Transmission Electron Microscopy: An Introduction

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Textbooks

- David B. Williams & Barry C. Carter

"Transmission electron microscopy", Volumes I-IV, Plenum Press, New York, 1996

- Marc De Graef, *"Introduction to Conventional Transmission Electron Microscopy"*, Cambridge University Press, 2003.

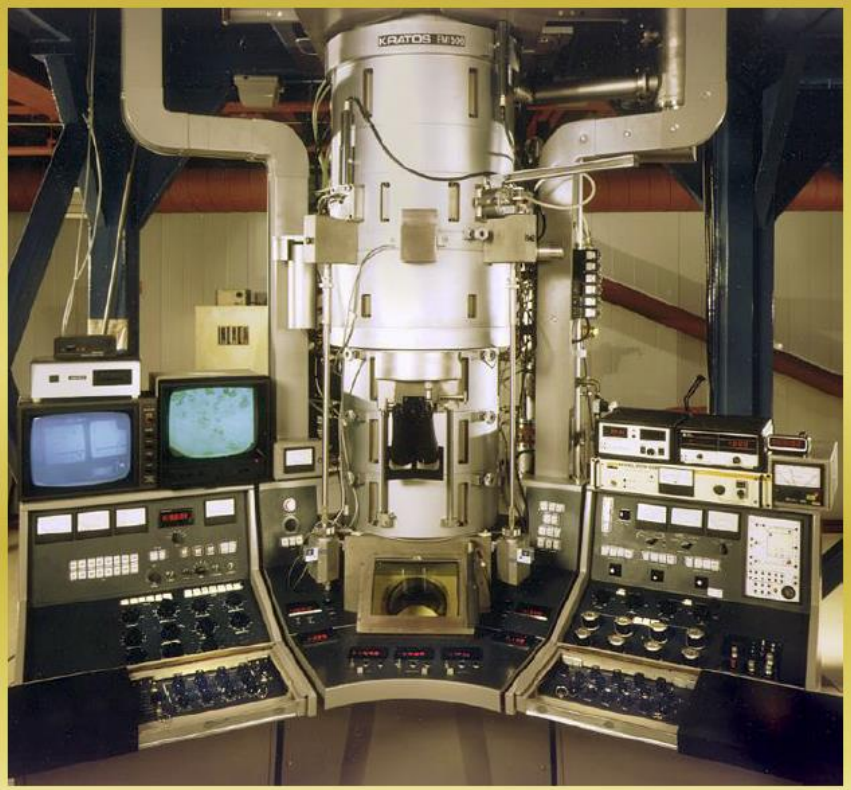
- See also:

http://www.matter.org.uk/tem/default.htm

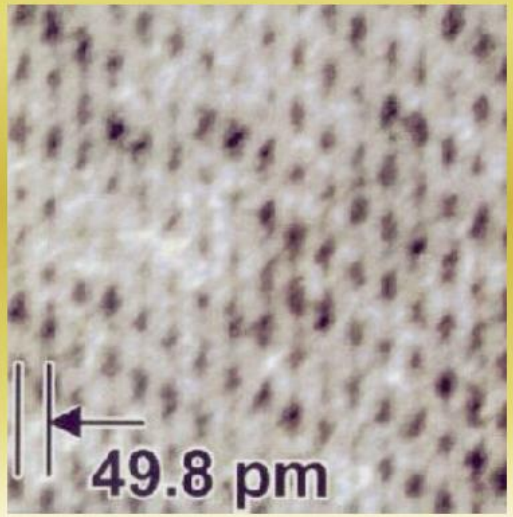
An extremely brief history

- 1925, Louis de Broglie: wave-like characteristics of electrons with λ substantially less than visible light
- 1927, Thompson and Reid: Diffraction experiments
- 1932, Knoll and Ruska (1986 Nobel Prize): Electron lenses idea! Demonstration of electron images!
- 1936: First commercial TEM instrument
- 1939: Siemens & Halske: regular production

