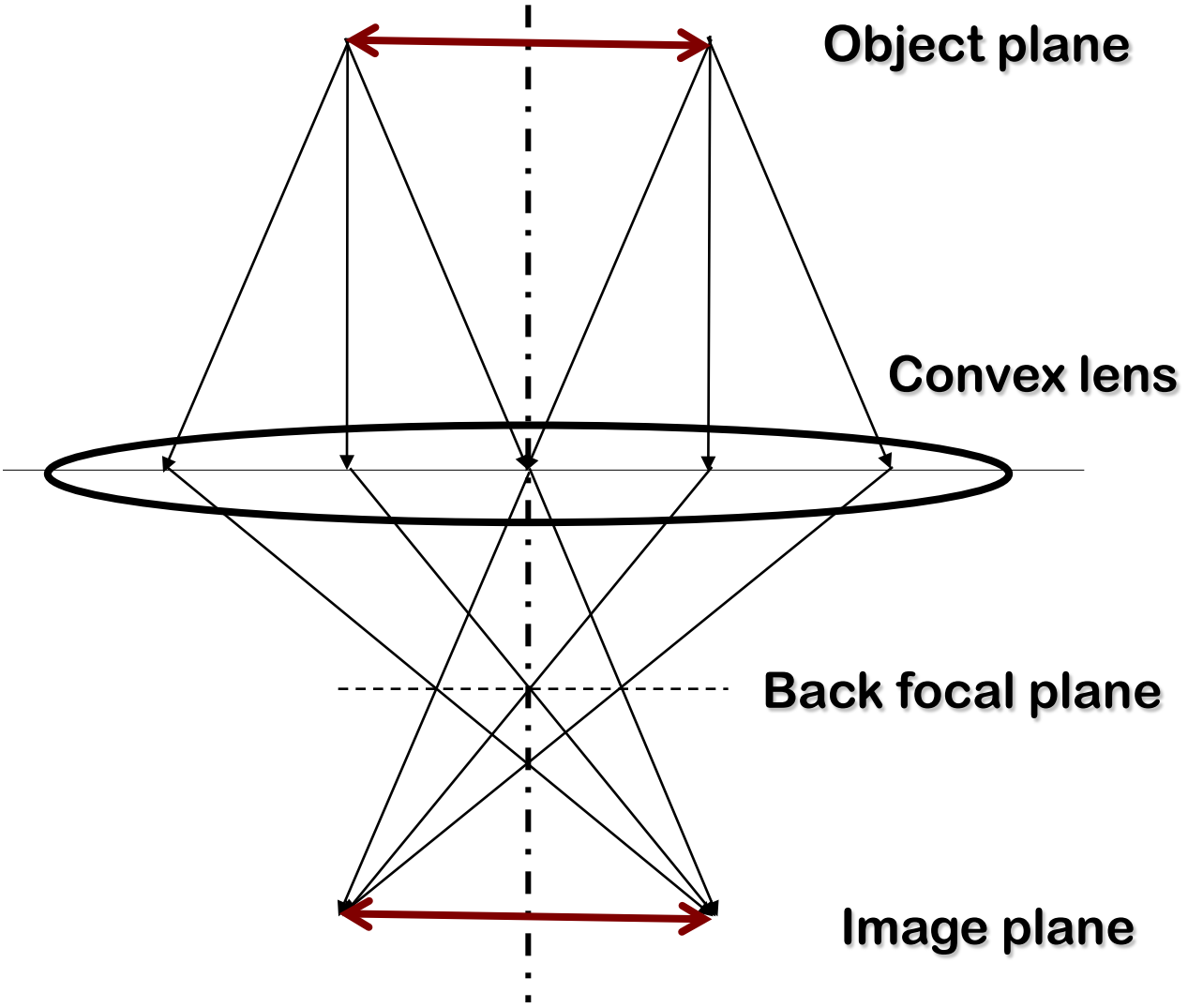
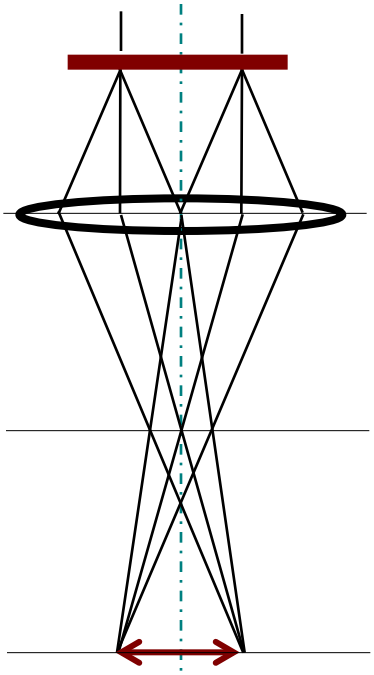
“The instrument”

