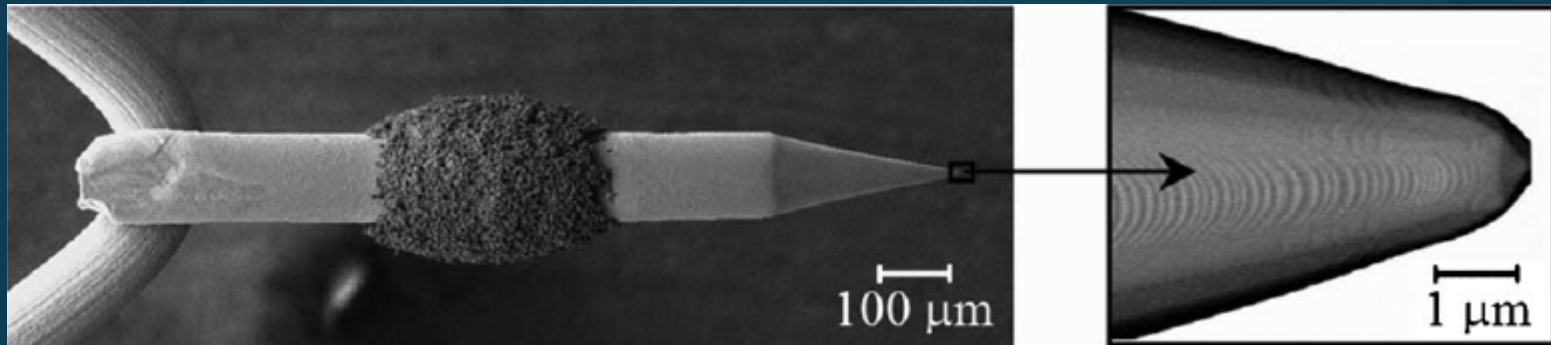


Microscope hardware and design



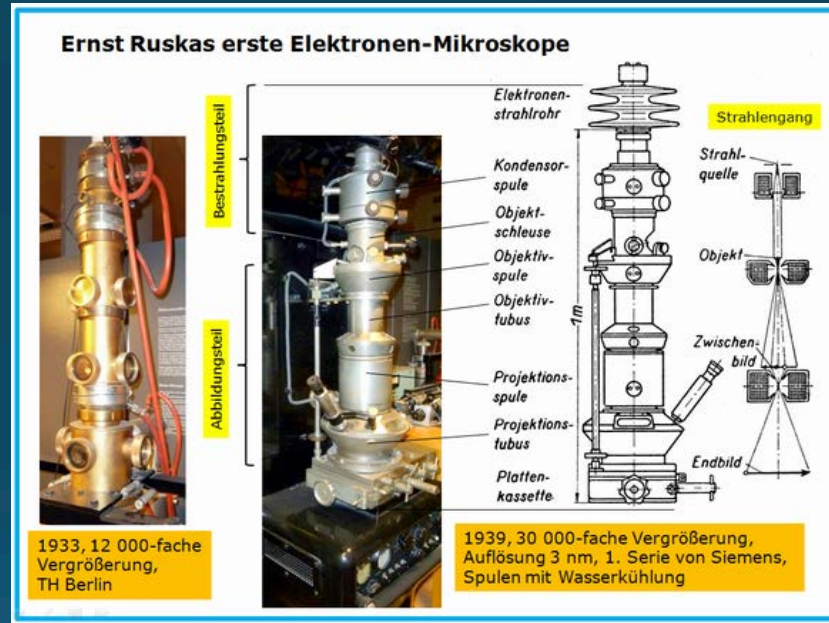
Eric van Genderen
Paul Scherrer Institut – Villigen – Switzerland
Eric.van-genderen@psi.ch

A brief history of hardware



Anton van Leeuwenhoek / Delft
(1632-1723)

A brief history of hardware

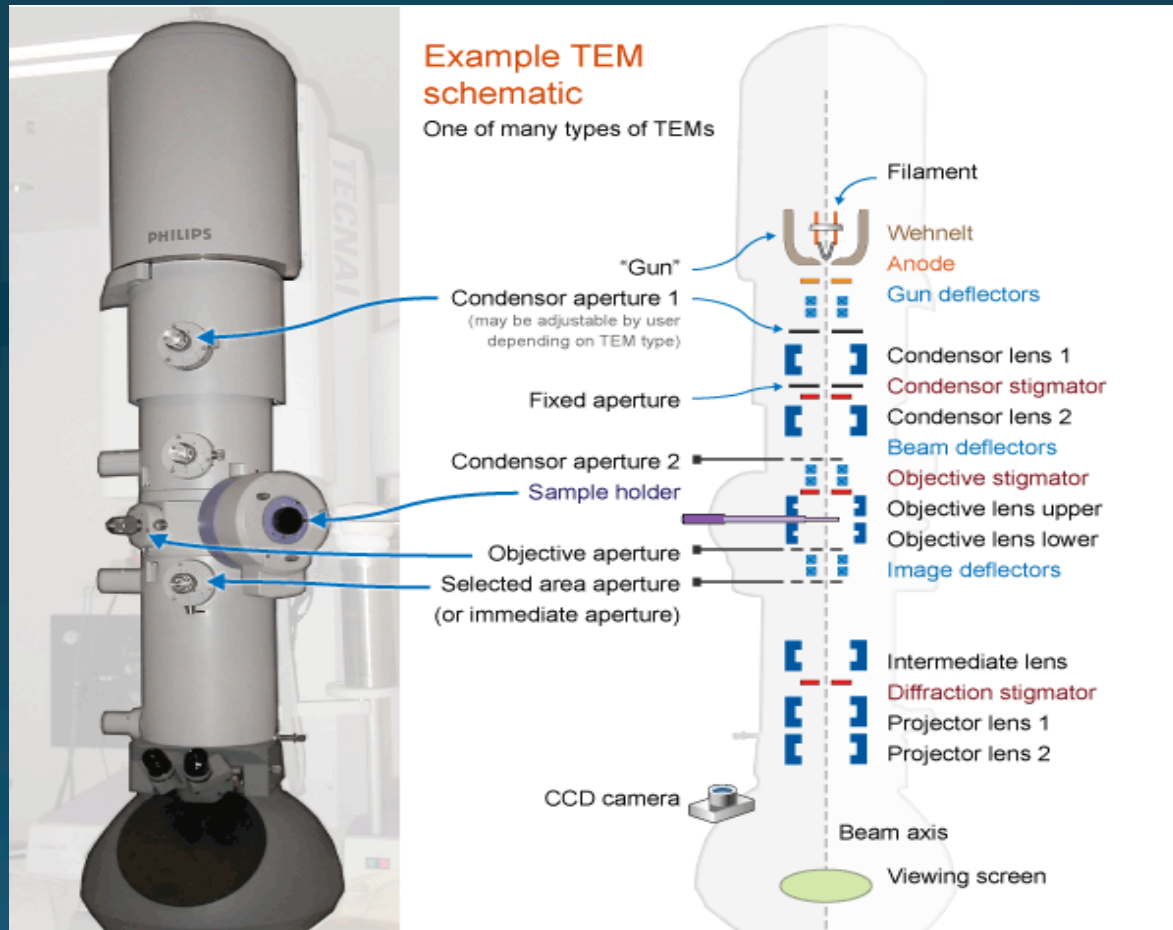


Ernst August Friedrich Ruska (1906 –1988)

