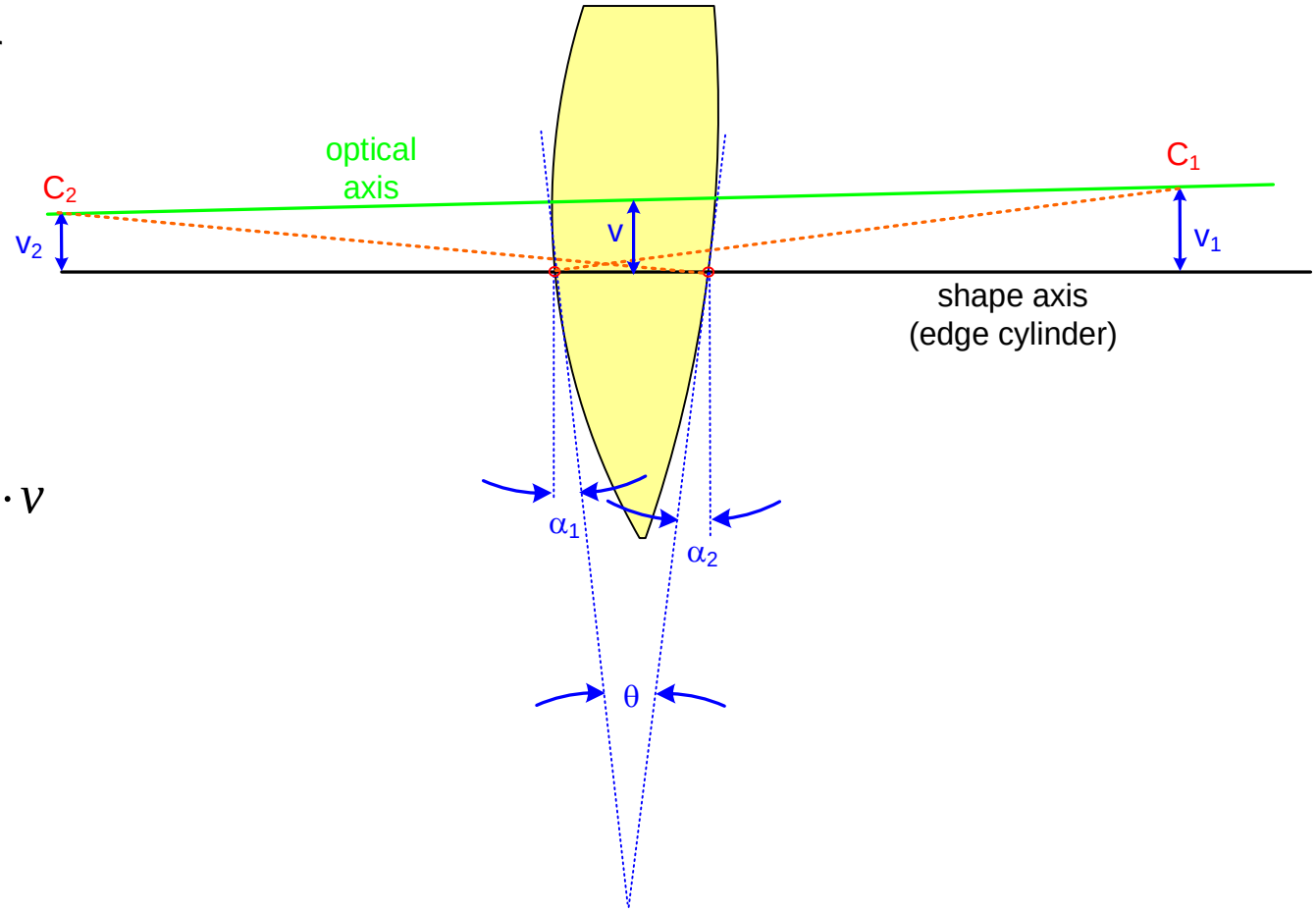
Thin lens with wedge error

$$\theta = -\frac{v}{(n-1)\cdot f}$$

$$\theta = \alpha_1 - \alpha_2 = \left(\frac{1}{r_1} - \frac{1}{r_2}\right)\cdot v$$