Lecture 4 – Part 2

Recall …



TEM imaging



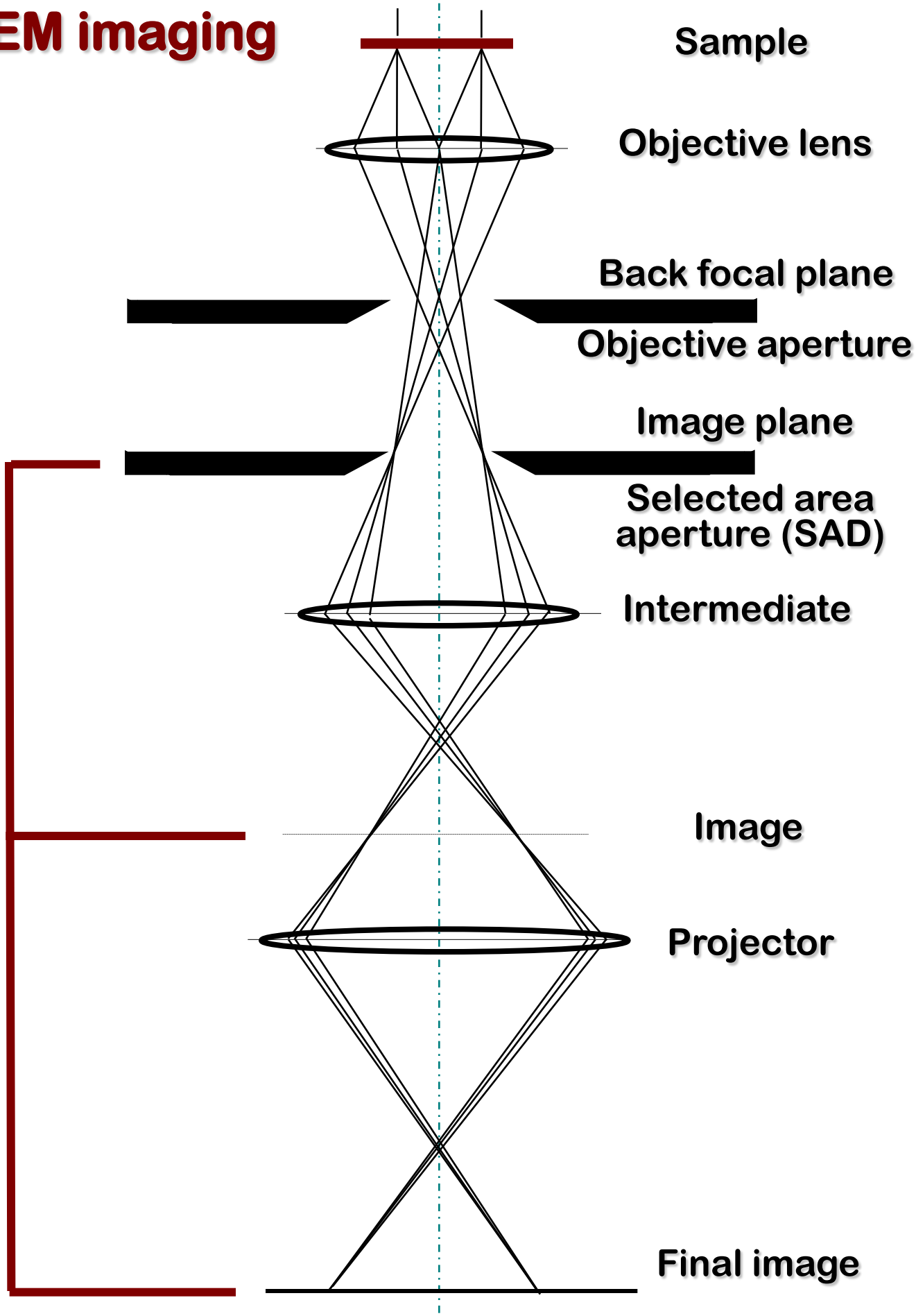
Sample

Objective lens

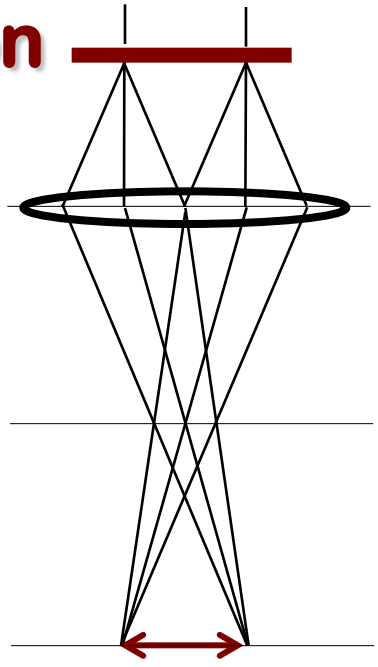
Back focal plane

Image plane

TEM imaging


Sample
Objective lens
Back focal plane
Objective aperture
Image plane
Selected area aperture (SAD)
Intermediate
Image
Projector
Final image

TEM diffraction



Sample

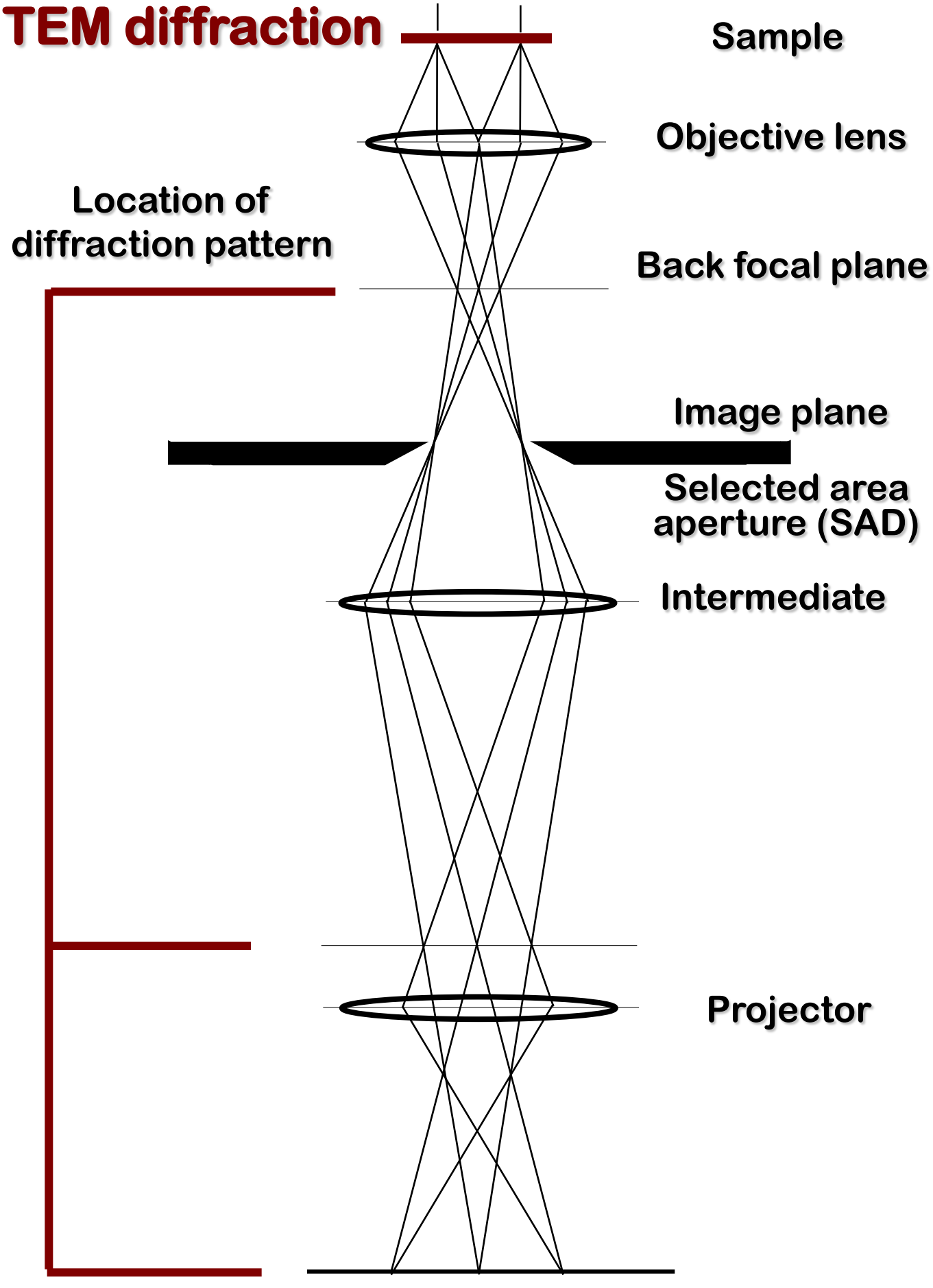
Objective lens

Location of diffraction pattern

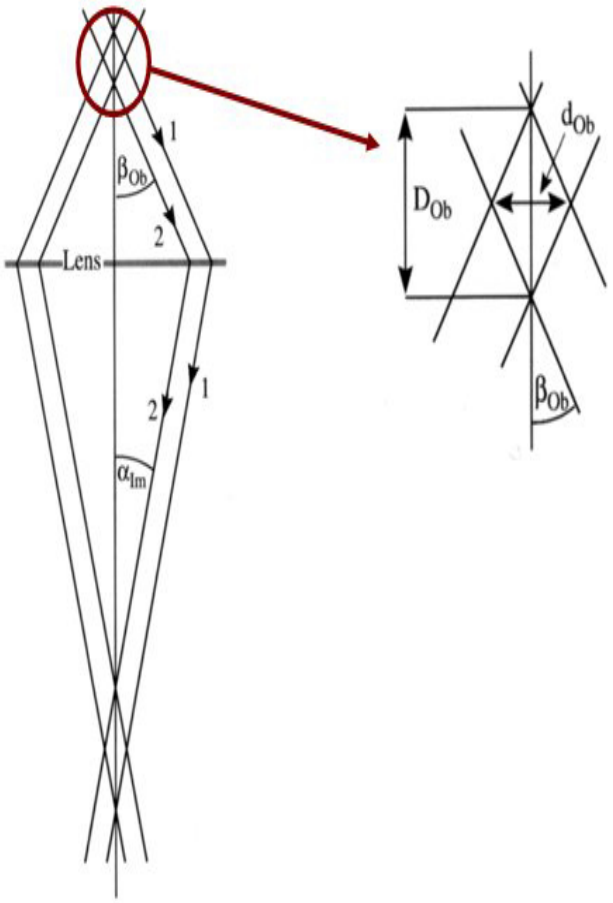
Back focal plane

Image plane

TEM diffraction



Depth of field



Depth of field:

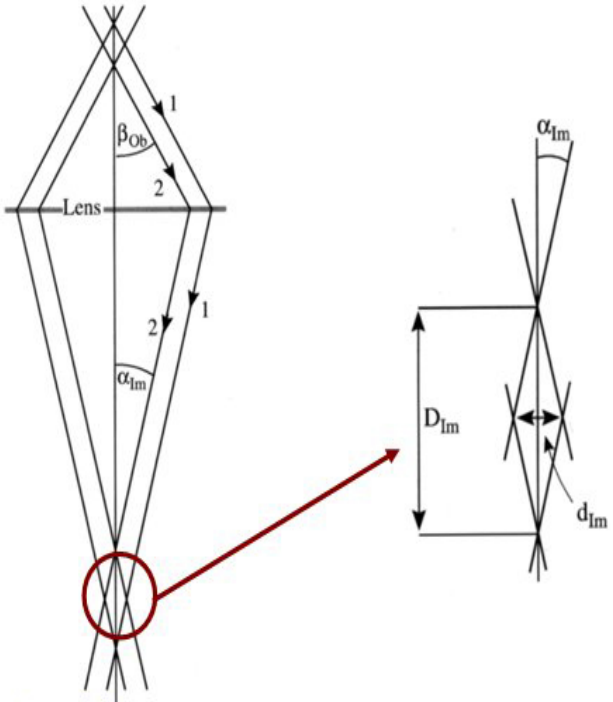
Depth of 'sharpness' in object space

$$D_{ob} = \frac{d_{ob}}{\beta_{ob}}$$

2Å detail ⇒ 20 nm thick

2 nm detail ⇒ 200 nm thick

Depth of focus



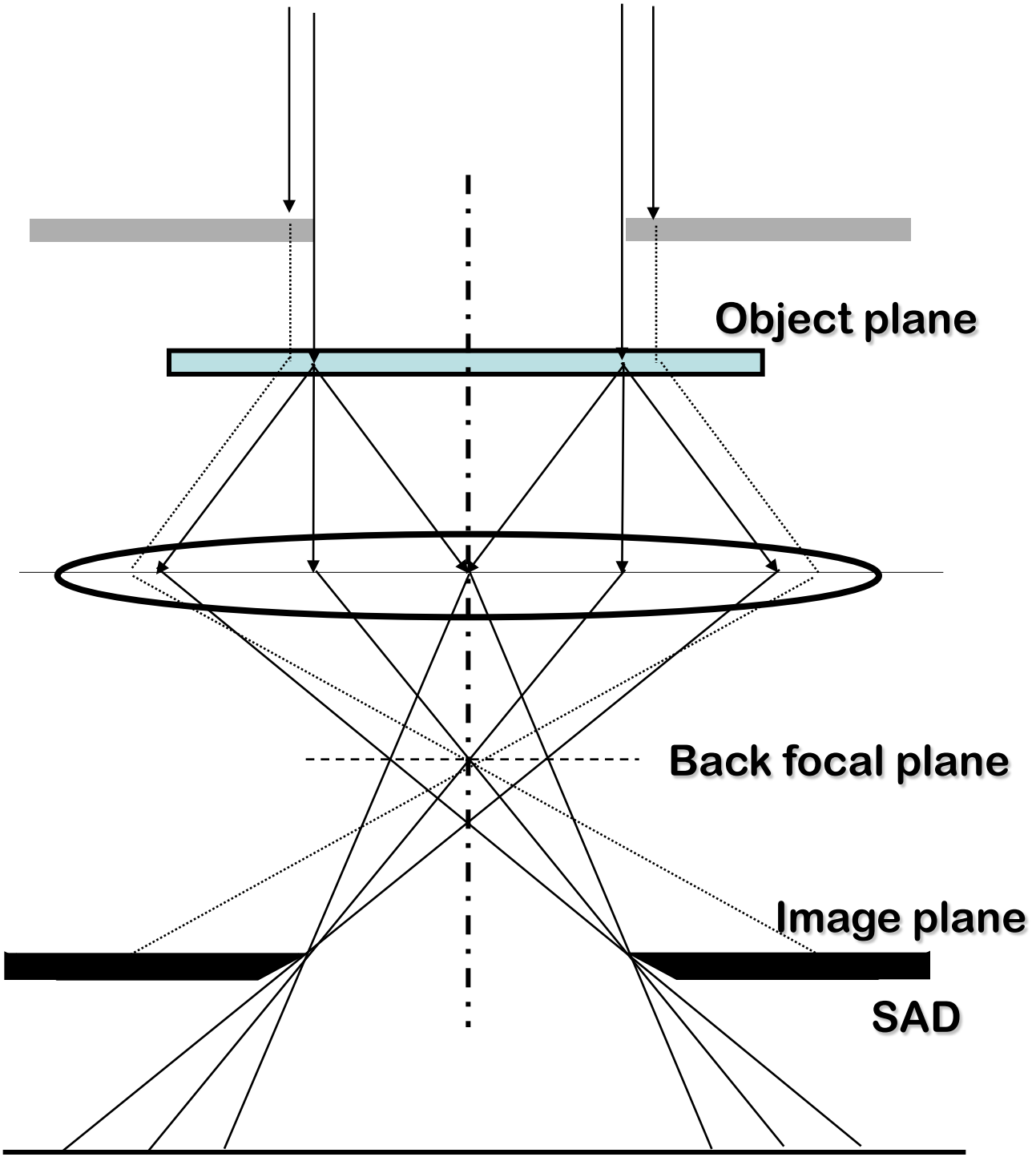
Depth of focus:

- Depth of 'sharpness' in image space

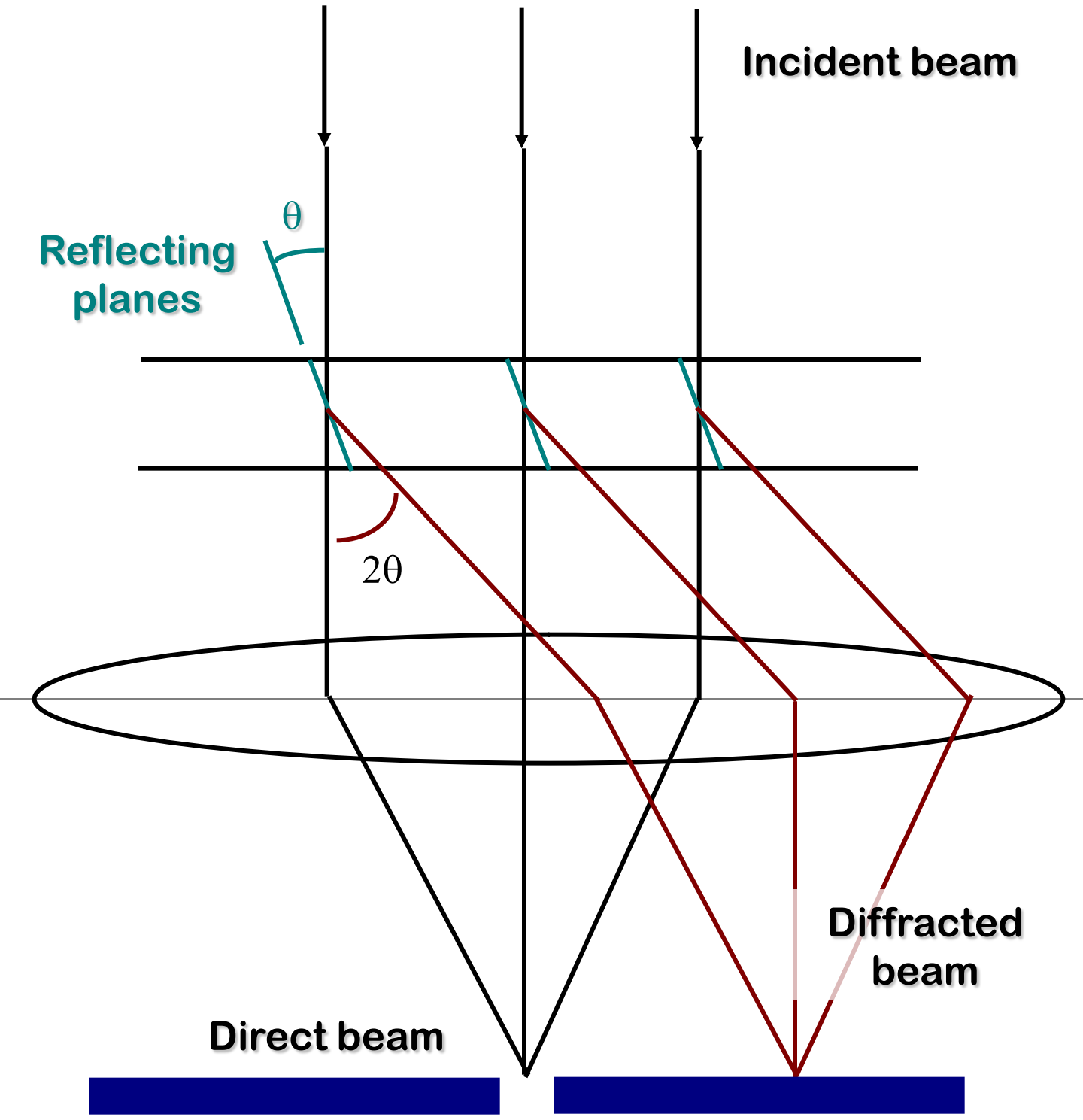
$$D_{im} = \frac{d_{ob}}{\beta_{ob}} M^2$$

