Lab 4

Alignment &
Affects of Misalignment

Definition of alignment

Placing the optical axis of each element on the optical axis of the system

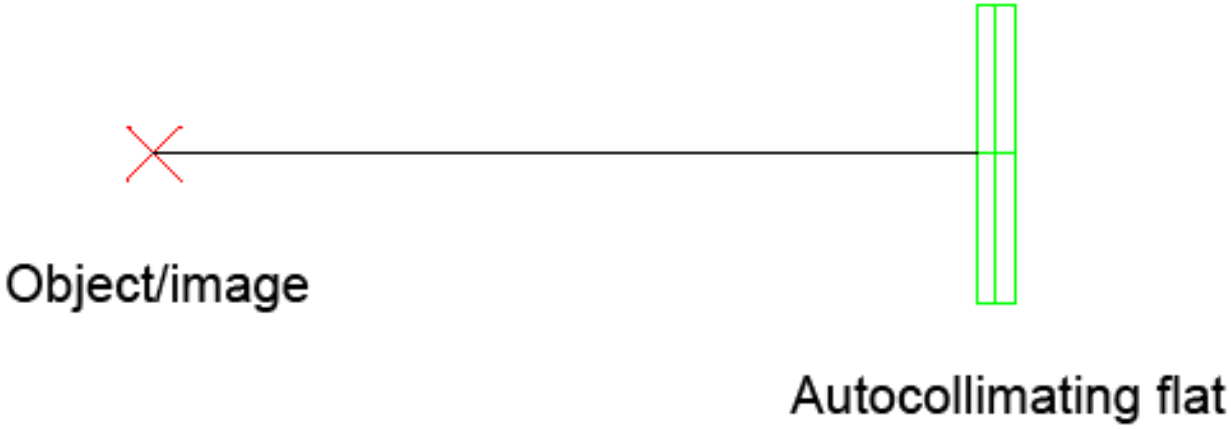
This implies defining the optical axis of the system and finding the optical axes of the elements

For a finite conjugate system the optical axis is the line joining the object and image

For an infinite conjugate system the optical axis is a line between the object/image and an autocollimating flat

System optical axis

Finite conjugate system



Infinite conjugate system

Motivation for alignment

Alignment is really a two step process -

A first order step using two degrees of freedom

A second step to zero out aberrations using remaining DoF

If only the first step done, light is focused at the correct location

but the image quality will be poor, in general

The second step must be done while holding the first order properties constant

Now we will look at a few definitions of DoF of verious optical elements

Then we'll look at some examples

Alignment properties of elements

Point – theoretical construct – defined by 3 position coordinates, x, y, z, or three degrees of freedom

Ball or sphere – physical realization of a point

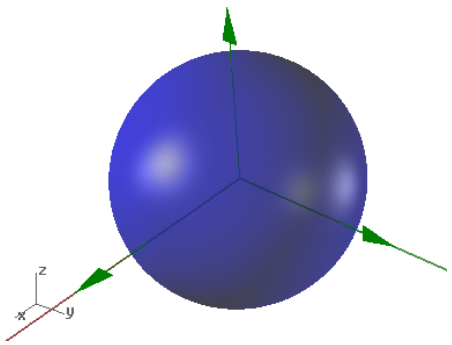
Defined by location of center, x, y, z and radius, r

The center is an intrinsic property of a sphere, the radius extrinsic

A sphere has no axis; repeat, no intrinsic axis

Spherical mirror – section of a ball – a center of curvature and a radius

There is no optical axis, only a mechanical axis



Alignment properties of elements, con't

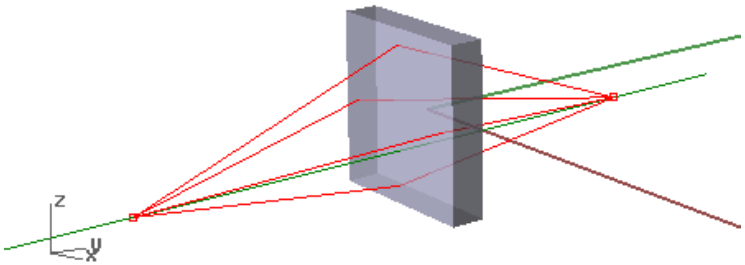
Line – theoretical construct – defined by 2 points at arbitrary distances along the line, say, x1, y1 and x2, y2, or 1 point, x1, y1 and 2 angles, alpha and beta, or 4 degrees of freedom

