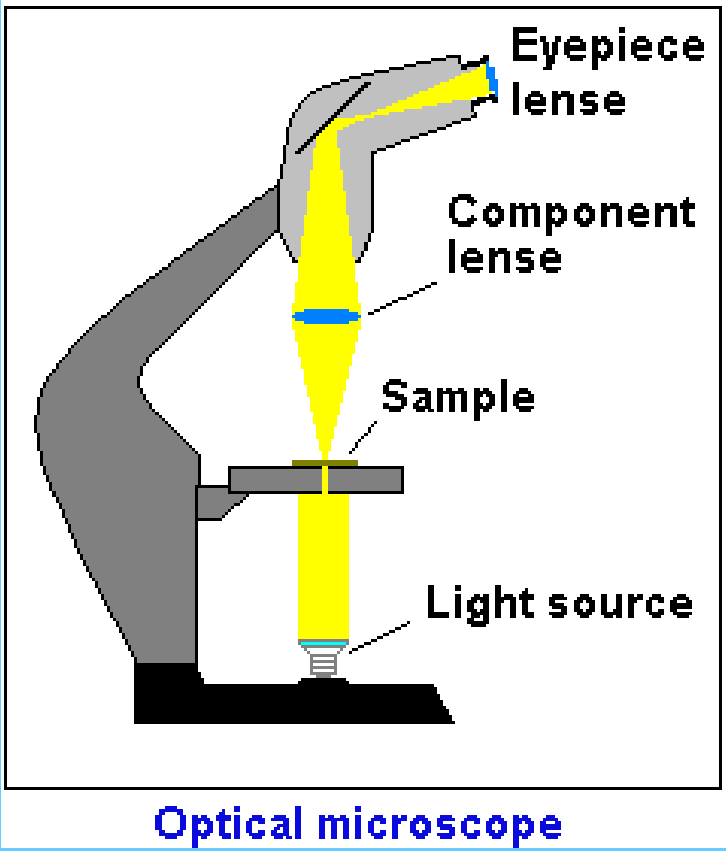
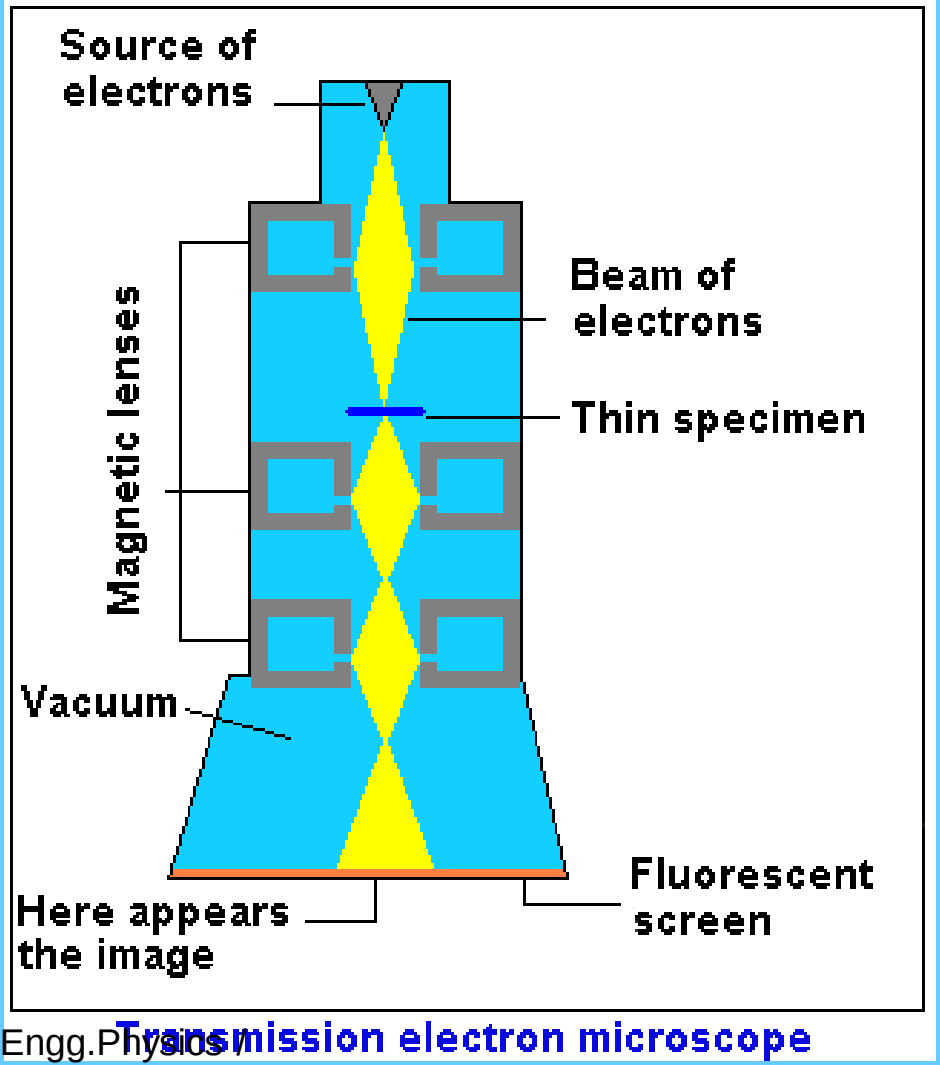
Diffraction in the Transmission Electron Microscope