- 2Å detail ⇒ 500 kX ⇒ 5 km
- 2 nm detail ⇒ 50 kX ⇒ 5 m

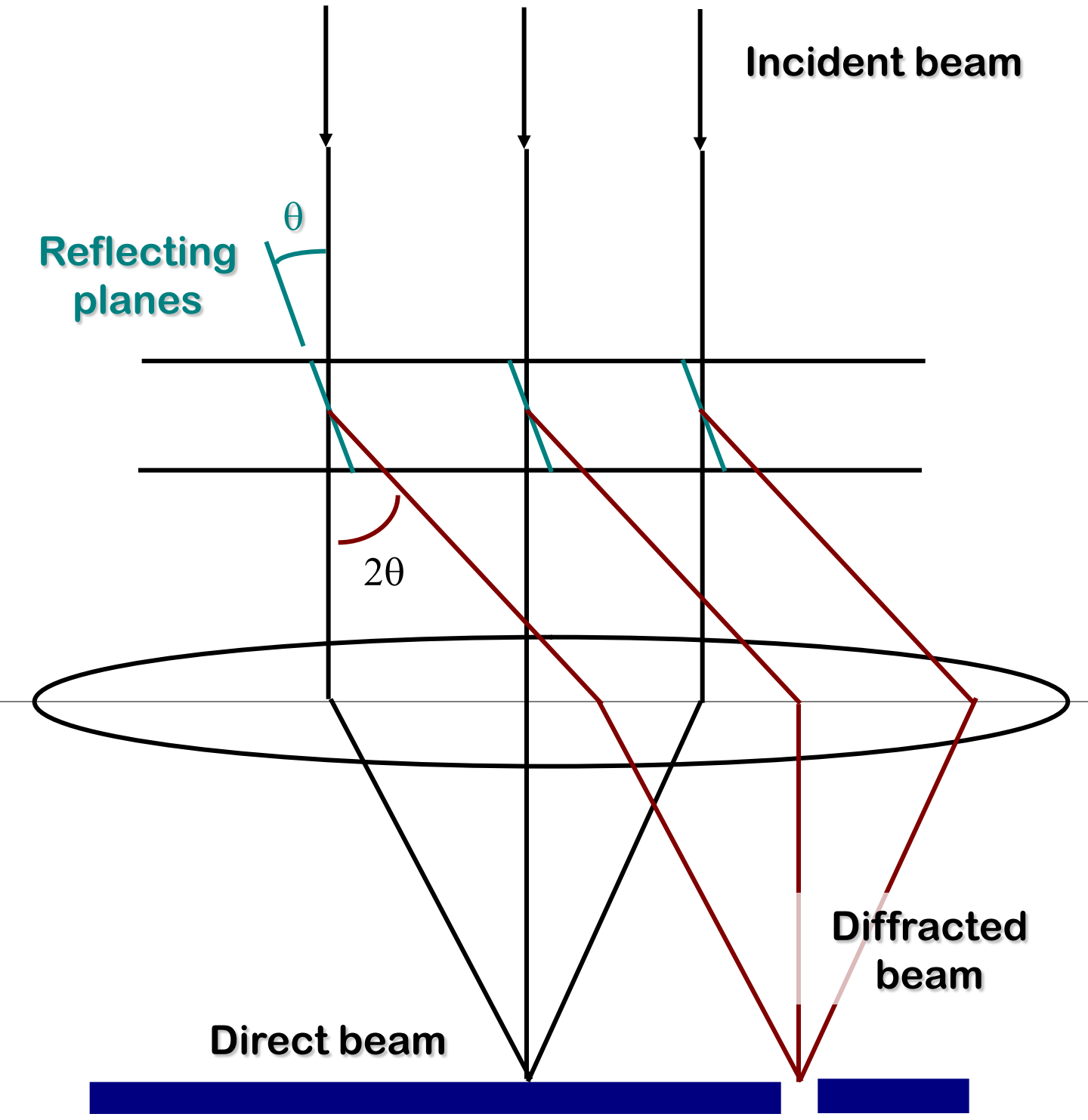
Selected area diffraction aperture



Bright field image



“Dirty” dark field

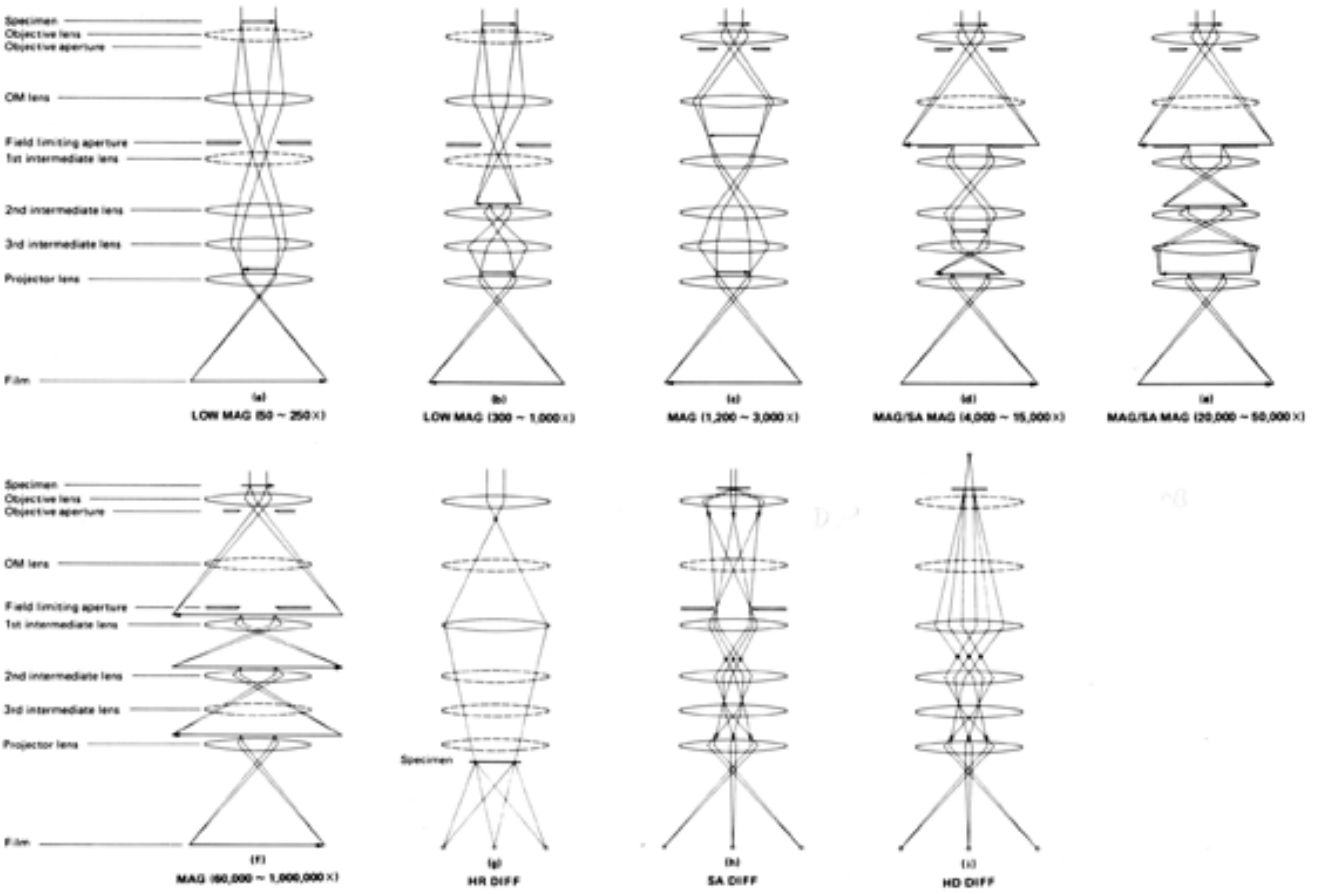


What can you do with a TEM?

'Weak beam' dark field image

Imaging system

Actual ray diagrams are always available in the operation manual of the microscope



Microscope alignment

Maximum intensity should be extracted from gun

Beam should pass through each lens on the optic axis

- **Spherical aberration**
- **Hey - it's the center …**
  - **My point - you need to have something to align with respect to …**