A brief history of hardware



The microscope



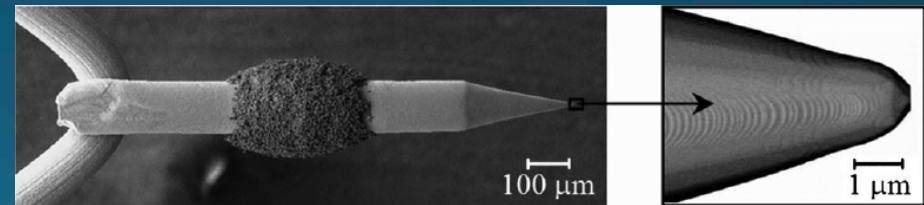
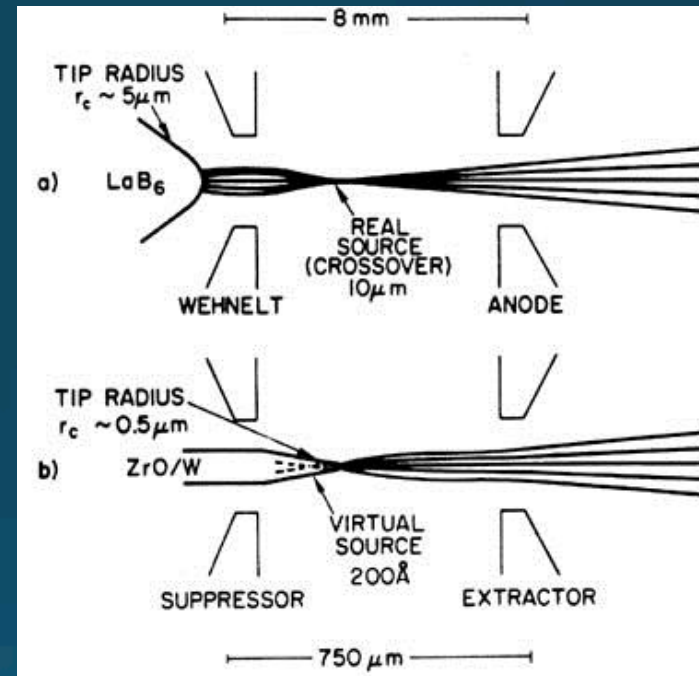
The electron source

- 2 types of sources
- Thermionic electron Gun
 - Lab6 crystal
 - Tungsten (W) – wire

Cheap (hardly ever used anymore)

- Field Emission Gun (FEG)
 - Single tungsten crystal combined with a ZrO material

Can create a smaller spot and high current densities, highly monochromatic

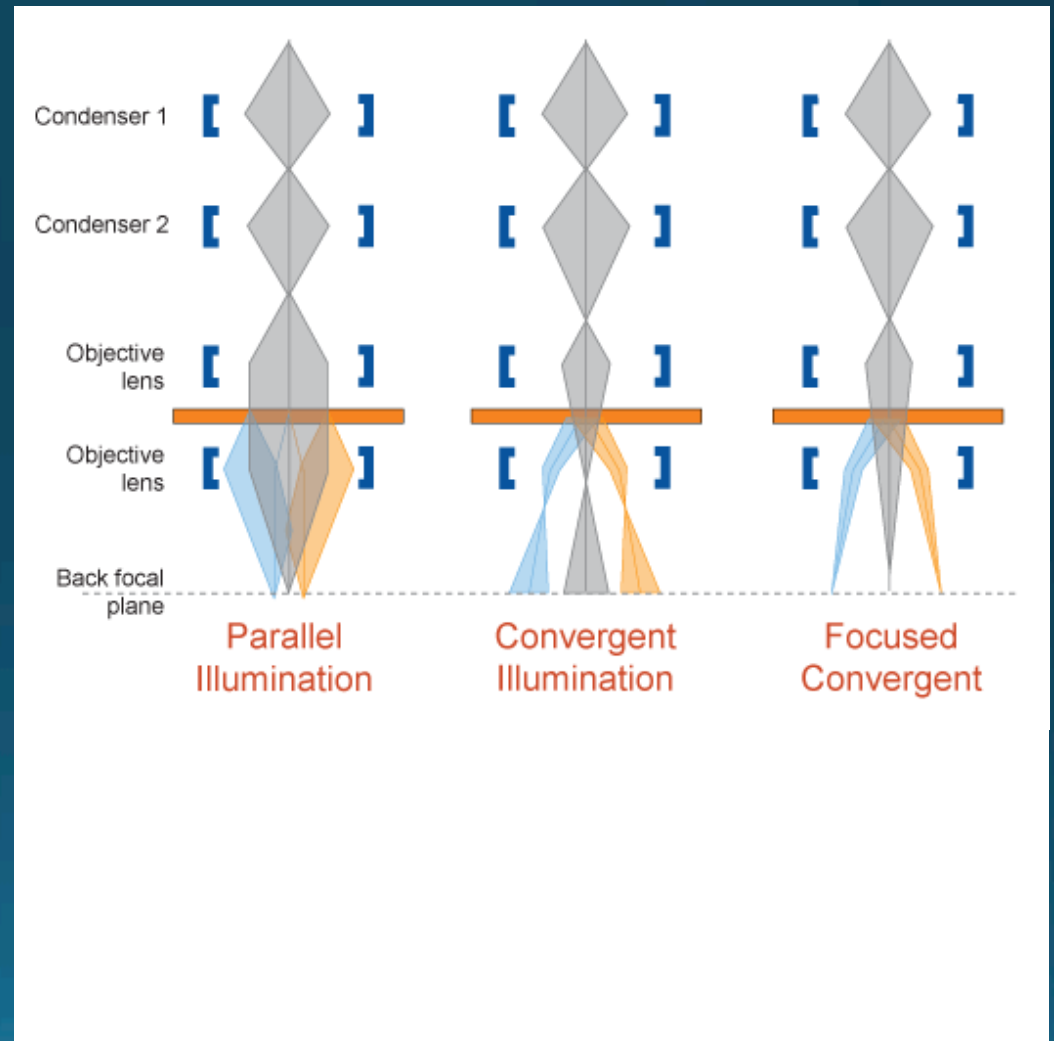
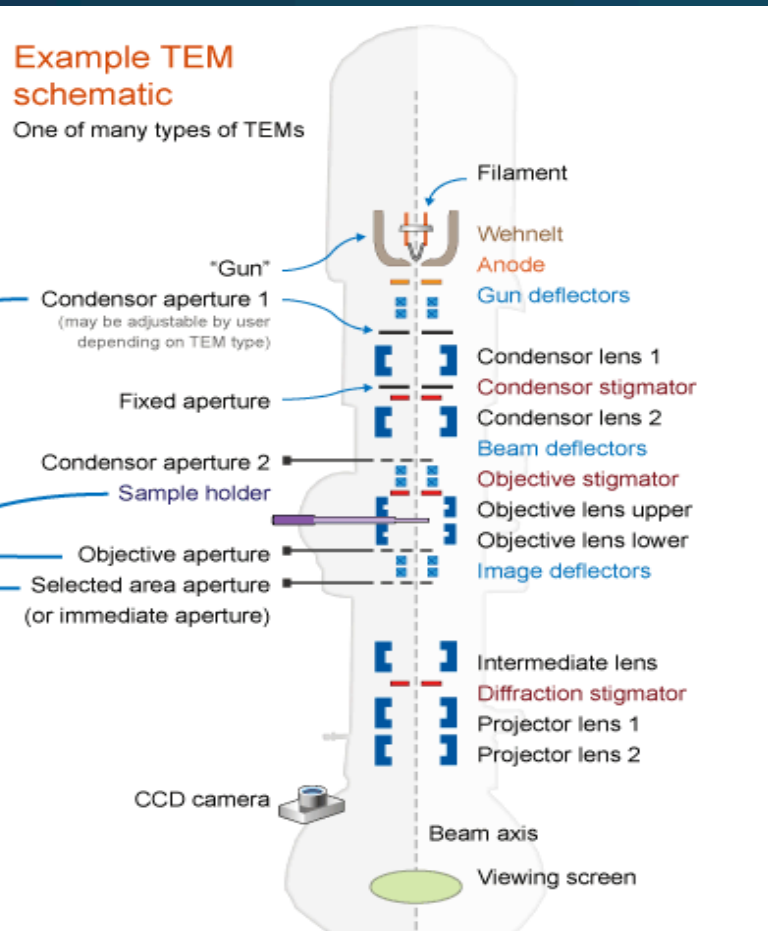