TEM- What is it?



Optical microscope



Transmission electron microscope

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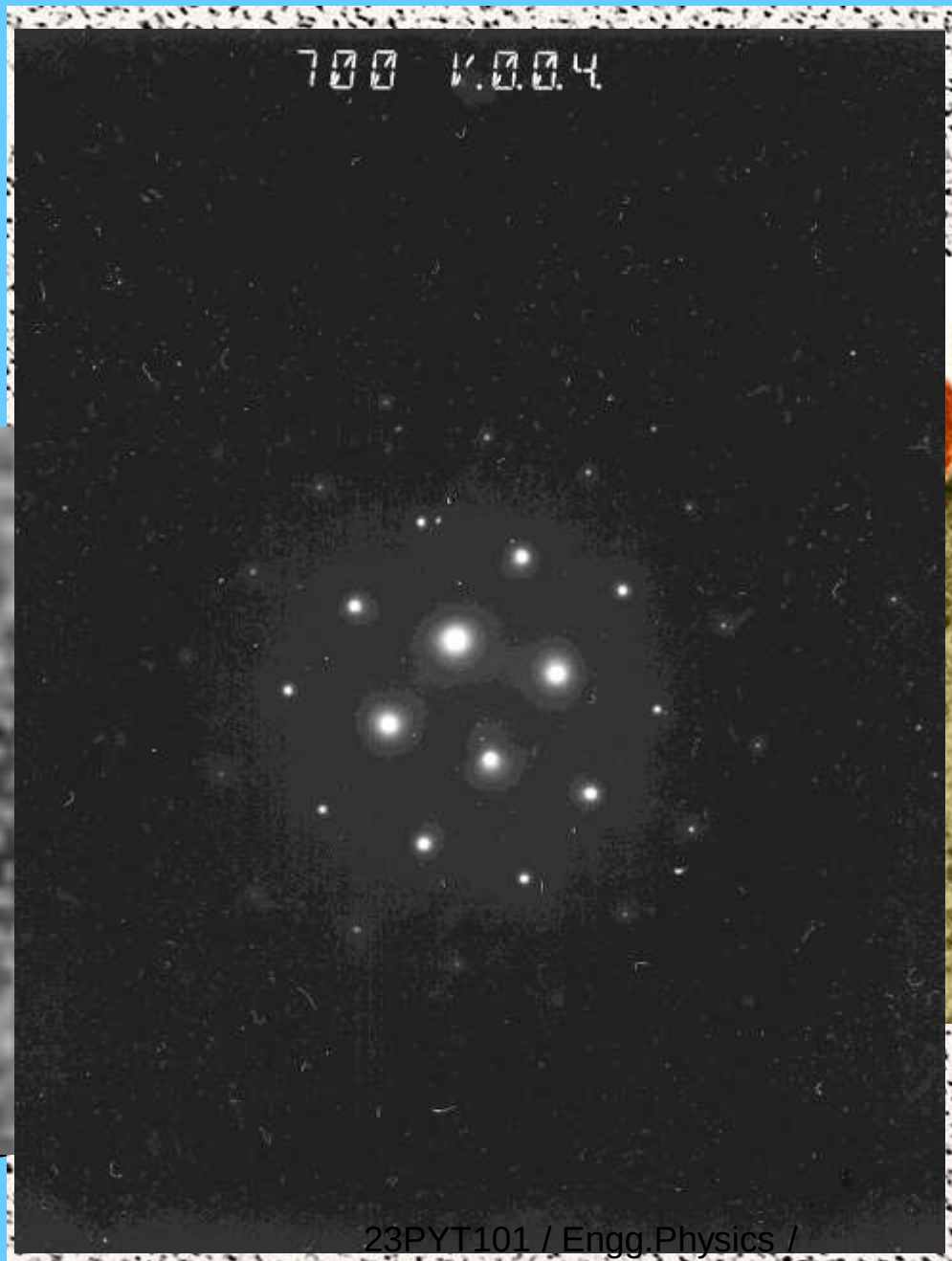