Apertures should be centered about the optic axis

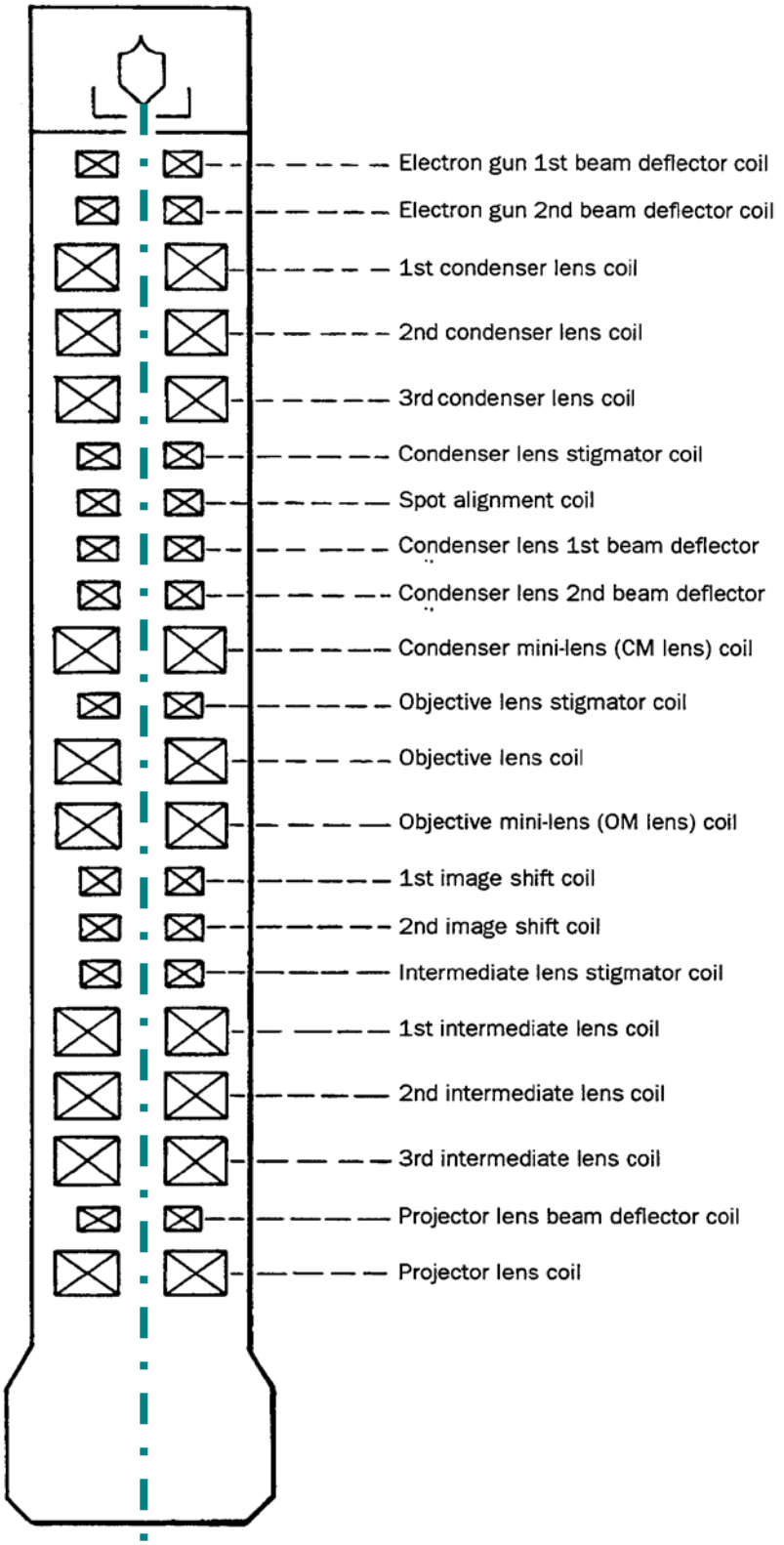
Astigmatism should be corrected

General idea

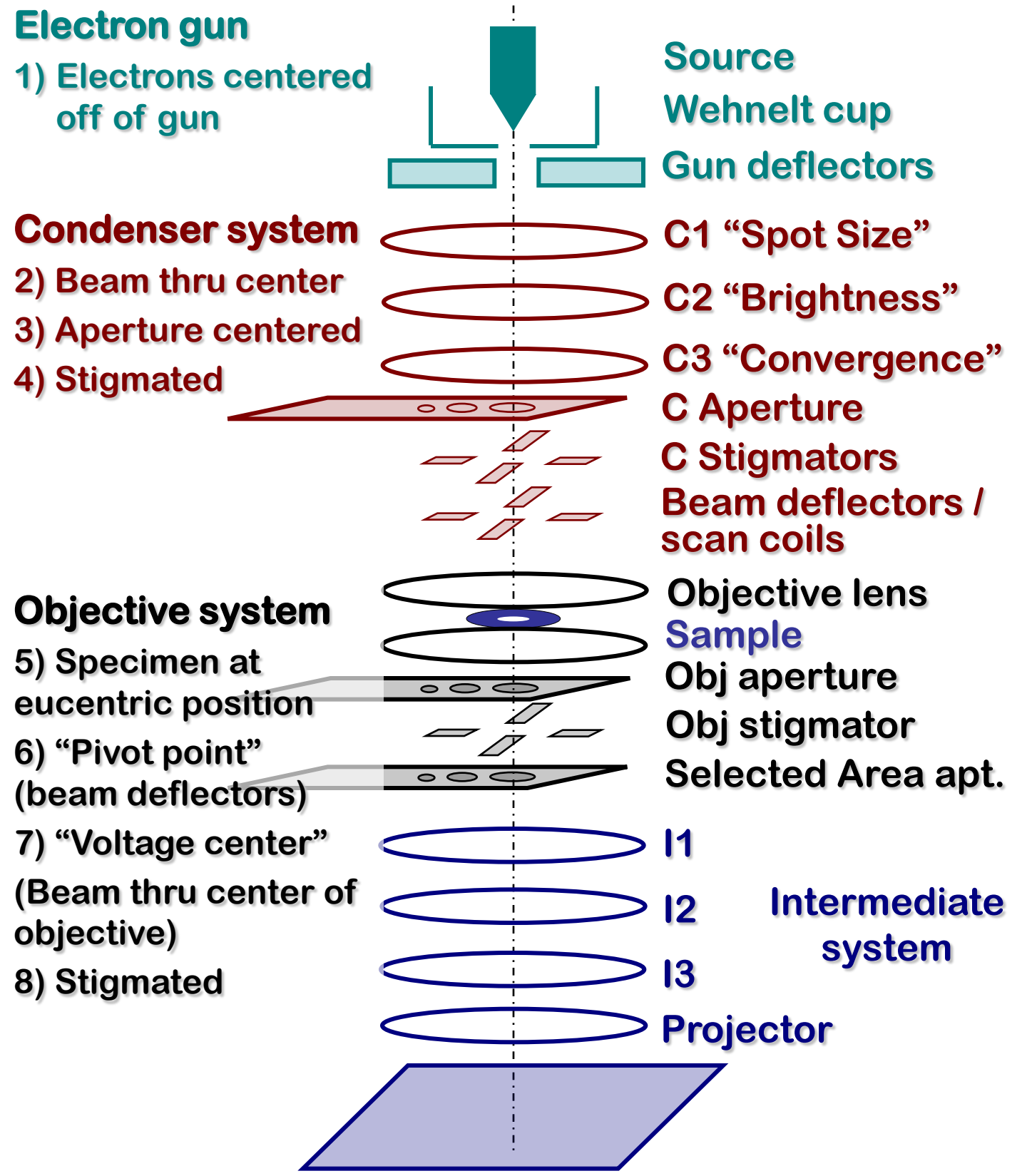
When aligning the condenser system, the filament is the 'object'

When aligning the objective, first fix sample at eucentric position

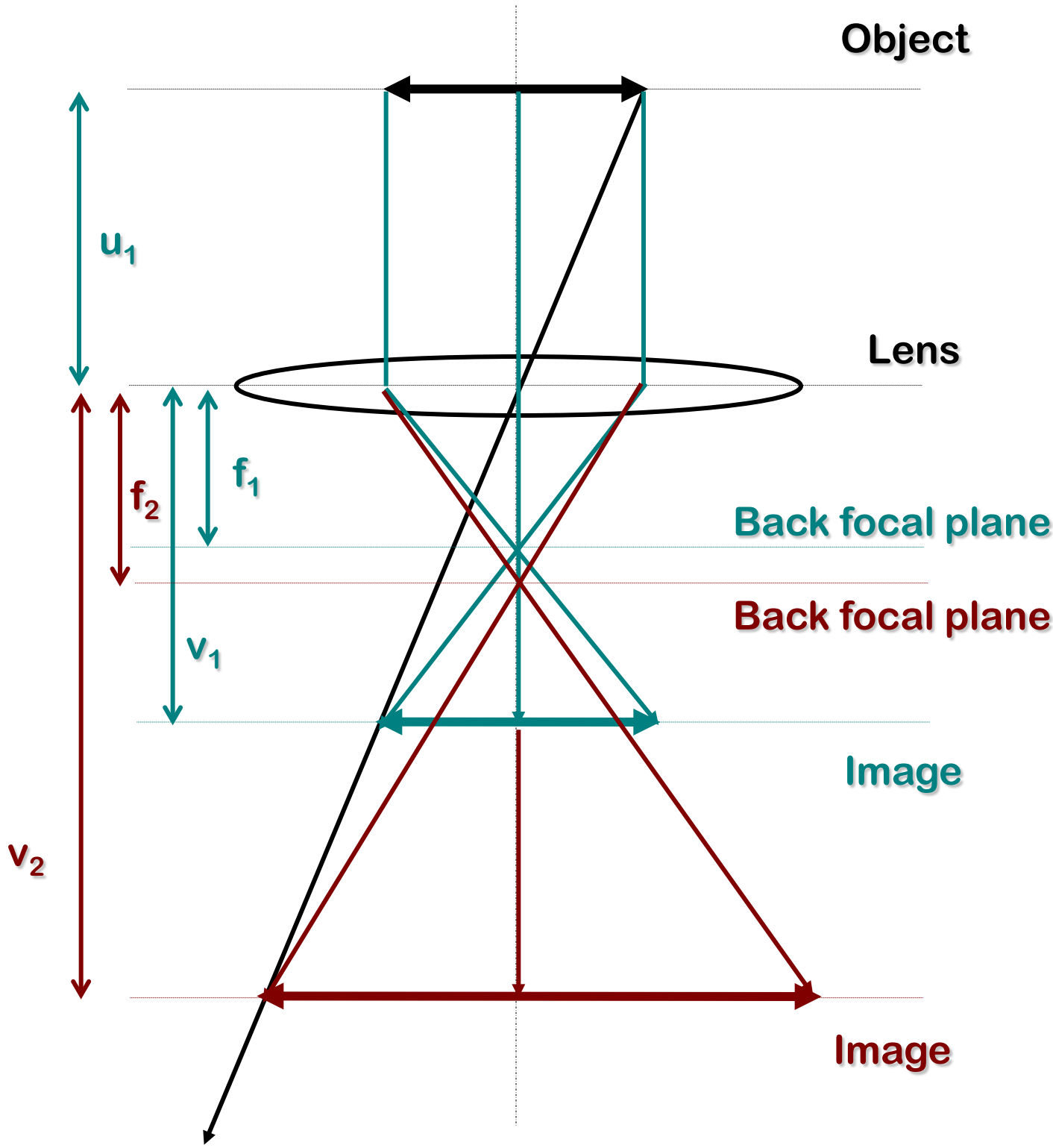
This defines the objective lens optics, everything else keys on that