Sources

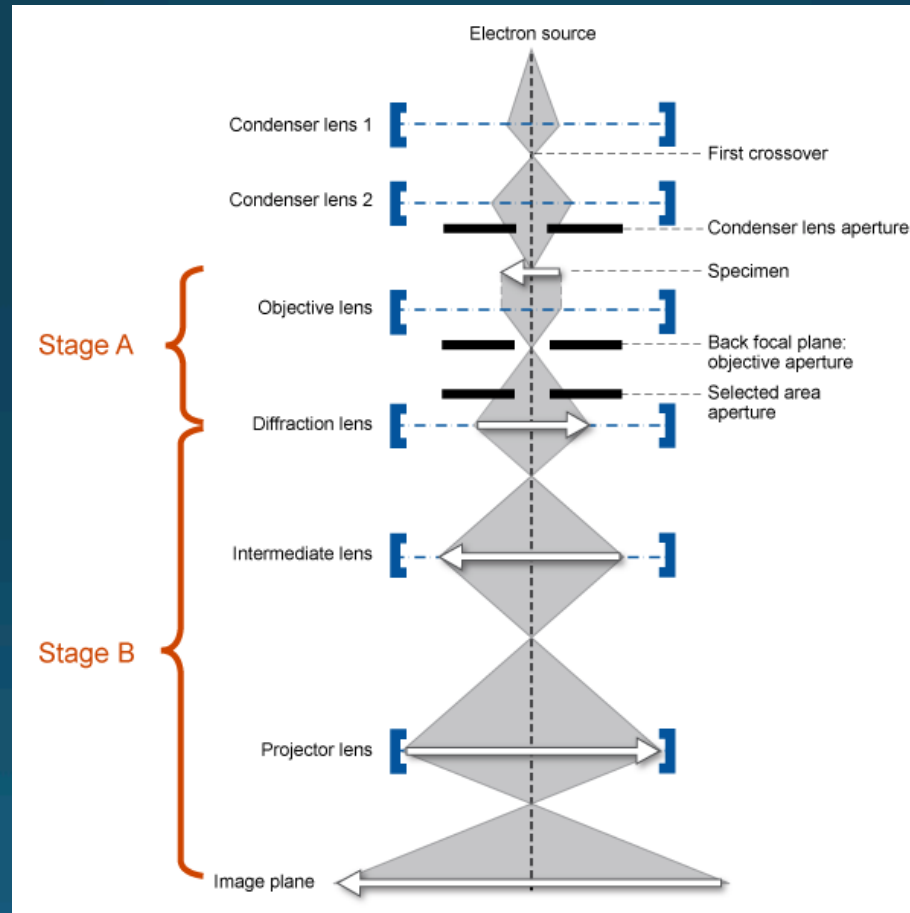
- Electrons leave guns with energy spread
 - Cathode type dependend
- Tungsten wire guns (energy spread 1.5-2.5eV)
- FEG energy spread (energy spread 0.3-0.8 eV)

- IMPORTANT because lens focus varies with energy
 - Chromatic aberration
 - Hurts when trying to get high resolution images

Illumination lens system

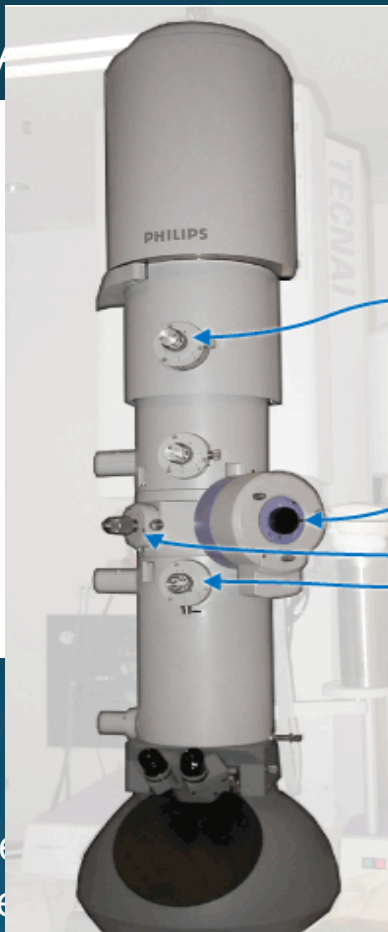
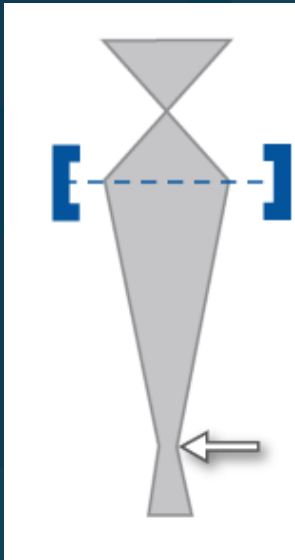