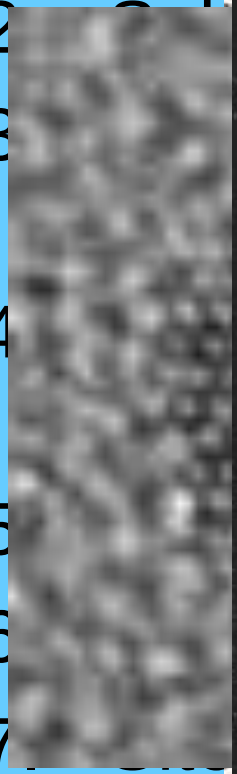

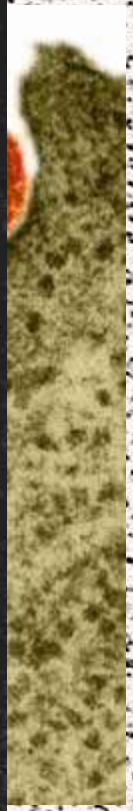

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Disadvantages of TEM

1. Sample size
2. Preparation
3. Instrument issues
4. Operation
5. Interpretation

Wavelength of electrons

Wavelength – magnification

$q*U = \frac{1}{2} mv^2, \quad \lambda = h/(m * v)$

where:

λ = wavelength

h = Planck's constant (6.6×10^{-27})

m = mass of the electron (9.1×10^{-28})