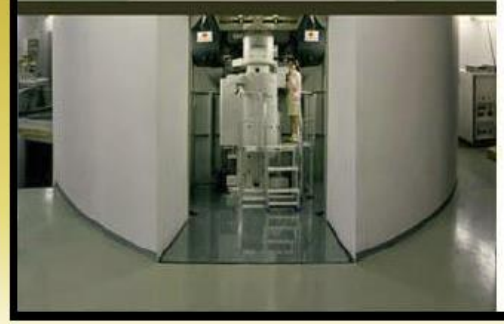
Extreme TEM instruments

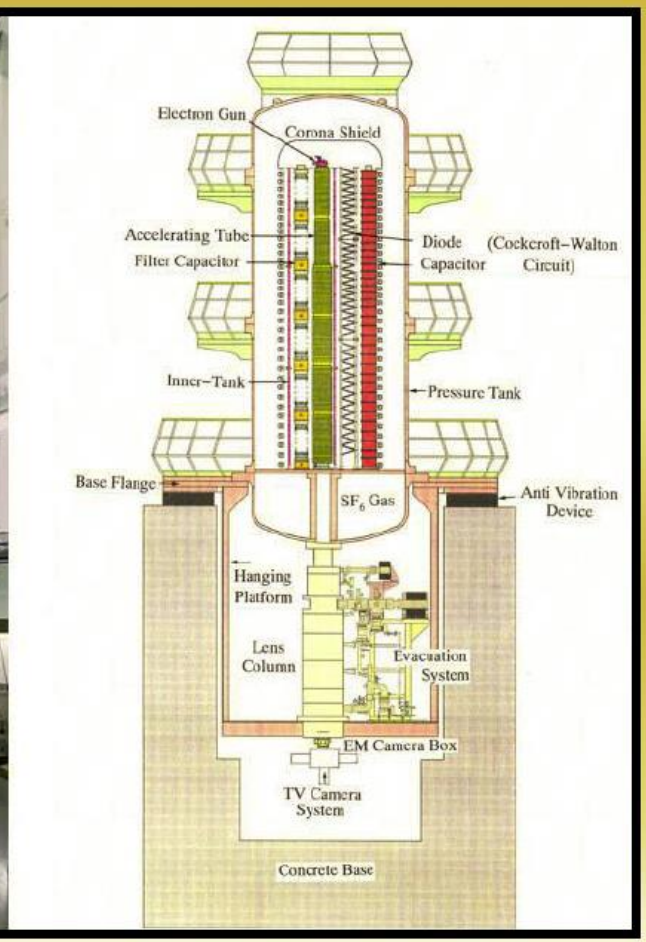


A 1-MeV TEM coupled with a field emission source can achieve resolutions that are in the range of 0.5Å !