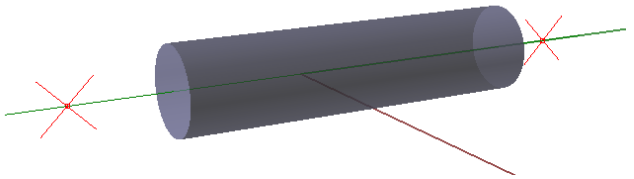
Plane mirror – defines a line as a normal to the surface, 2 angles

Cylinder or rod – is a physical realization defined by a pair of points or a point and a pair of angles plus a radius about the line or axis

Cylindrical mirror – defined by an axis or line and a radius

Again, the four points are intrinsic, and the radius extrinsic





Alignment properties of elements, con't

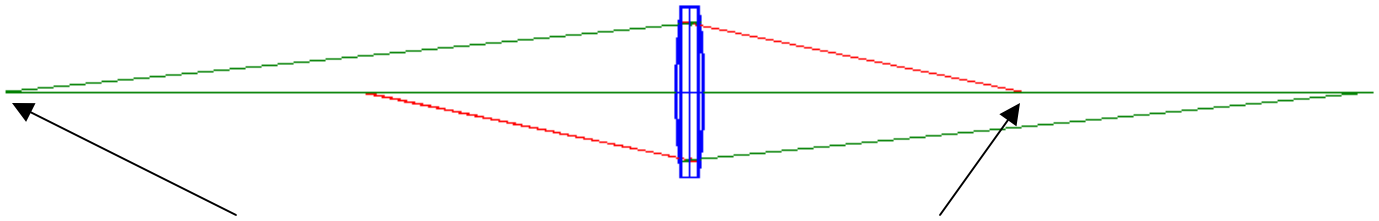
The axis of a lens is defined by the line joining the centers of curvature

This can be the physical CoC or the optically apparent CoC

There are four intrinsic degrees of freedom defined,

and extrinsic radii and thicknesses

Rotation about the optical axis is undefined



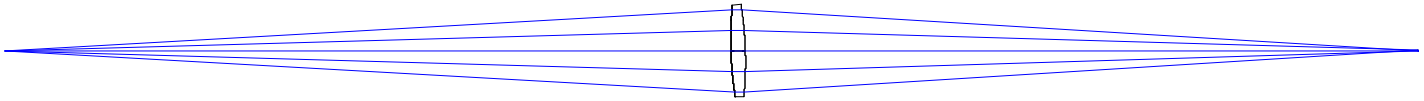
Physical center of curvature

Optical center of curvature

1:1 relay example

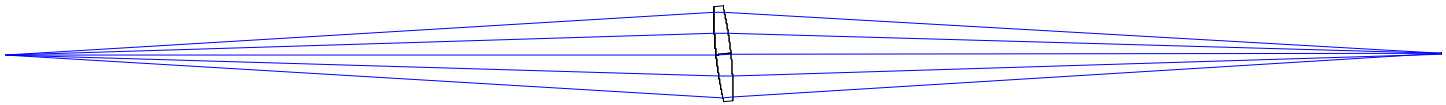
Biconvex lens with 100 mm efl used at 1:1 conjugates – Lab 1

If perfectly aligned and used at full aperture has 3.5 waves p-v of spherical aberration



If the lens is decentered just 2 μm we found the image moves 4 μm

To restore the image position the lens must be tilted almost 6 degrees and this introduces 10 waves p-v of astigmatism



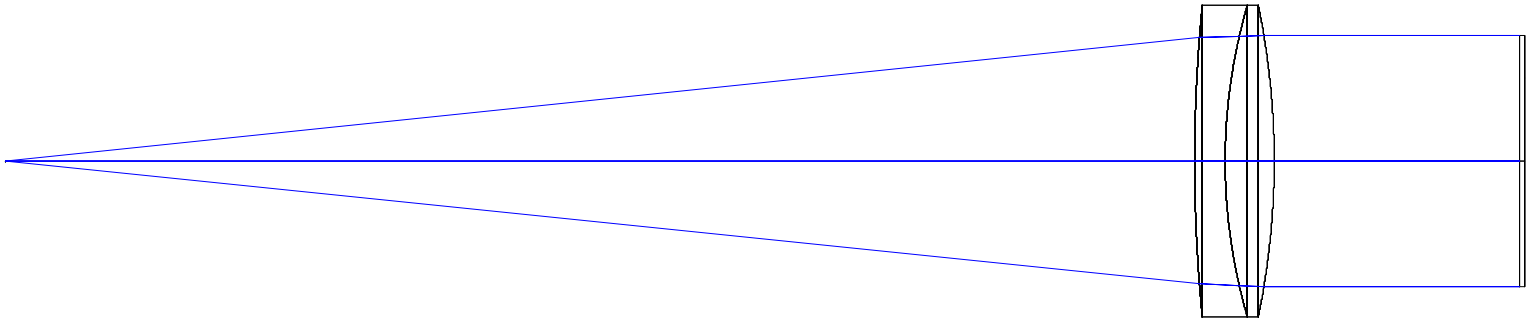
Physical CoC is 10 mm off-axis Optical CoC is 4.8 mm off-axis