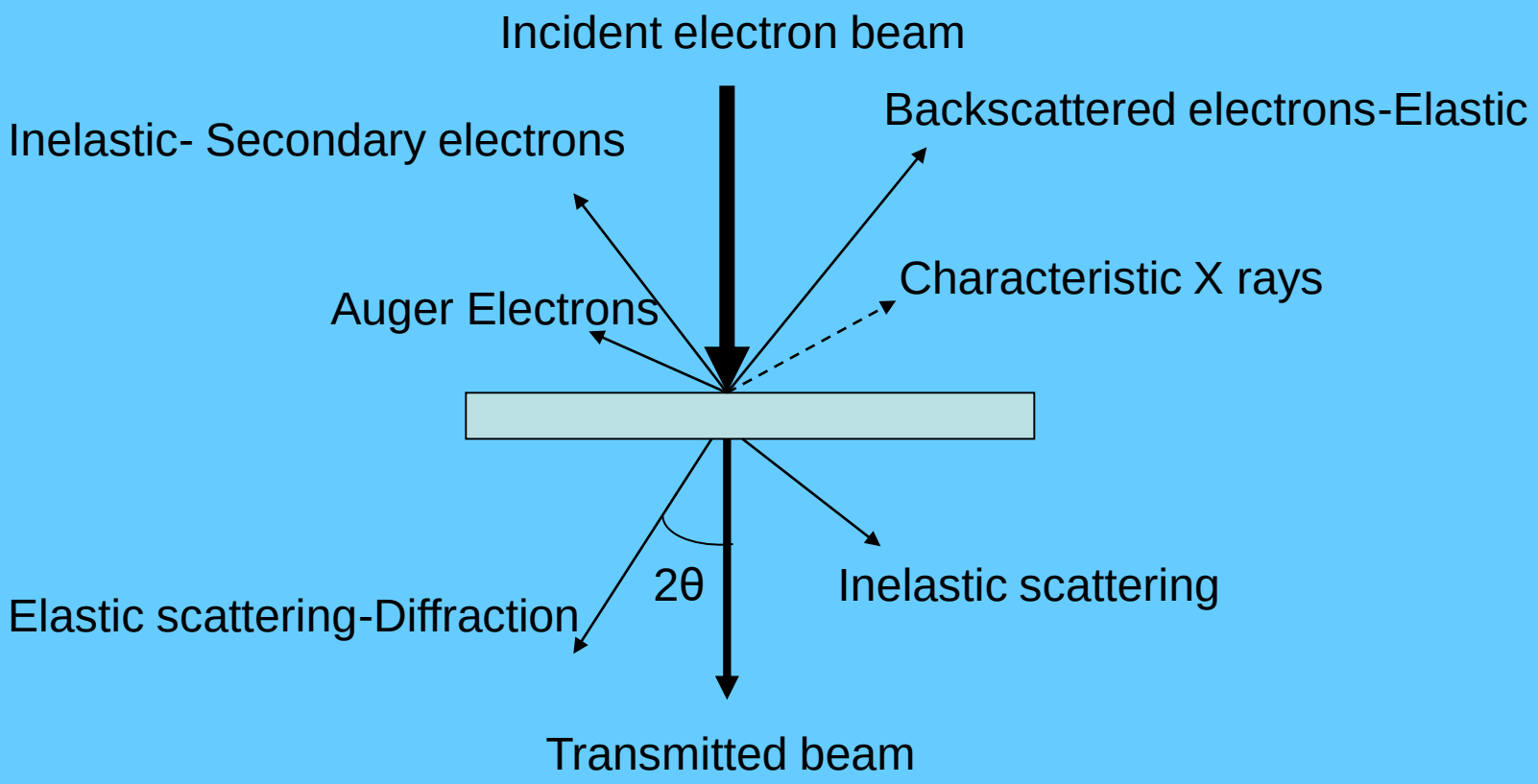
v = velocity of the electron

U = Potential drop

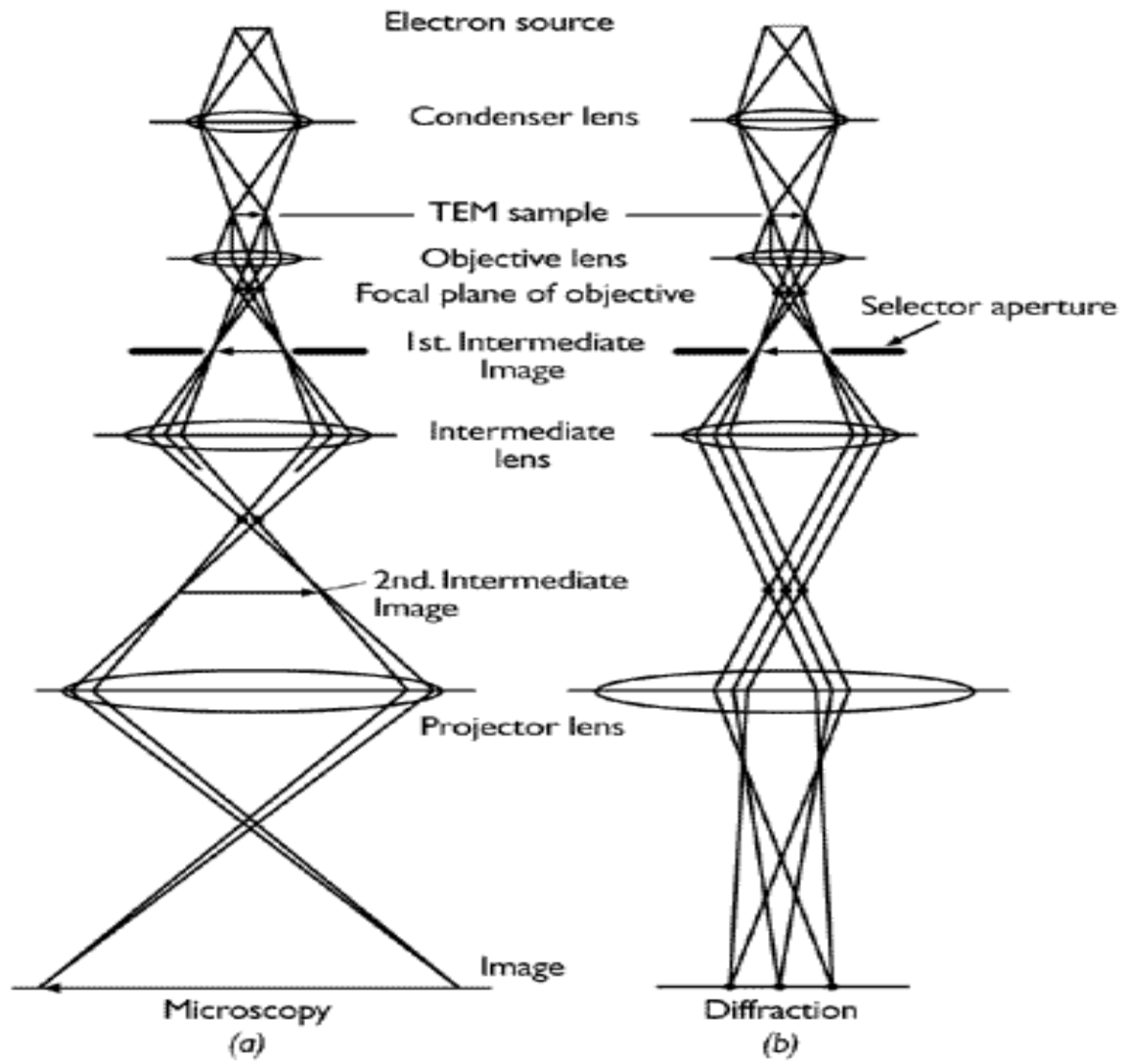
$\lambda = (1.23 \text{ nm})/ U^{1/2}$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_0 eU + \left(\frac{eU}{c}\right)^2}}$$