Extreme TEM instruments





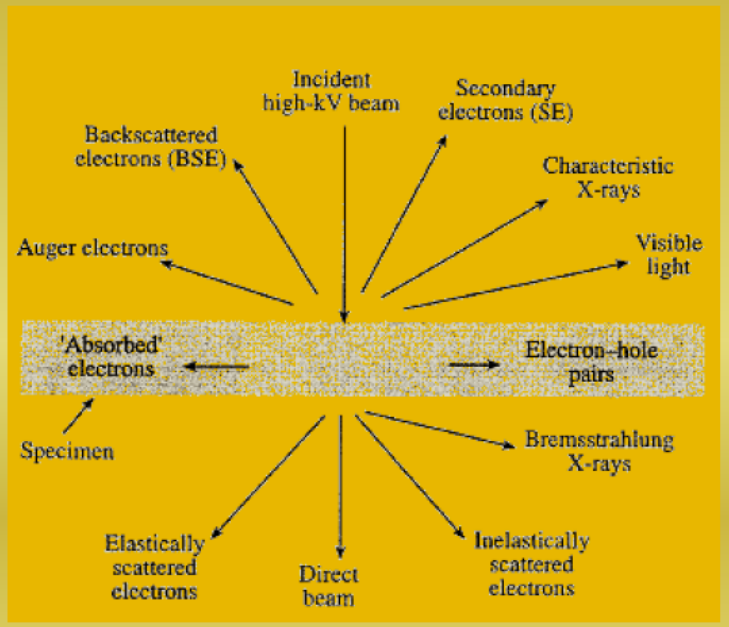
A 3 MeV TEM by Hitachi

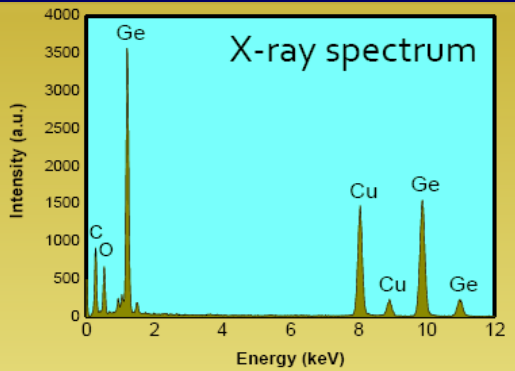
Regular HR-TEM instruments

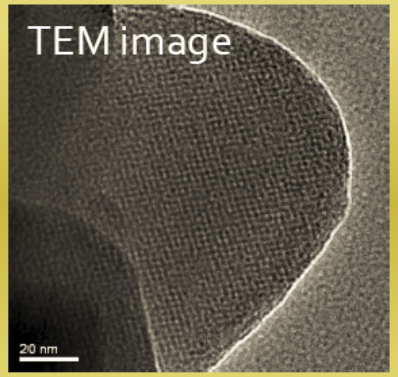
JEOL, JEM-2100 LaB_6

FEI, TITAN 80-300 keV

Interaction of an electron beam with matter



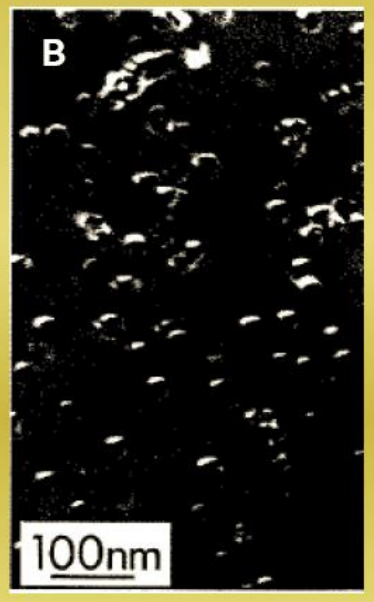




- To get the best signal out we have to put the best signal in (electron source)
- Today TEM form very fine electron beams < 10 nm even < 1 nm in diameter (STEM)