Holding CoC to 10 or 20 μm results in no aberrations

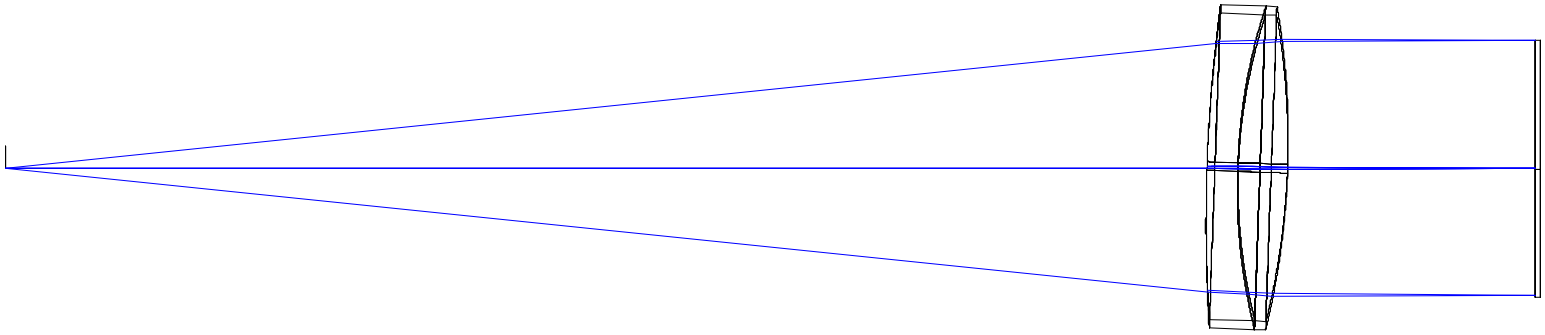
f/5 objective in autocollimation

100 mm efl achromatic objective in autocollimation off a plane mirror

If perfectly aligned the reflected wavefront is .6 waves p-v SA3 mostly



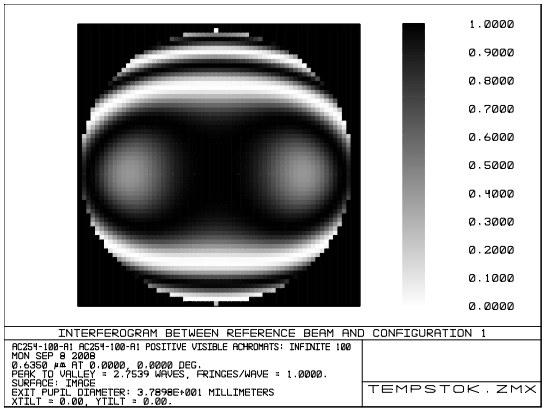
Tilt about 2 ° and decenter lens to keep image on top of object ~.34 mm

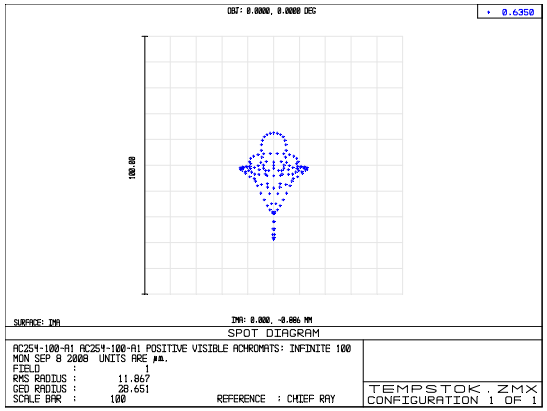


f/5 objective, con’t

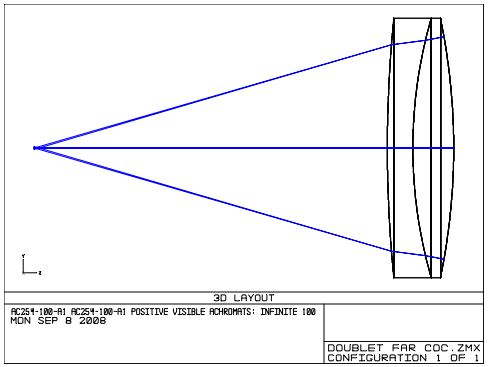
Now 2.75 waves p-v, mostly astigmatism, an off-axis aberration