Electron Sample Interaction



Optics of the TEM



- Gun
- Lenses
  - Focal length
- Apertures
- Screen

Image Contrast in TEM

- Thickness
- Composition
  - Atomic num
- Diffraction (o
- Strain fields
- Fringe Effect

Diffraction in TEM

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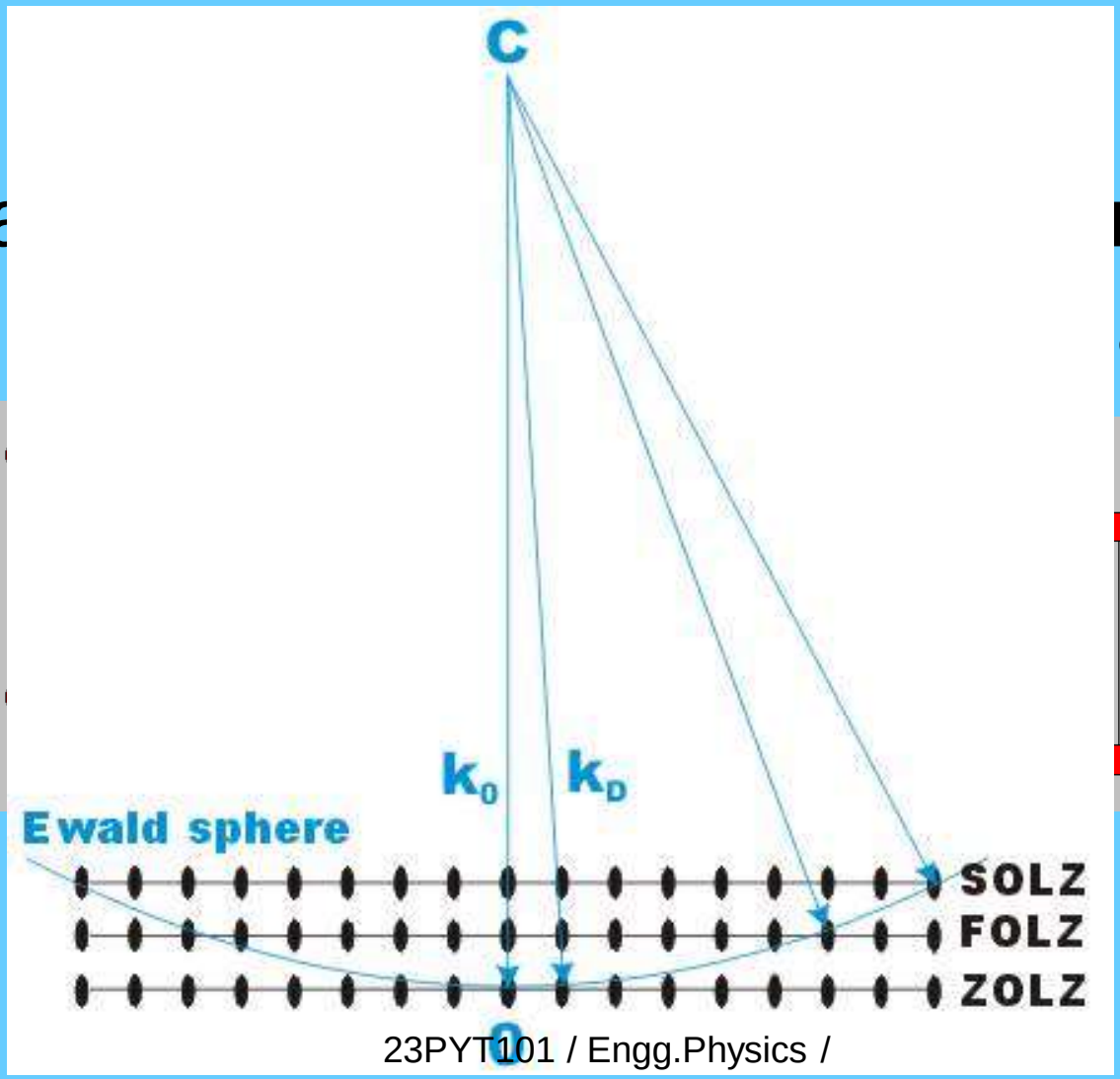
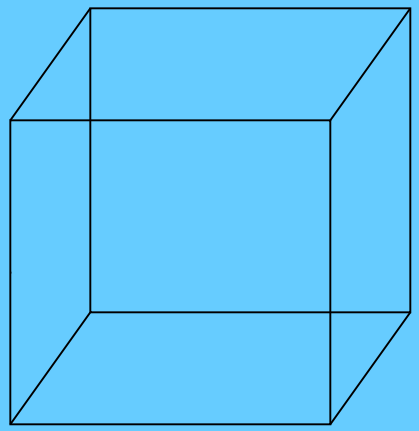
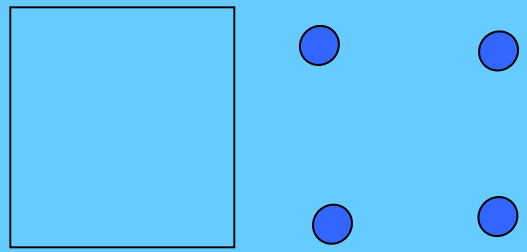