Measurement of Centering Errors in Transmission

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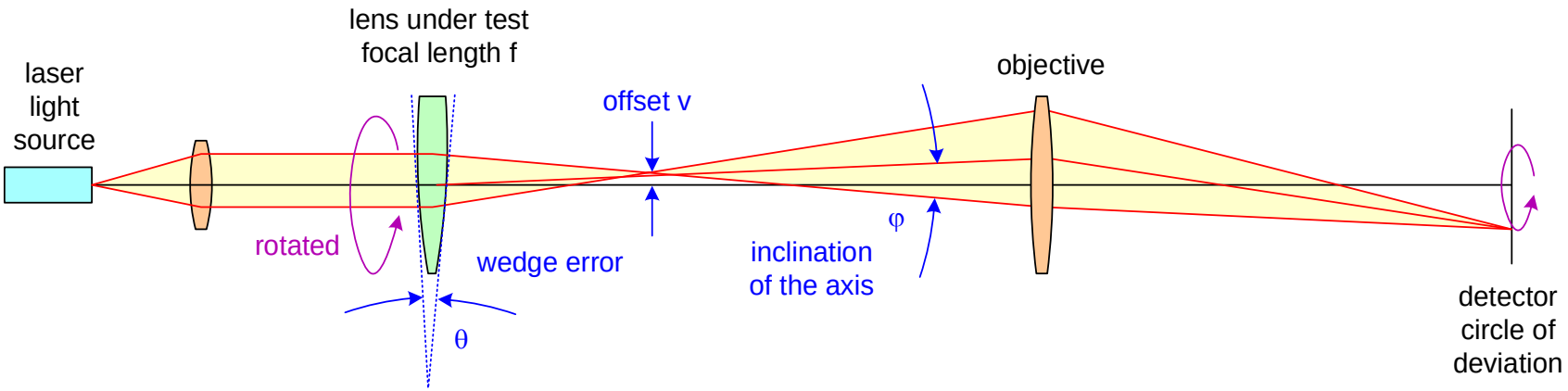
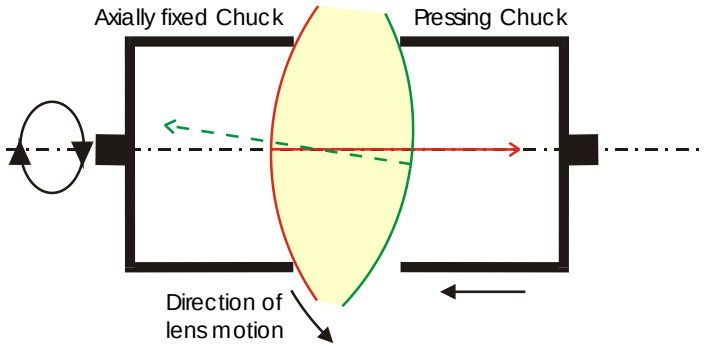
- Thin collimated beam through lens
- Focussing of the beam onto detector
- Measurement of wedge angle by lateral shift v
- Tilt angle of lens not detectable
- Not feasible for very short focal lengths