The projection lens system



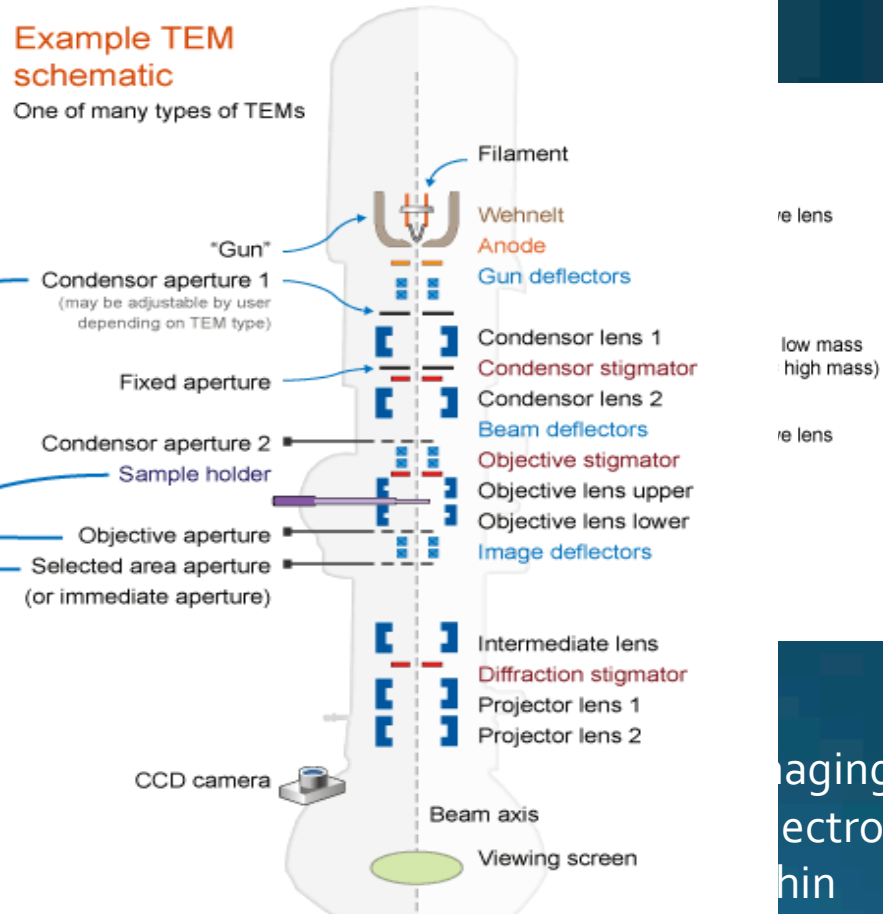
The role of apertures

Condensor A



Example TEM schematic

One of many types of TEMs



Role:

- reduce the divergence of the beam
- produce a parallel beam
- minimize lens aberrations

re lens

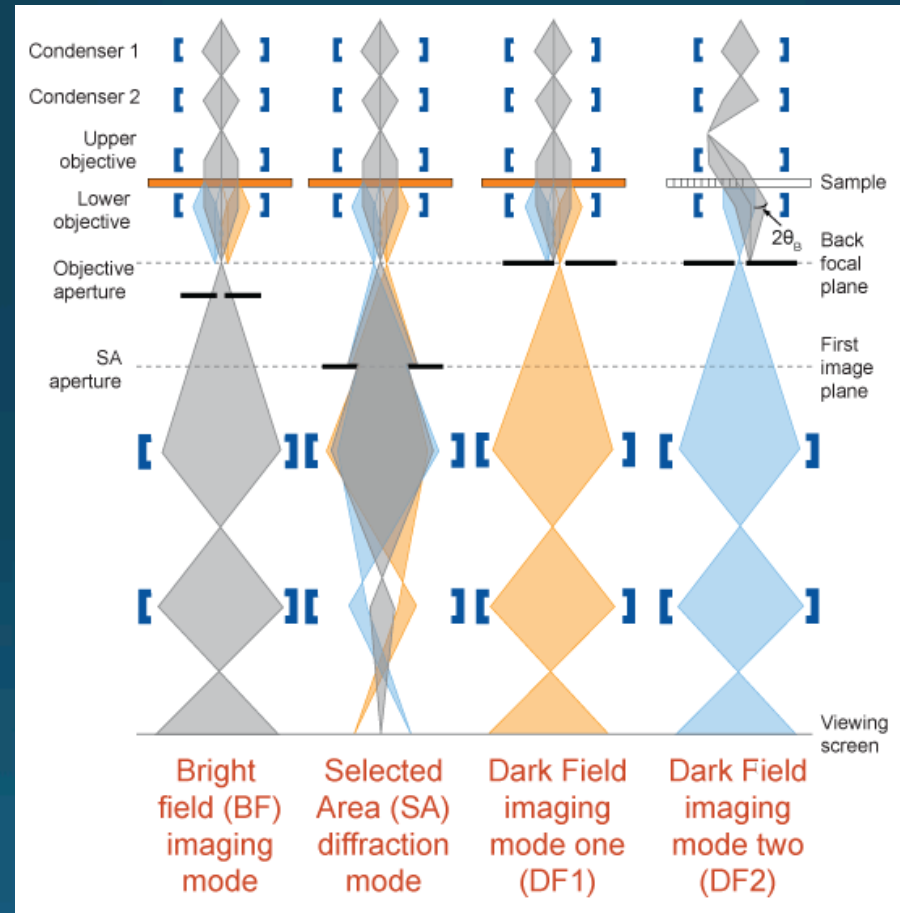
low mass
high mass)