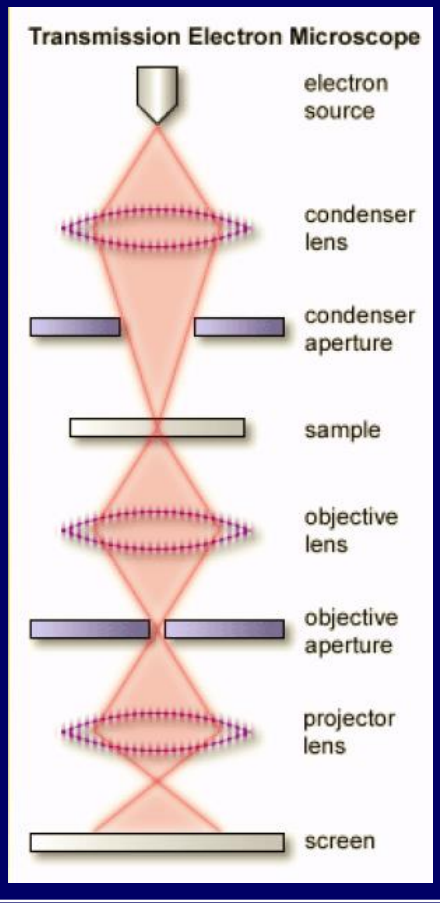
Drawbacks and limitations

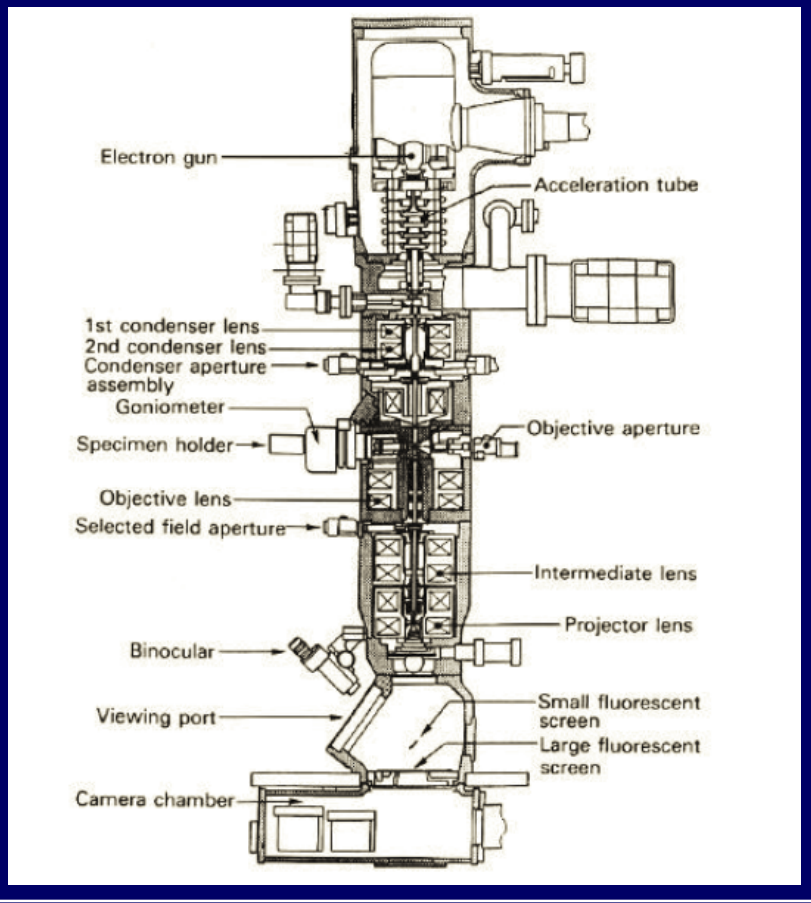
- Limited in a very small area of sample,
  till now ≈ 1 mm² of materials are have been examined !
- Presents 2D images of real 3D specimens, Fig. A



- Beam damage (up to 400 kV), Fig. B
- Thin "electron transpared" specimens are needed for HRTEM
  (usually a sample thickness < 50 nm is essentially)