$$\varphi = (n-1)\cdot\theta = (n-1)\cdot(\alpha_1 - \alpha_2) = \frac{v}{f}$$

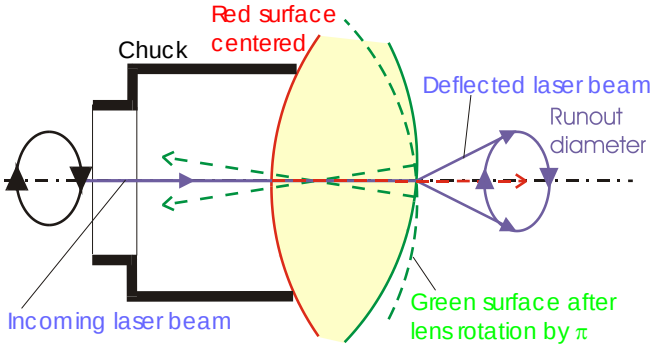


Tolerances: Centering Methods

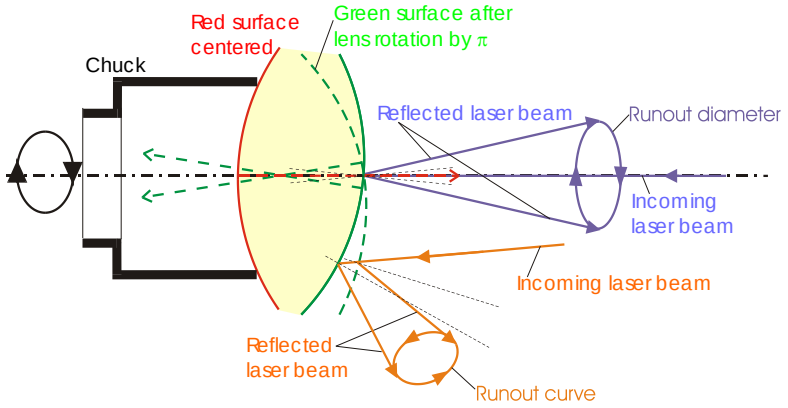
- Mechanical



- Ray in transmission



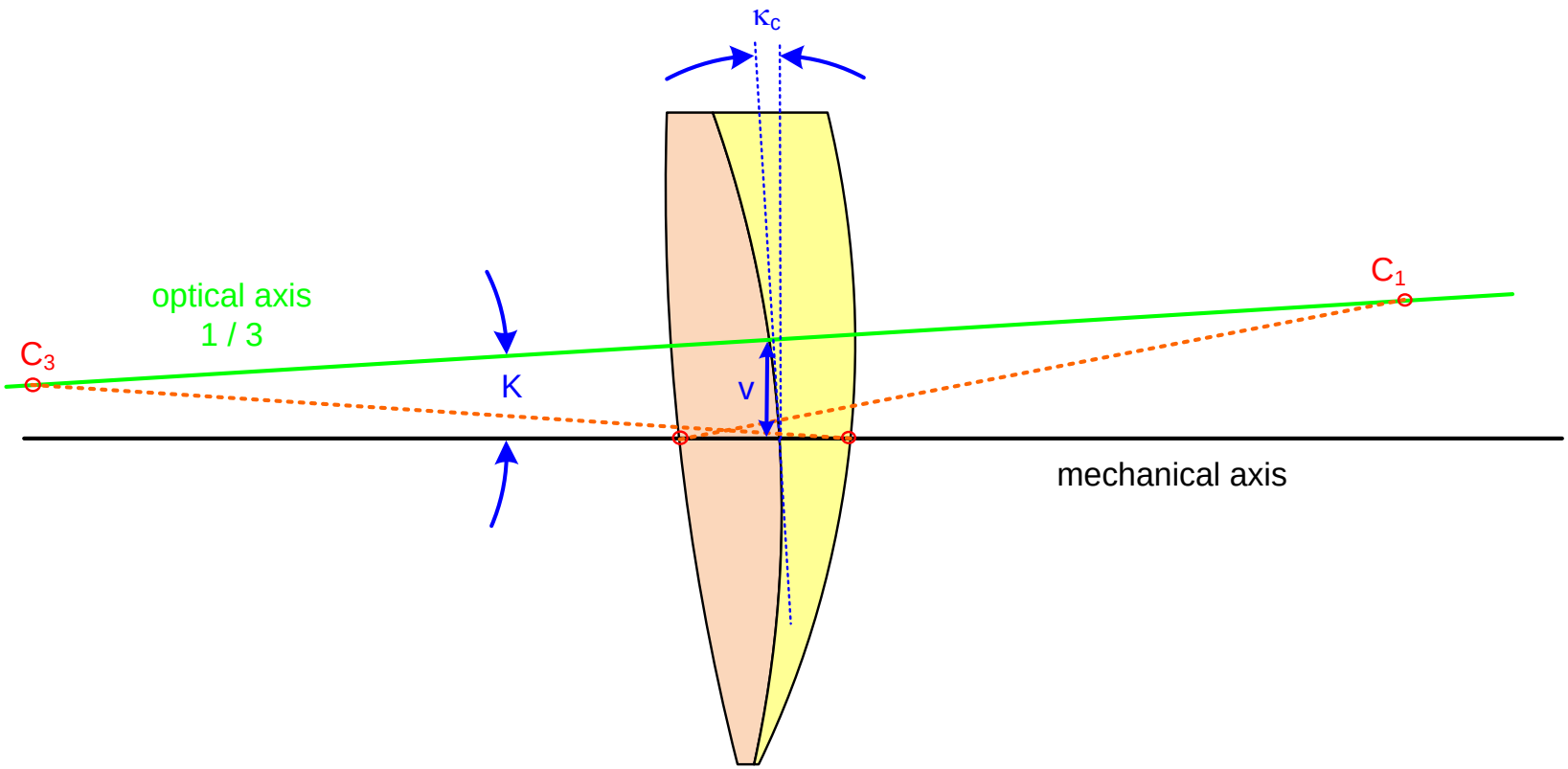
- Rays in reflection