re lens

aging by
electrons
thin

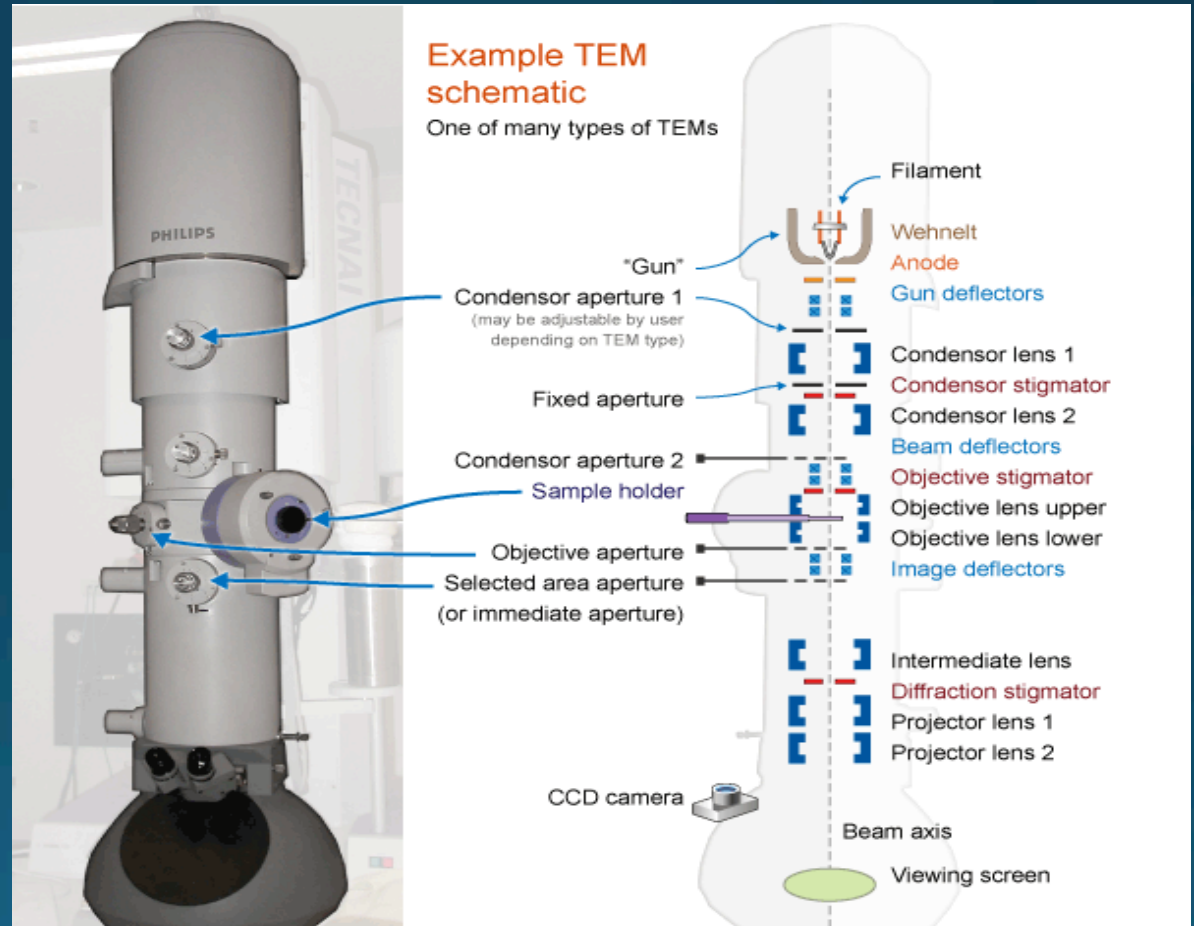
materials

Different operation modes and their apertures



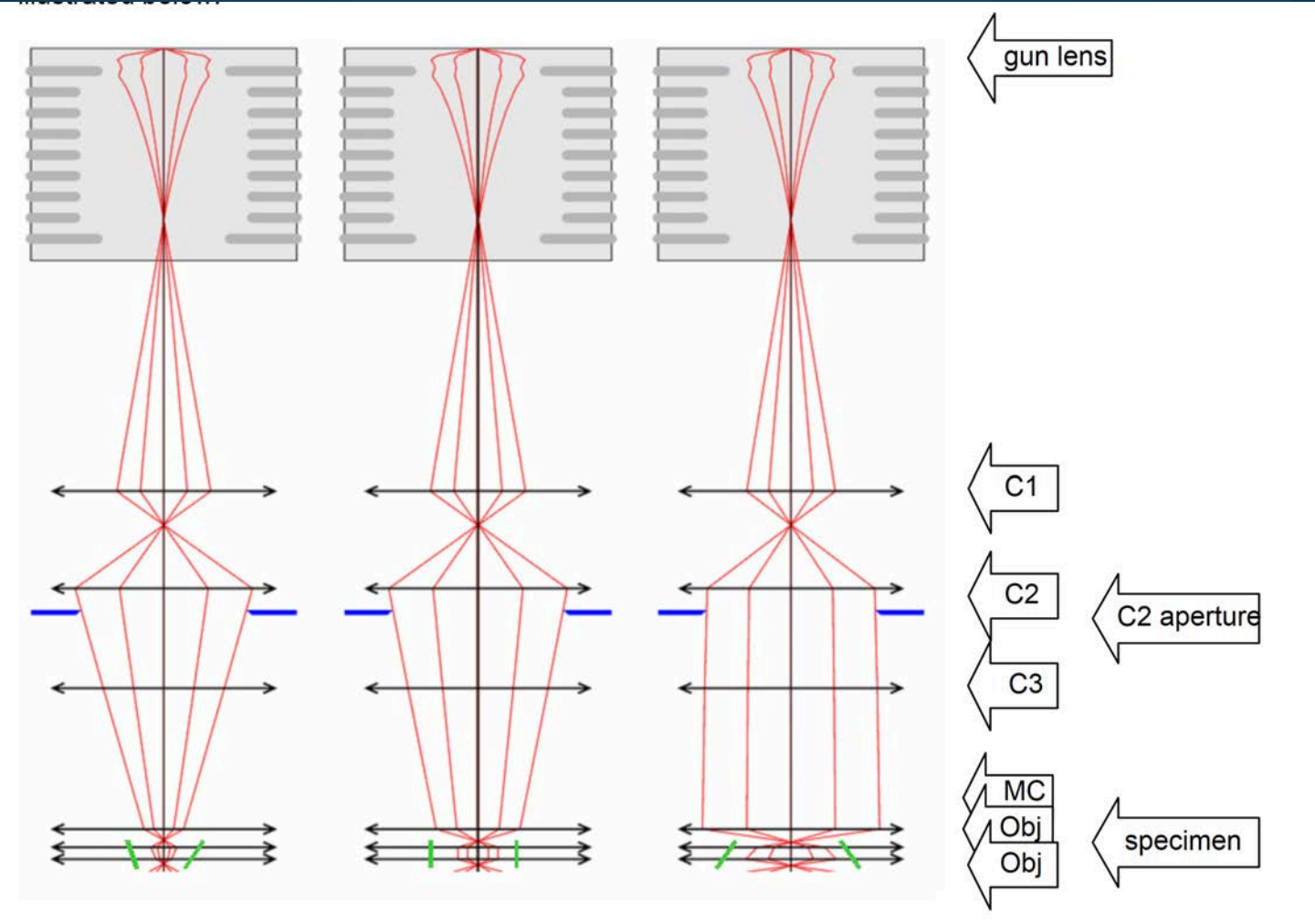
Special lenses

- C₃ lens
- Stigmators
- Cs correctors
- Energy filtering



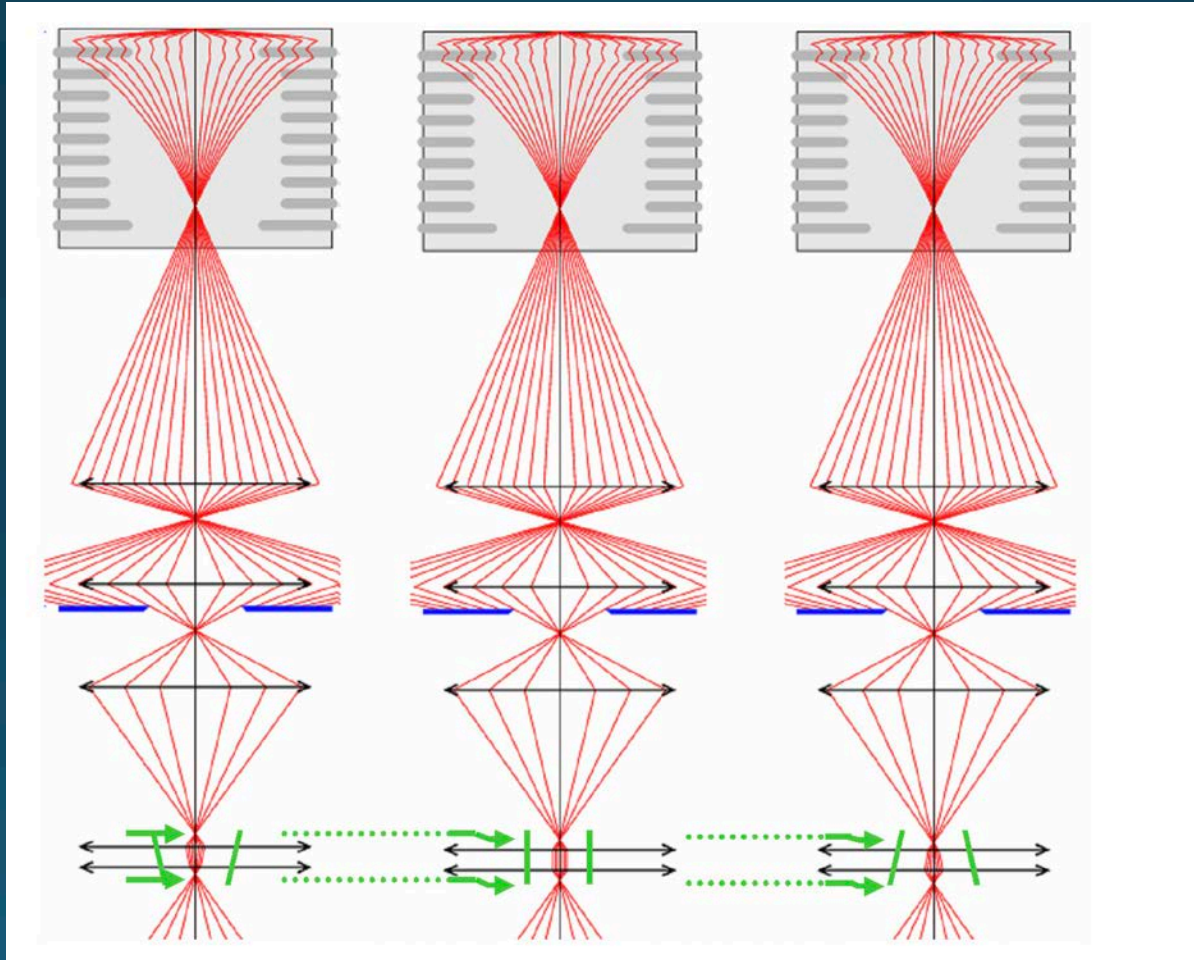