Zone axis for SC





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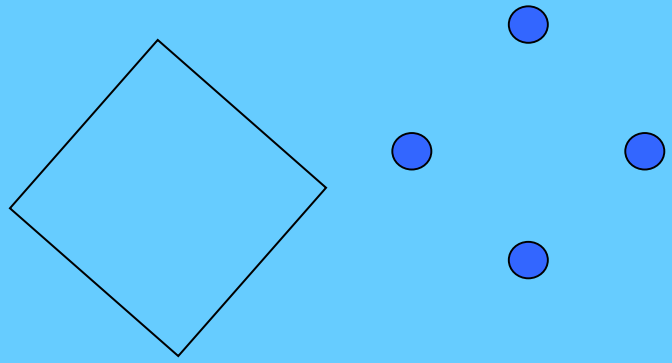

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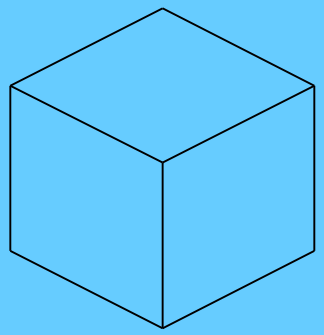

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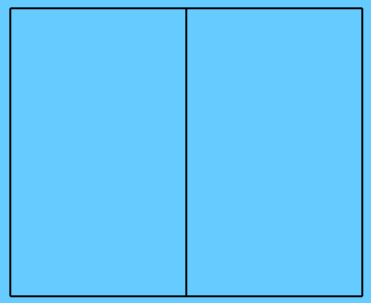

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Real to Reciprocal lattice equations