Ref.: M. Peschka

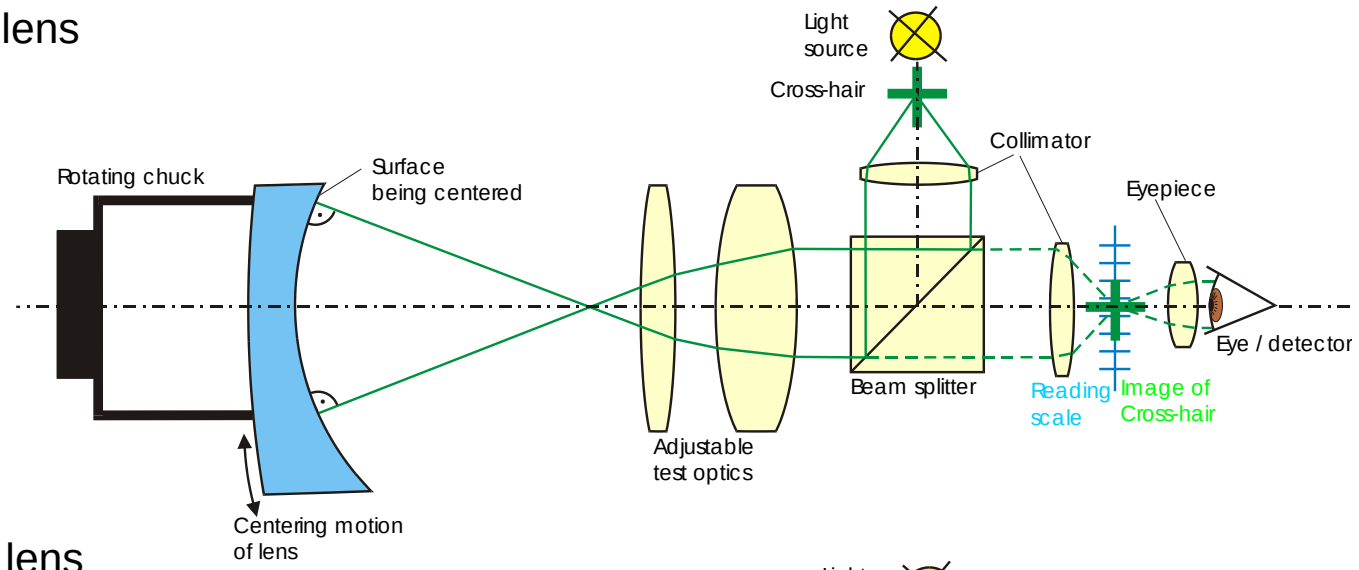
Centering of a Cemented Dublet

- Two equivalent forms of description:
  1. Three single surface tilt angles
  2. Decenter v, overall tilt angle K, tilt of cemented inner surface κ_c , better correspondance to manufacturing steps