Special lenses – C₃ lens

Without C₃ lens



Special lenses – C₃ lens

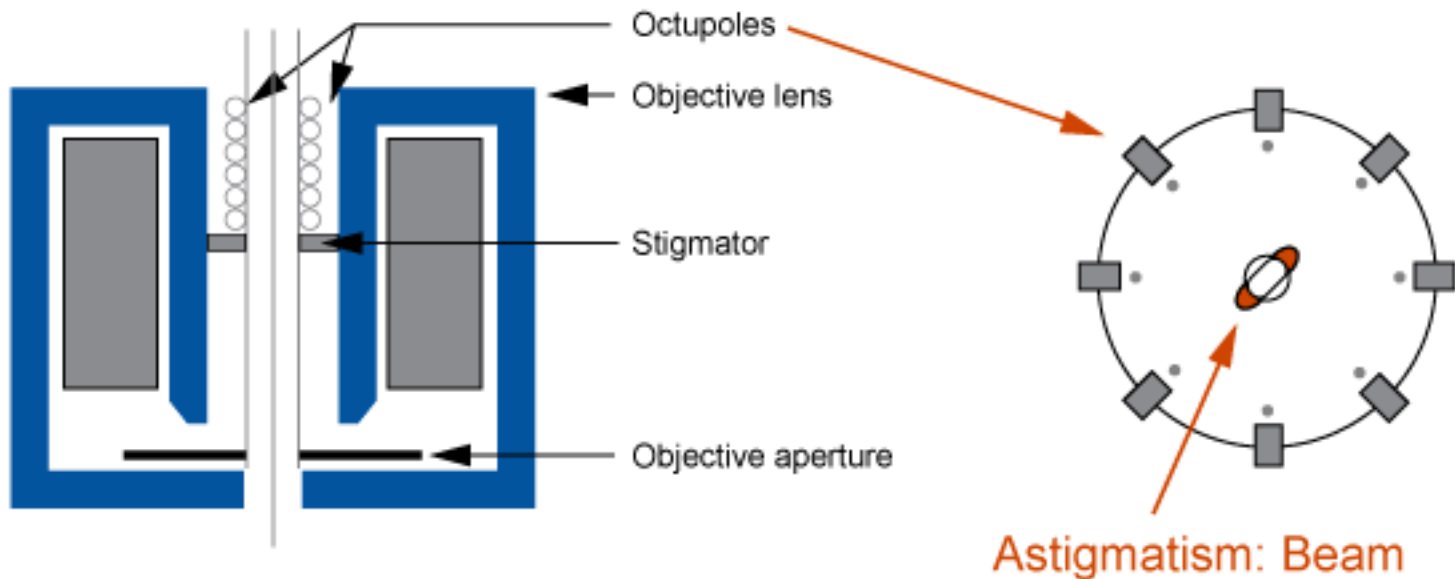
With C₃ lens



Special lenses – Stigmators

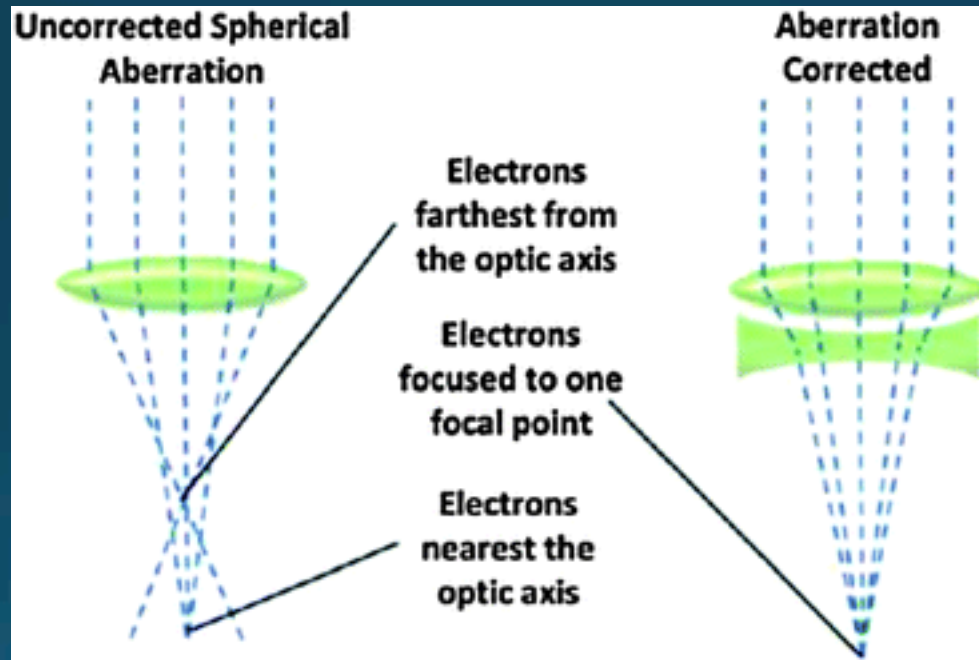
- Condensor
- Objective
- Diffraction

Astigmatism: Non-spherical electron beam