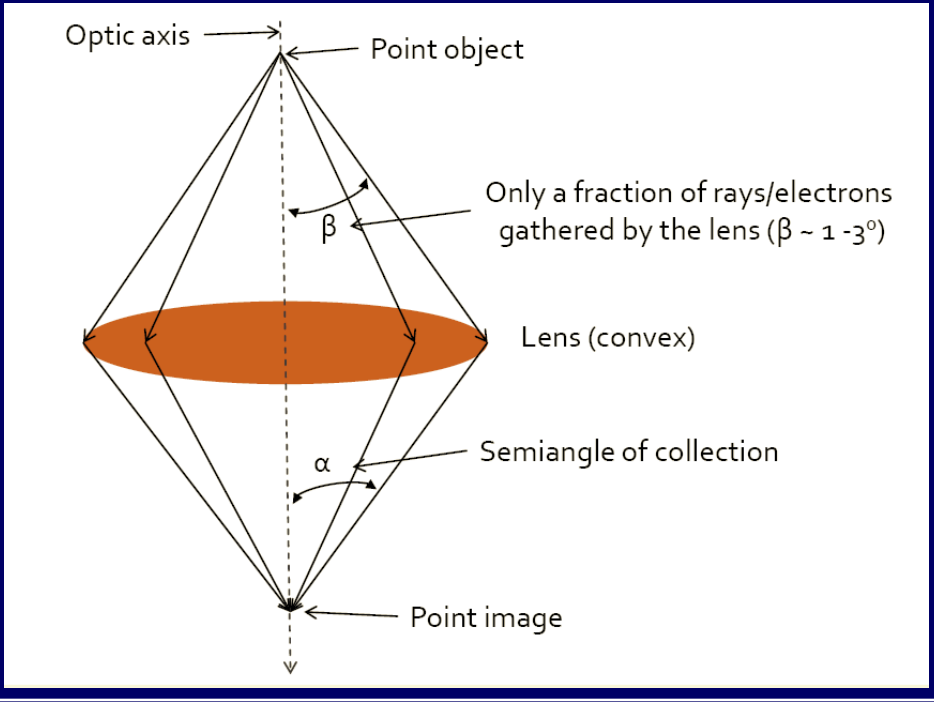
TEM Anatomy


Transmission Electron Microscope
electron source
condenser lens
condenser aperture
sample
objective lens
objective aperture
projector lens
screen

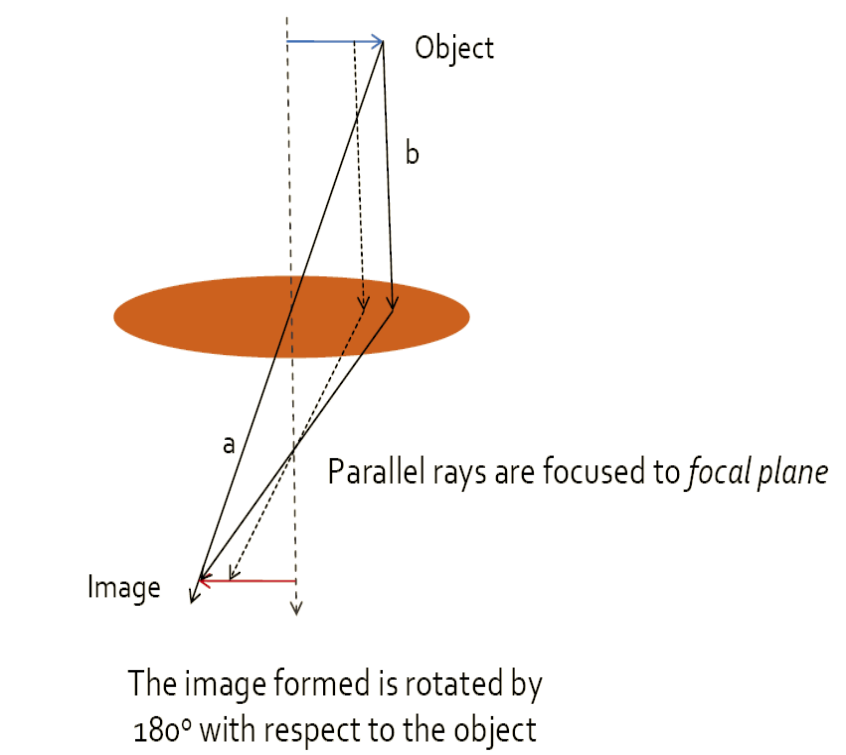

Electron gun
Acceleration tube
1st condenser lens
2nd condenser lens
Condenser aperture assembly
Goniometer
Specimen holder
Objective aperture
Objective lens
Selected field aperture
Intermediate lens
Projector lens
Binocular
Viewing port
Small fluorescent screen
Large fluorescent screen
Camera chamber