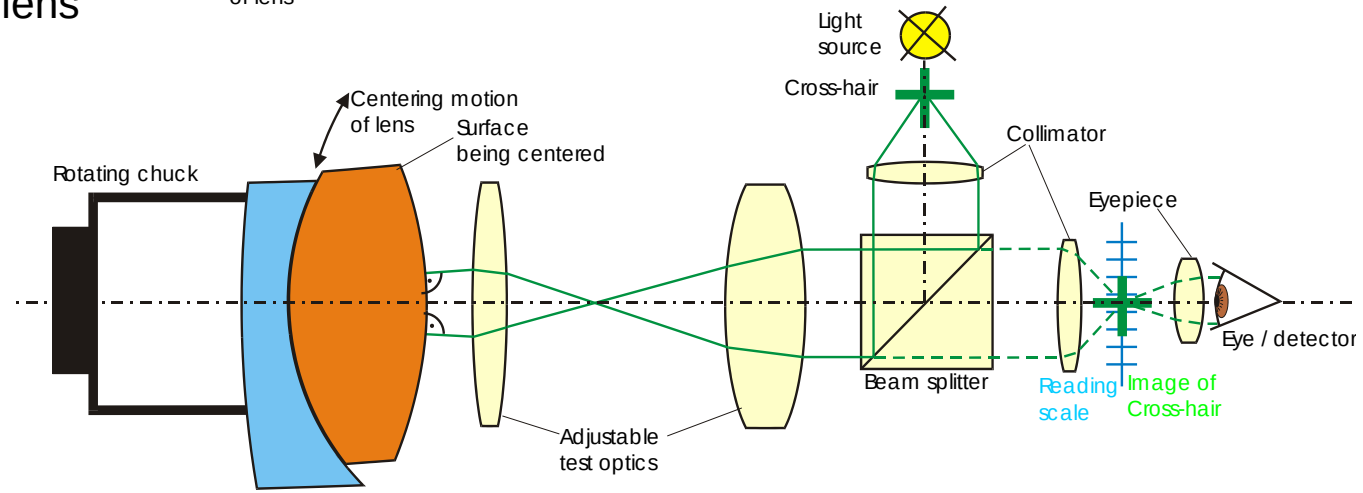


Centering in Bonding Process

- Centering carrier lens



- Adjusting second lens



Ref.: M. Peschka

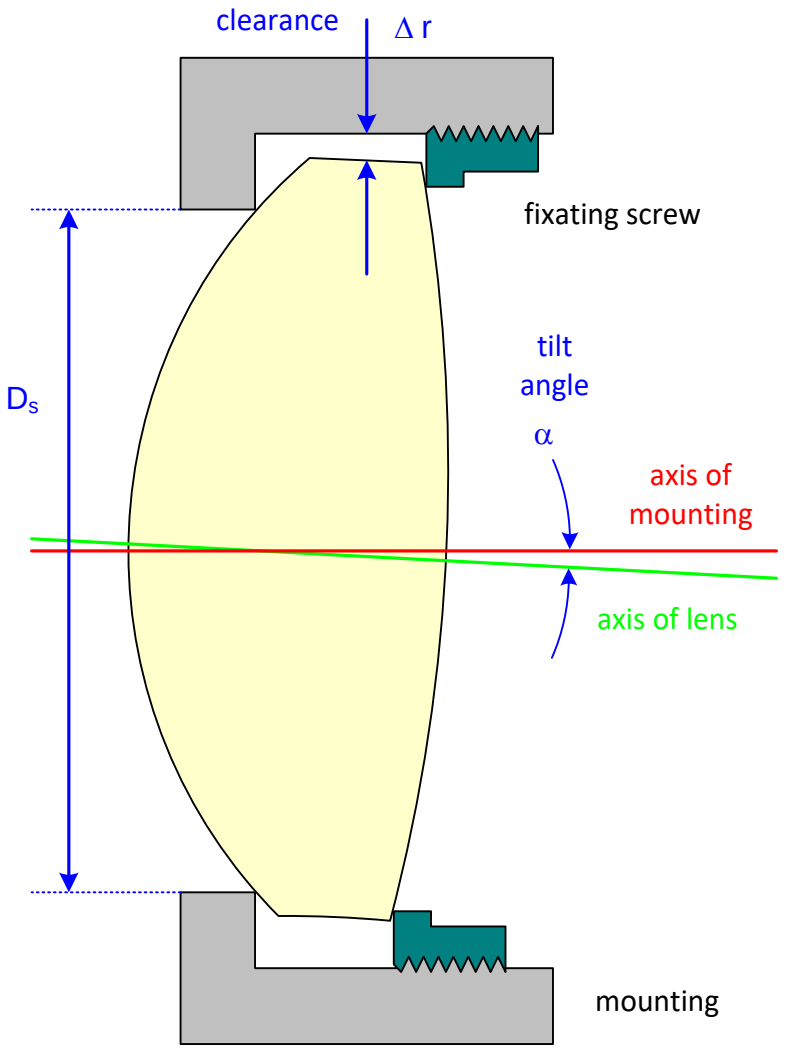
Tolerances and Mechanical Interface

- Coupling optics – mechanics
  Interface glass – metal

- Mechanical design of mountings and housing

- Typical options:
  1. Filling cylinder with fixating screw
  2. Cementing, later centering
  3. Lace / bordering

- Critical:
  - Centering tolerances
  - reference surfaces
  - analysis of complete geometry (kinematic)



Mechanicl Mounting Geometry

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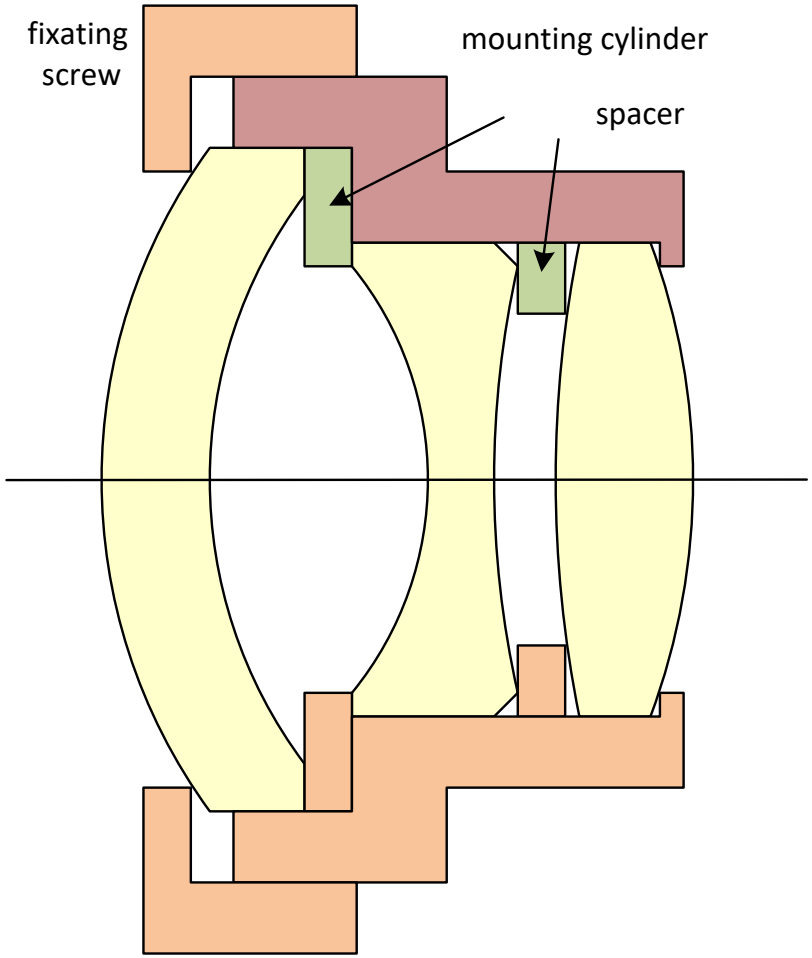
- Filling of lenses into mounting cylinder with spacers
- Accumulation of centering errors by transportation of reference
- Definition of lens positions by:
  1. mechanical play inside mounting
  2. fixating ring screw
  3. planarity of spacers