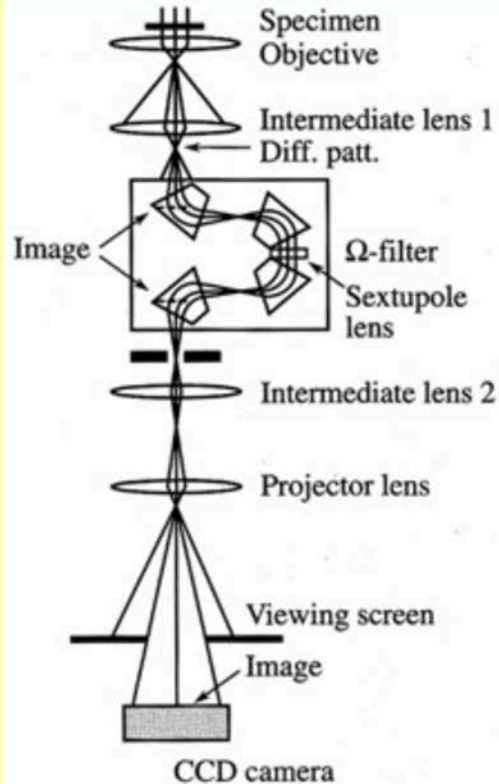


Special lenses – Cs-corrector

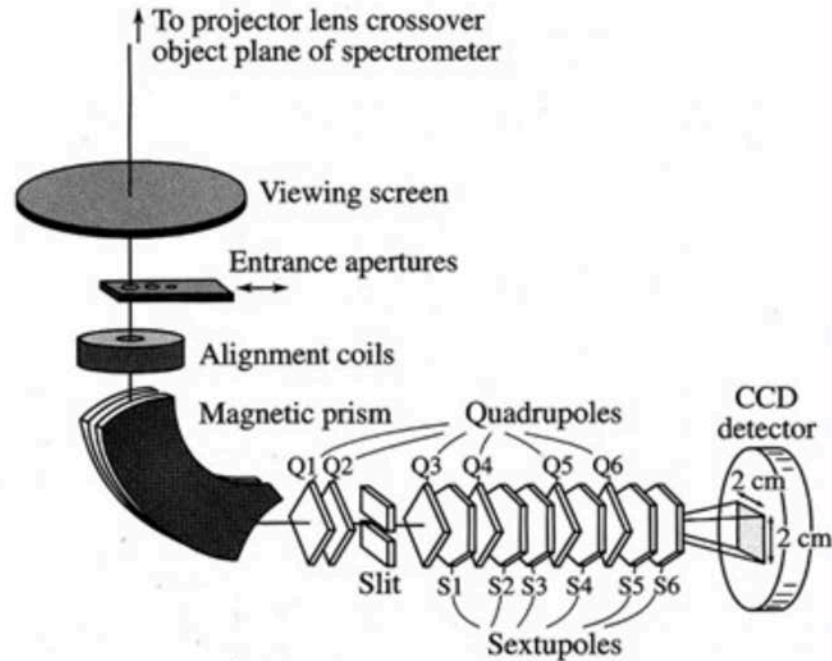
With C_3 lens, corrects spherical aberration



Energy filtering in TEM



Omega Filter



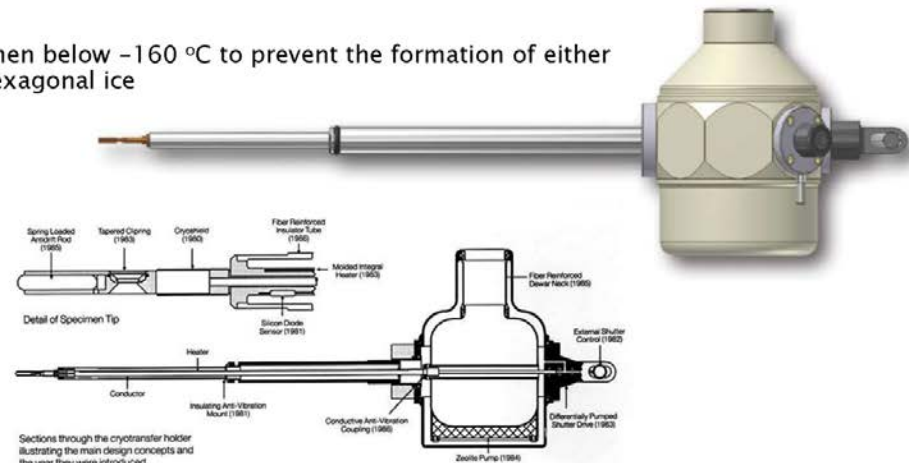
Gatan Imaging Filter (GIF)