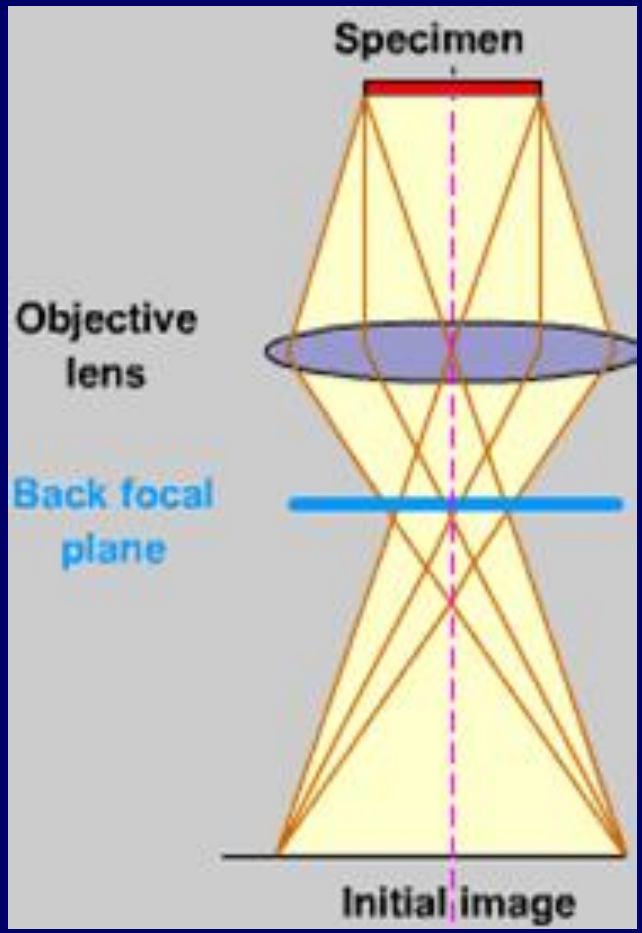
Lenses & Apertures

- The lenses are considered the ***HEART of the TEM*.**
- We are talking about ***magnetic lenses,*** but you may consider these operating as typical magnifying glass (convex lens).



Lenses & Apertures





Lenses & Apertures

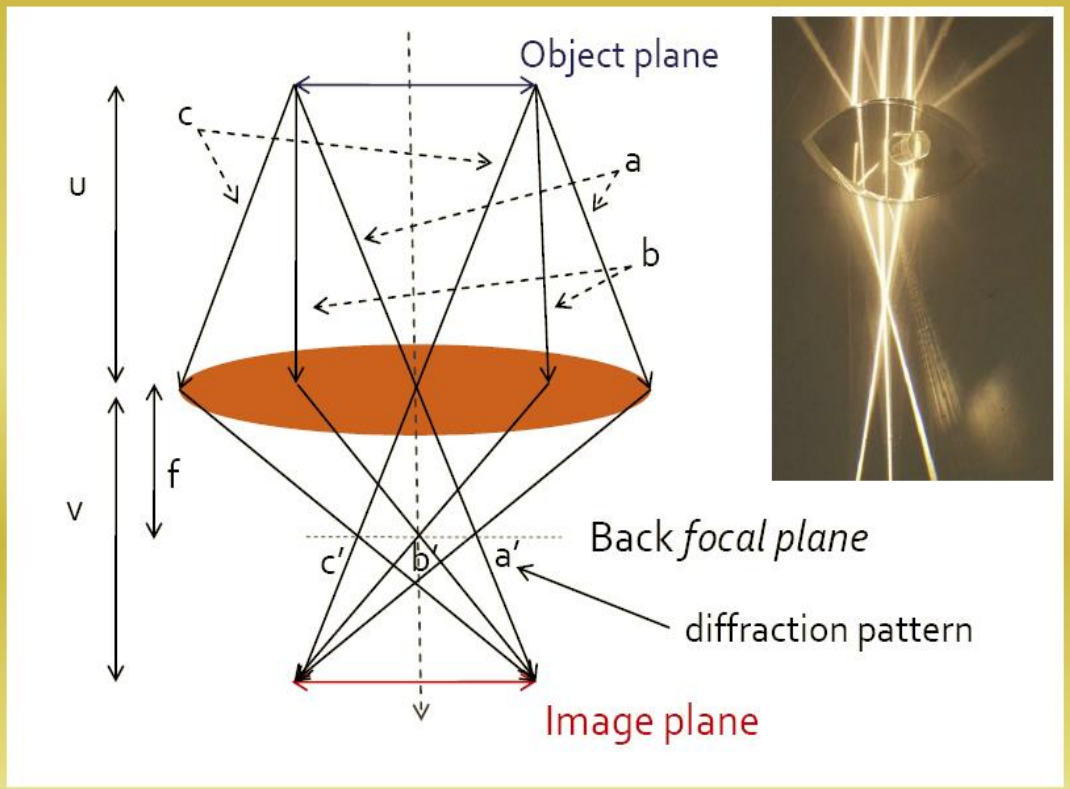
In perfect lenses:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