Xray CT-Tomography

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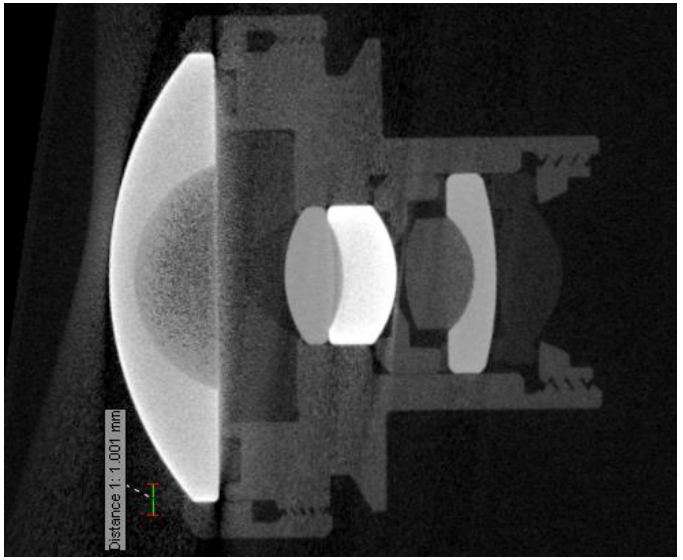
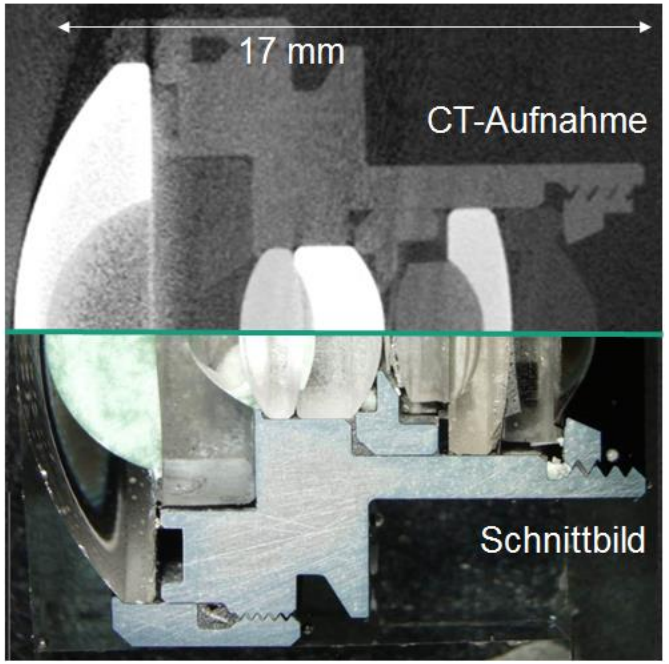
- Determination of
  1. number of lenses
  2. thicknesses
  3. radii of curvature
  4. refractive indices (!?)
- Typical uncertainties of linear dimensions:
  0.050 mm ... 0.010 mm
- Errors are scaling with size
- Contrast for plastics poor
- Different absorption for glass types
- Cross section vs CT-projection image