Physical CoC are off axis by 4.4 and 2.2 mm

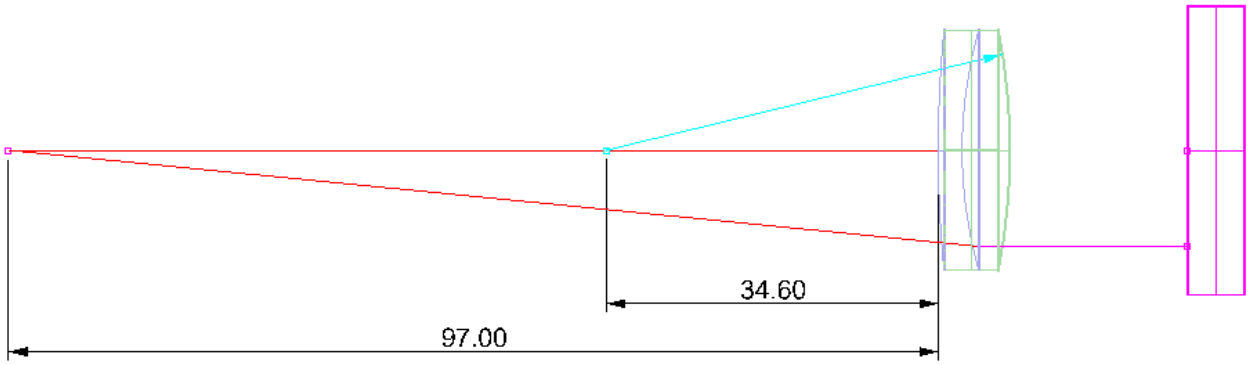




Distance from focus to vertex is 34.6 mm



Alignment of objective



Insert lens in front of plane mirror

Find autocollimated image, reflection from far surface of lens

Adjust tilt and decenter of lens, and tilt of plane mirror until both image and far surface reflection are centered when PSM moved along straightedge

Plane mirror will be perpendicular to table top and straightedge, and lens used in center of field

Use alignment telescope

The alignment telescope is a precision instrument for the alignment of objects on a reference line defined by the line of sight, or optical axis of the telescope

Alignment telescope works like PSM except it focuses along its axis

Its near focus is about .5 m in front of the objective, far at infinity

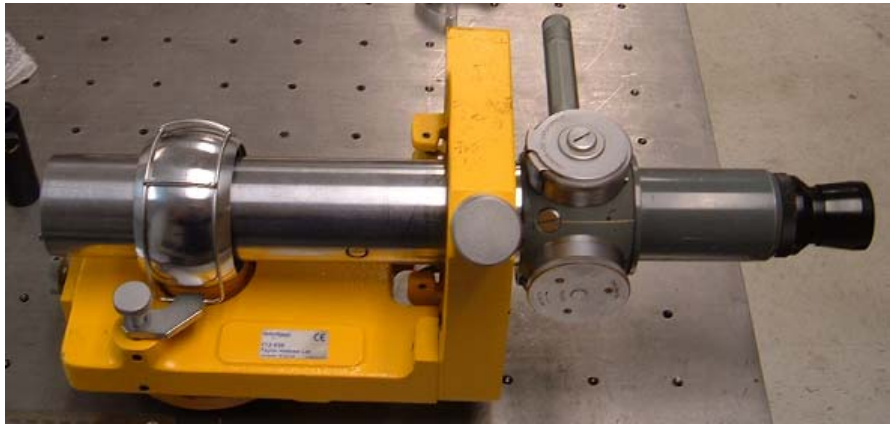
Return reflection is a set of concentric rings

X, y adjustments will have to be made with the hardware

The alignment telescope will adjust in angle

Alignment Telescope

- The alignment telescope is a precision instrument for the alignment of objects on a reference line defined by the optical axis of the telescope



Alignment Telescope

- Determine optical axis
  - Rotate telescope in holder to ensure telescope is calibrated
  - Center the target at position 1 using the reticle
  - Move target to position 2
    - Note which way the crosshairs moved
    - Using bottom and left knobs, move the reticle half the distance
  - Repeat above 2 steps until the reticle doesn't move

Alignment Telescope

- Aligning two lenses
  - Place the first lens in front of the alignment telescope. Focus on the lens and tip/tilt the lens till the image of the reticle is centered.
  - If the image of the reticle is too faint, use a PIP generator and look at the image of the focal point.
  - Images are obtained from the front an back of lens (from the interface too if using an acromat)
  - Tip/tilt and translate lens till all images overlap.
  - Insert second lens and follow the same procedure.
  - Use a PSM to cross check alignment