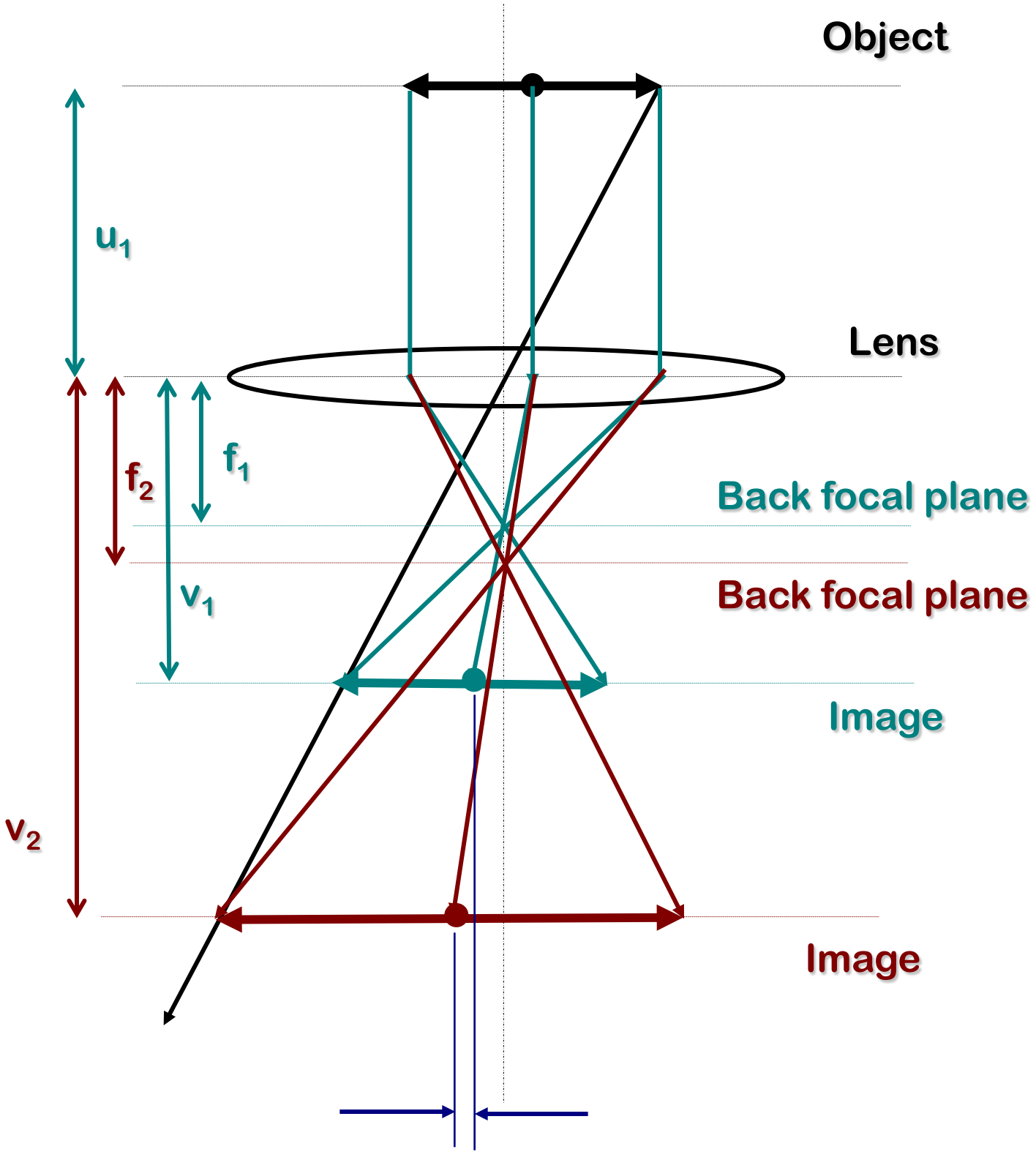
Alignment


Electron gun
1) Electrons centered off of gun
Source
Wehnelt cup
Gun deflectors
Condenser system
2) Beam thru center
3) Aperture centered
4) Stigmated
C1 "Spot Size"
C2 "Brightness"
C3 "Convergence"
C Aperture
C Stigmators
Beam deflectors / scan coils
Objective system
5) Specimen at eucentric position
6) "Pivot point" (beam deflectors)
7) "Voltage center"
(Beam thru center of objective)
8) Stigmated
Objective lens
Sample
Obj aperture
Obj stigmator
Selected Area apt.
I1
I2
I3
Intermediate system
Projector