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Xray CT-Tomography

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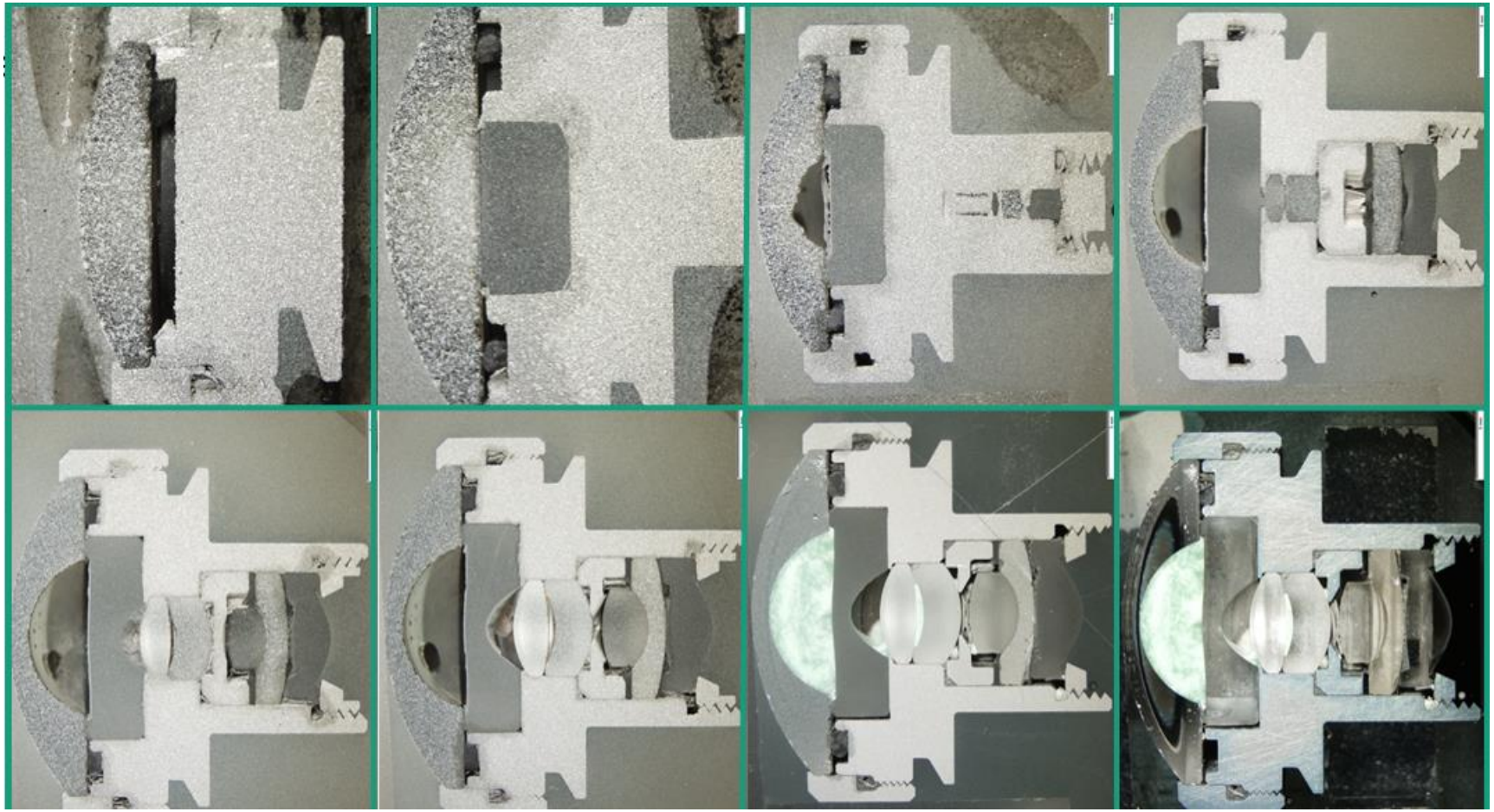
- Various cross sections



Ref: B. Satzer