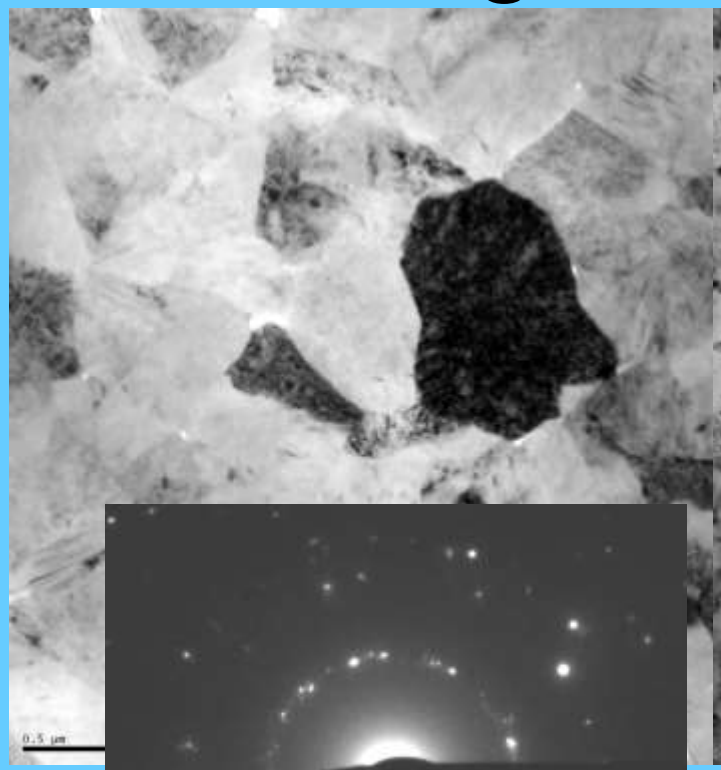
The relationship

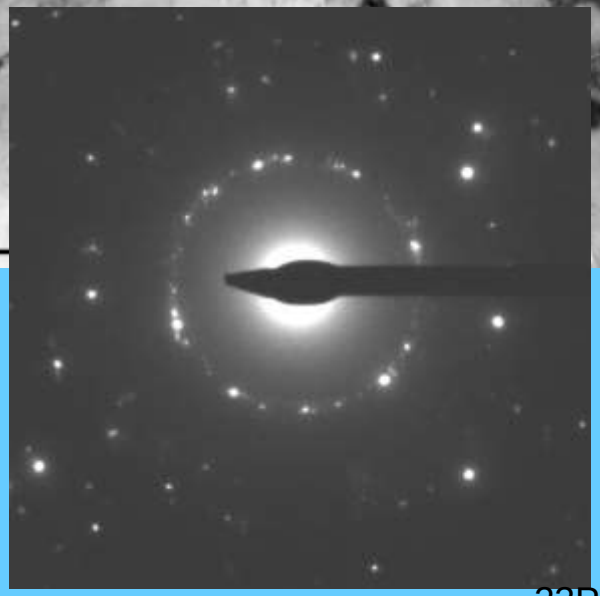
- Bragg's law $n\lambda = 2d \sin\theta$
- Laue equation $\boldsymbol{r} = (\boldsymbol{S}\text{-}\boldsymbol{S}^0) / \lambda$
- Fourier Transform $F(s) = \int_{-\infty}^{\infty} dx\, f(x) \exp(-i2\pi sx)$

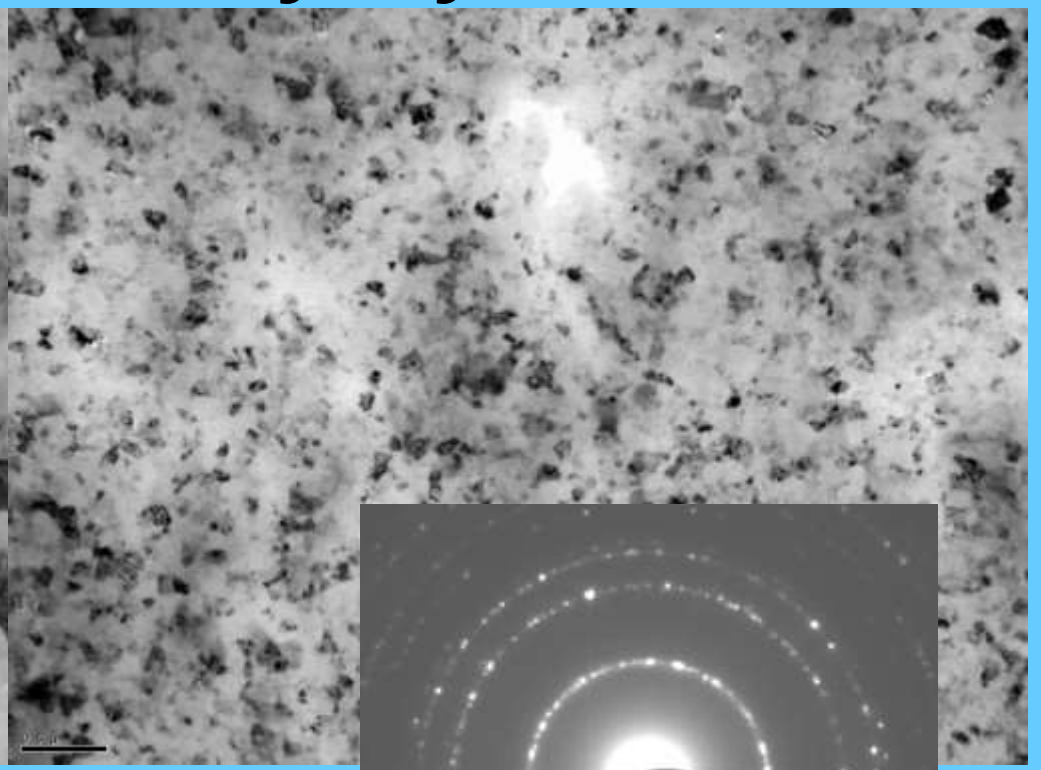
Structure factor

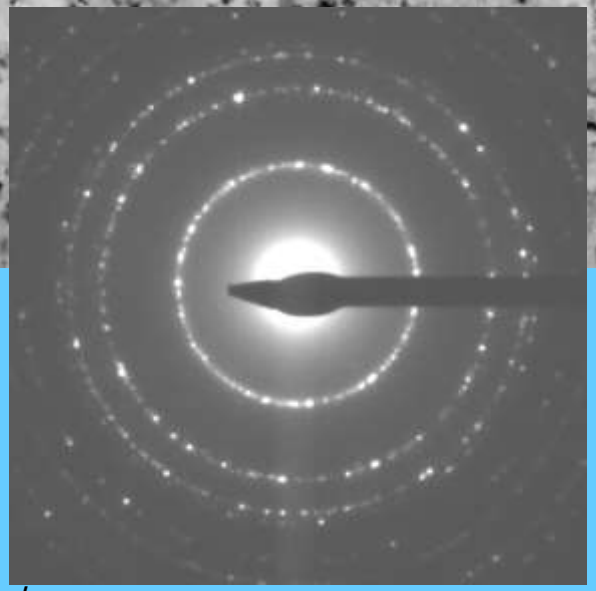
$$F_{hkl} = \sum f_n \exp \{ 2\pi i (hx_1 + ky_1 + lz_1)\}$$