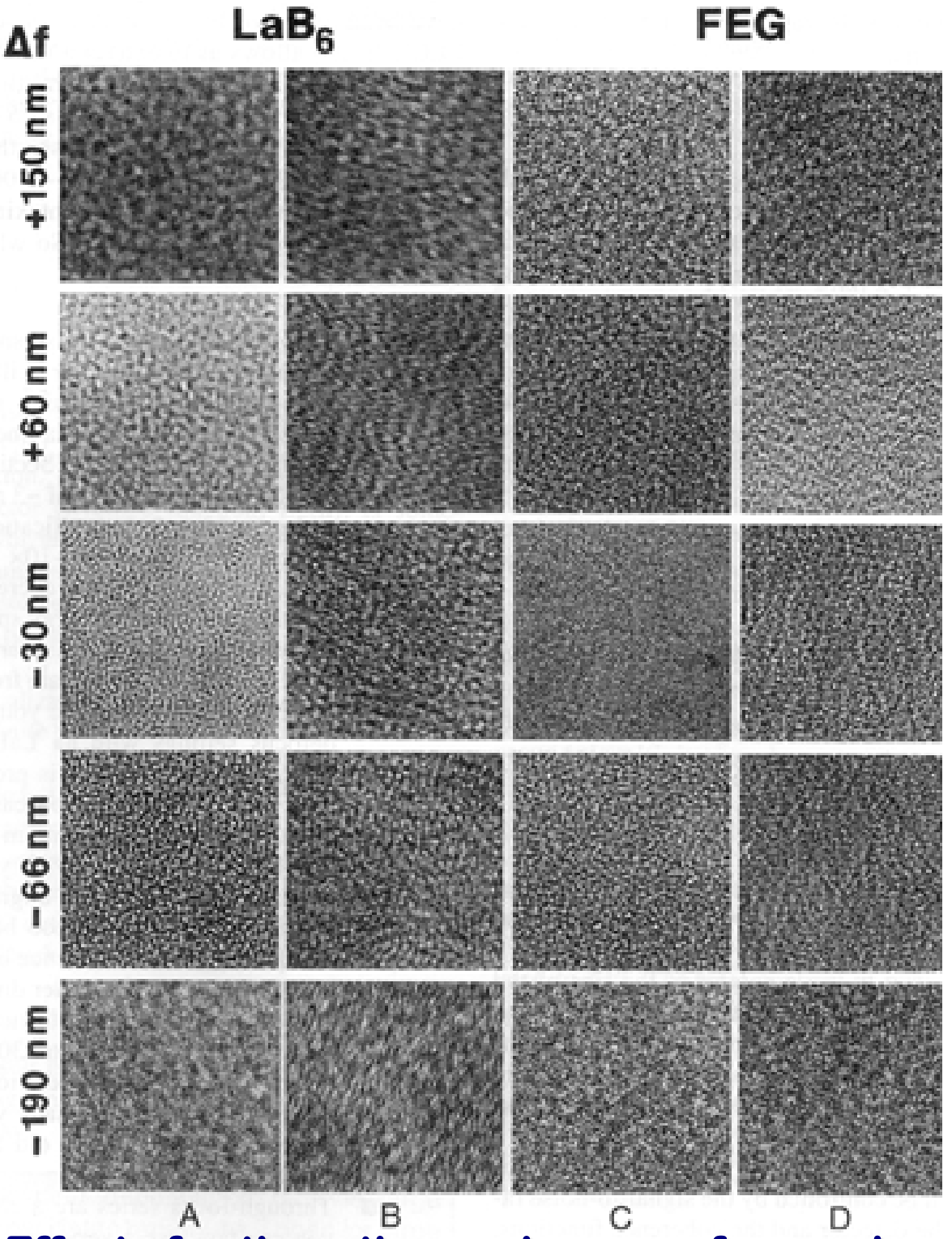
Centering


Object
u_1
Lens
f_2
f_1
Back focal plane
Back focal plane
v_1
Image
v_2
Image

Centering


Object
u_1
Lens
f_2
f_1
Back focal plane
Back focal plane
v_1
Image
v_2
Image

Astigmatism



Effect of astigmatism on images of amorphous carbon (A&C - correct / B&D - astigmatic)

Magnification calibration

Actual magnification highly dependent on the exact objective lens focus (i.e. current)

Can be off by ± 10%

Must be measured - use known standards

- **Diffraction grating**
- **Microspheres**
- **Direct lattice spacings**
- **"MAG-I-CAL Standard"**

Carefully grown SiGe superlattice

Spans range from 1kX to 1MX

Pretty expensive ($1k) so you might just want to make your own!

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Rotation calibration

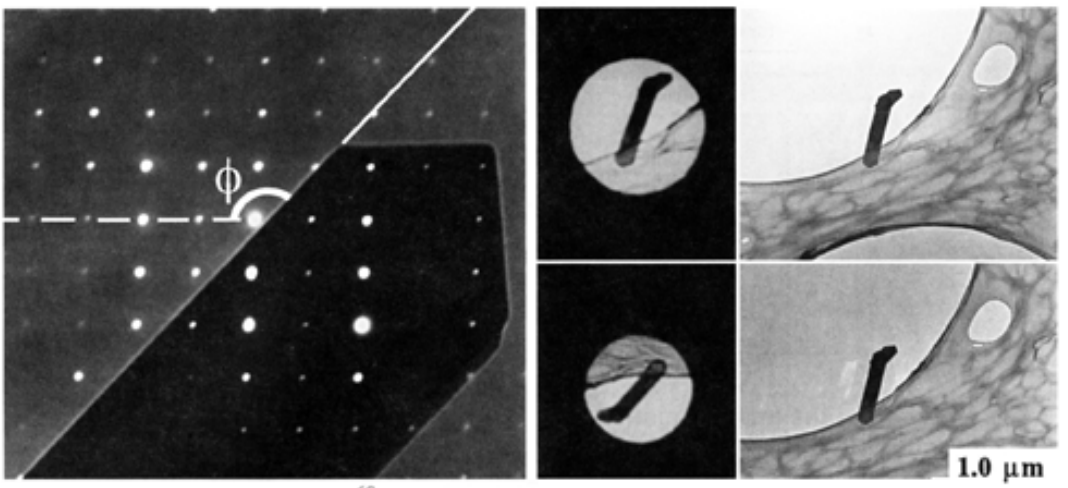
Magnetic lenses introduce image rotation

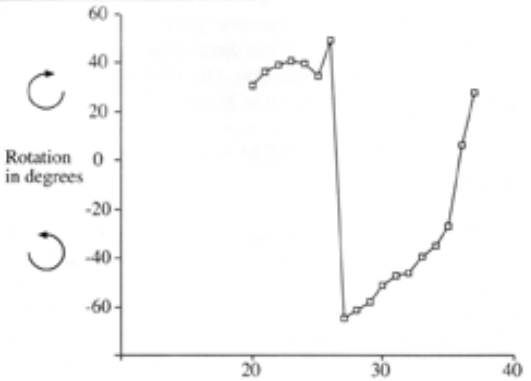
Older microscopes need to have this calibrated

- **JEOL200CX and older**
- **Philips 430 series and older**
- **Most anything pre-1980**

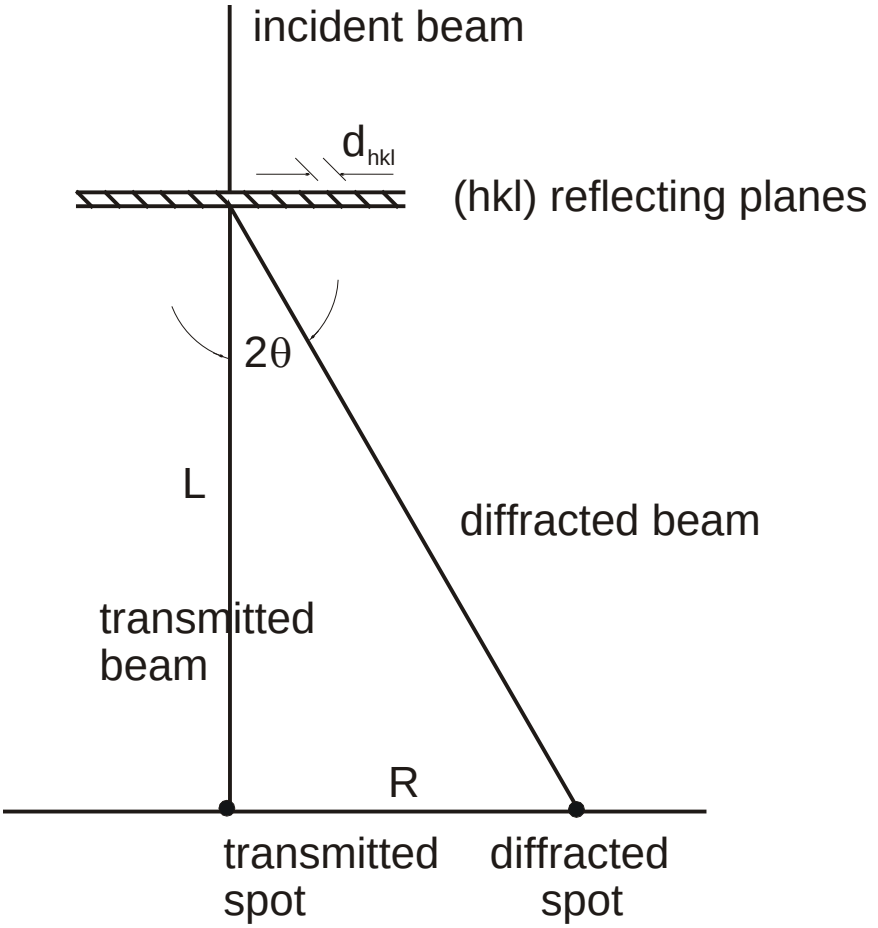
Again, depends on exact objective lens focus (i.e. current)

Use MoO_3 as a standard





Camera constant



Simple geometry: $R/L = \tan(2\theta) \approx \theta$

Bragg's Law: $\lambda / d = 2\sin(\theta) \approx 2\theta$

Yields: $Rd = \lambda L$

"Camera constant"

Other calibrations

Convergence angle

- Use of CBED patterns

Accelerating voltage

- Use of “Higher order laue zone” lines in CBED patterns

Focal Step

- Use translation of HREM images with changes in focus