Sample holders

- Multi-grid
 - Automated (Titan)
 - Manual (Polara)
- Single-tilt

CRYO HOLDER

- Keep specimen below $-160\text{ }^{\circ}\text{C}$ to prevent the formation of either cubic- or hexagonal ice

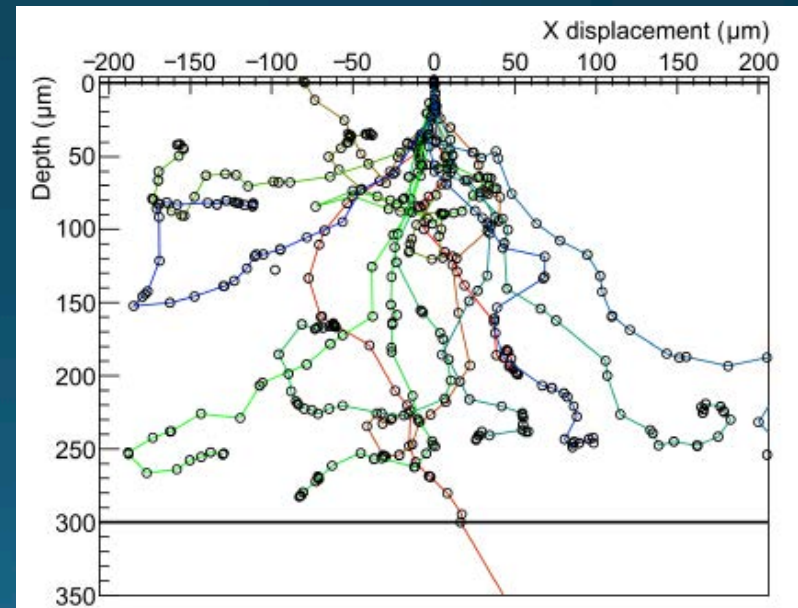


臺大貴重儀器中心

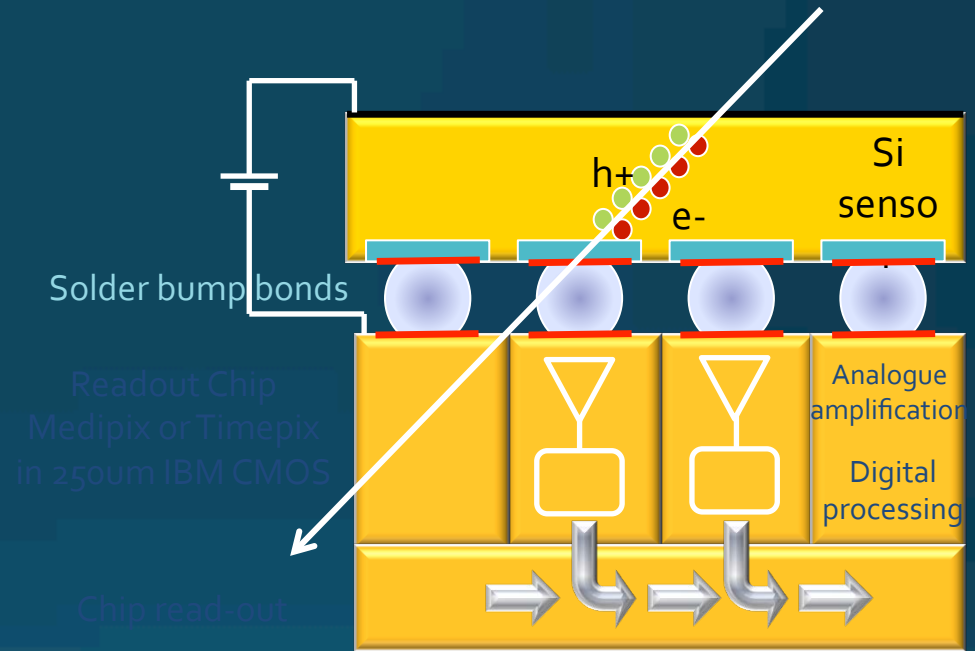
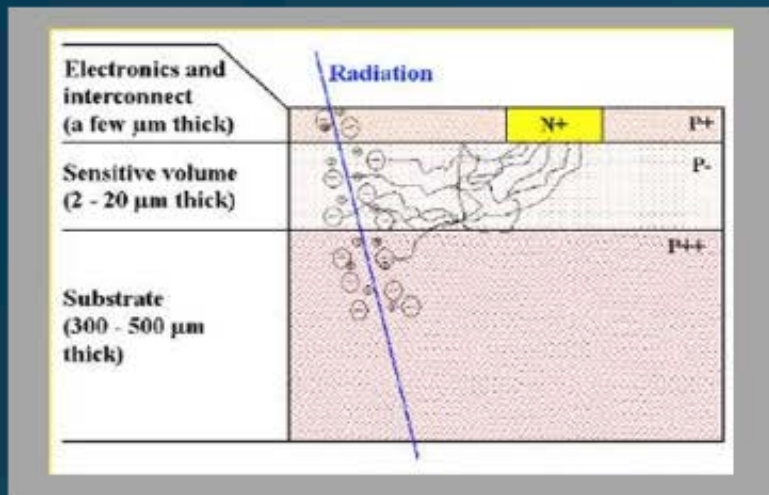
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Detectors

- Fluor screen
- CCD camera
 - Diffraction & imaging
- Direct detection camera's
 - Imaging
 - Gatan K2 & Fei Falcon series
 - High energy electrons needed
- Quantum counting detectors
 - Diffraction
 - Very radiation hard
 - Big pixels
 - For imaging low energy is better
 - Medipix and Eiger (Dectris)



Direct Electron Detectors



Monolithic direct electron detector:

- damage prone
- Small point spread
- Low dynamic range

Ideal for imaging

Hybrid pixel detector:

- radiation hard
- Larger point spread
- High dynamic range

Ideal for diffraction

Detectors – a new era



| | Radiation hard | High contrast | Low noise | Speed |
|-------------------|----------------|---------------|-----------|--------------|
| CCD | Y | Y/N | N | 1-30 fps |
| Direct detection | N | N | Y | 0.1-10 fps |
| Quantum detection | Y | Y | Y | 100-1000 fps |

Questions