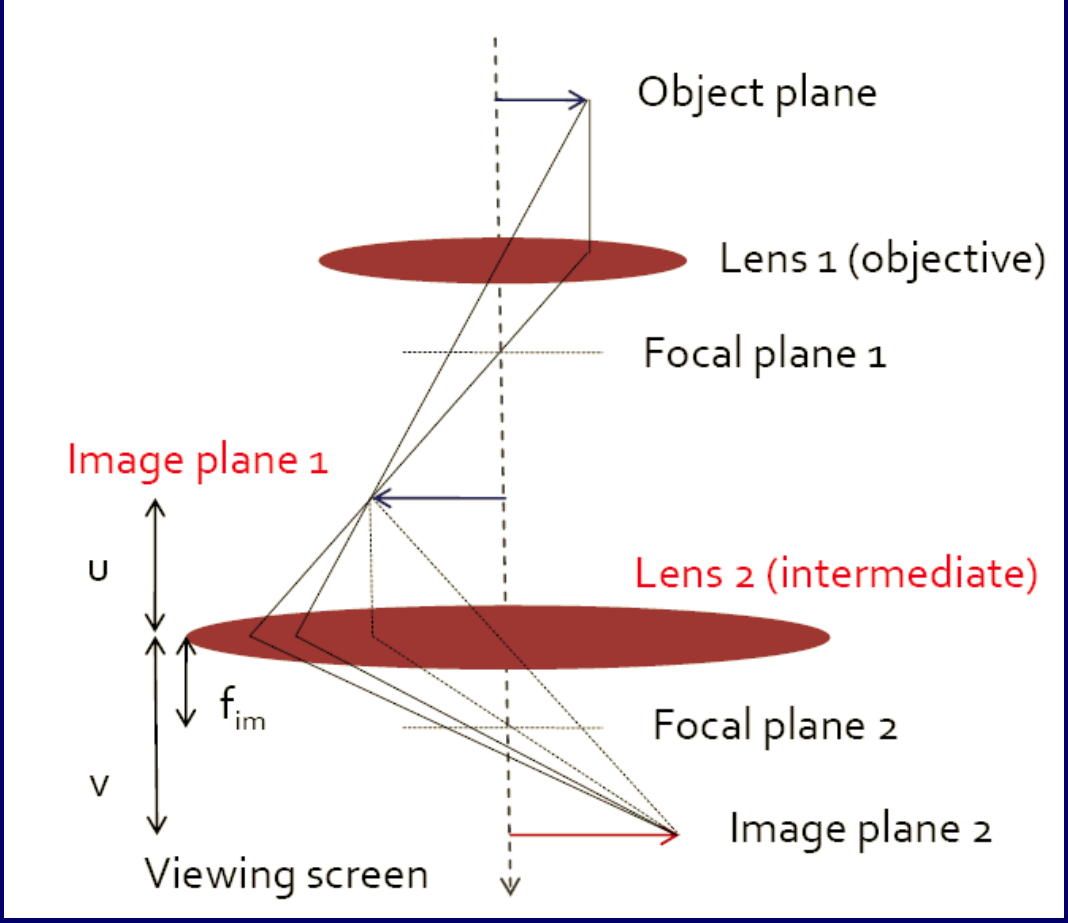
"lens formula"

M = v/u

- if u=f, then v=∞
- if u=v, then u=v=2f
- if u<f, no real image can form



Lenses & Apertures



Multi-lens system

Magnification in TEM

The total magnification in the TEM is a combination of the magnification from the *objective lens* times the magnification of the *intermediate lens* times the magnification of the *projector lens*.

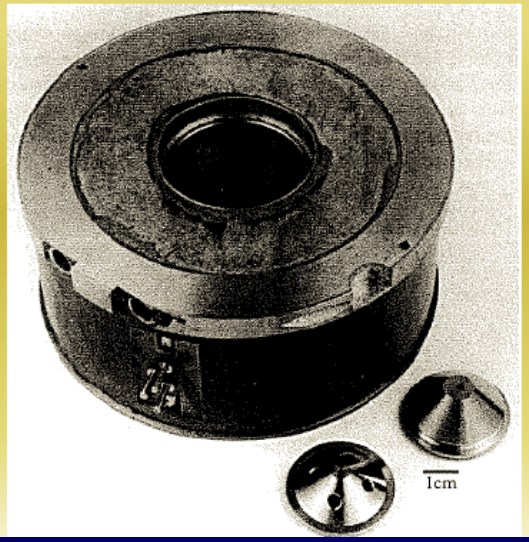
Total Mag. = M_{ob} x M_{int} x M_{proj}

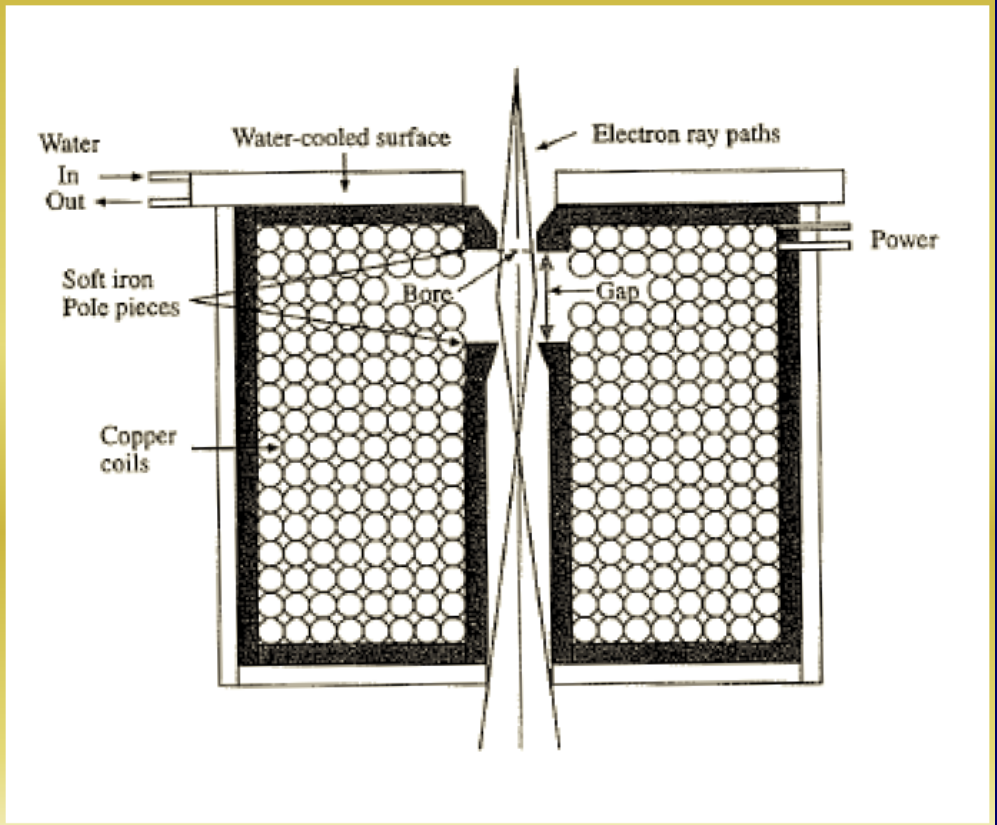
(M_{ob} = 50, M_{int} = 16, M_{proj} = 250; M_{total} = 200.000)

A example of a real lens

Characteristics of electron lens:

- Length of the lens
- The bore/gap ratio
- Strength of the field/current





Further reading…….

- A proper ***alignment*** is very important before any TEM work is to be conducted.
- ***Sample preparation*** for TEM work is of paramount importance. Different samples require very different preparation procedures.
- Remember: TEM is a versatile, integrated instrument suitable for ***imaging, diffraction and spectroscopy studies*** at the atomic scale.