Single vs Polycrystal

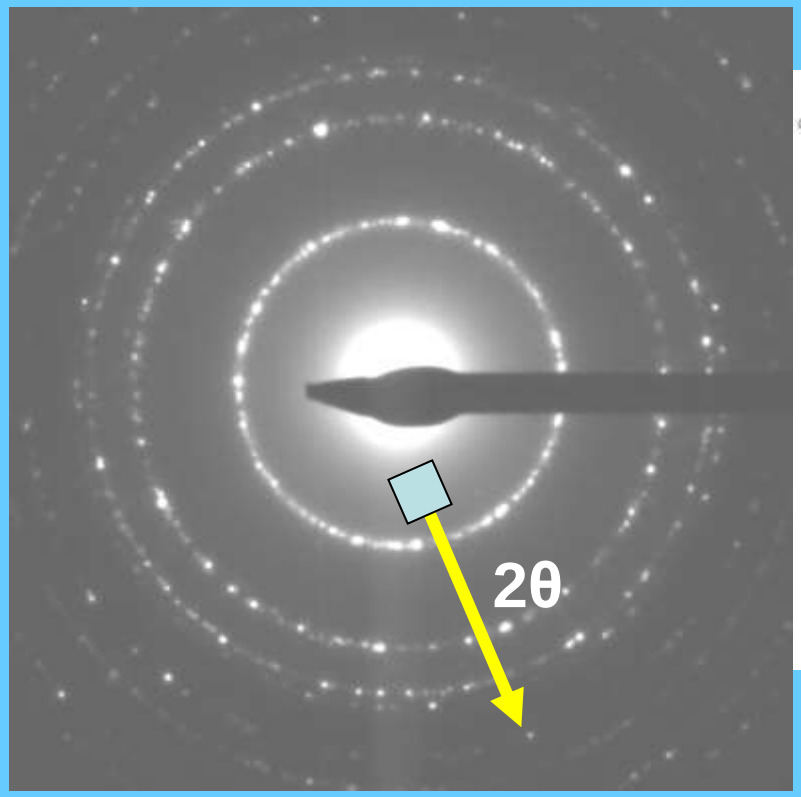


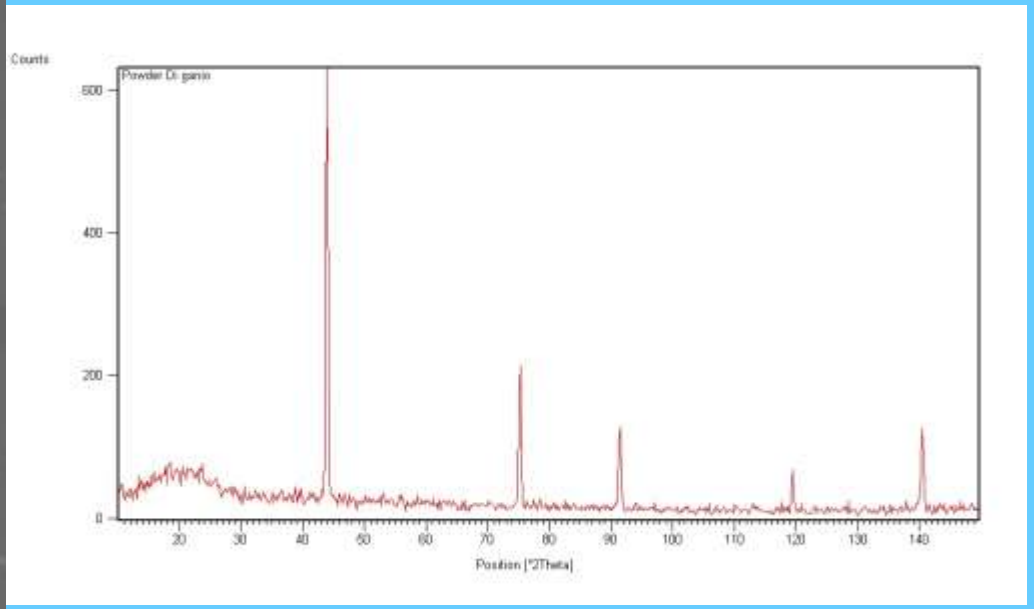






Electron vs XRay Diffraction

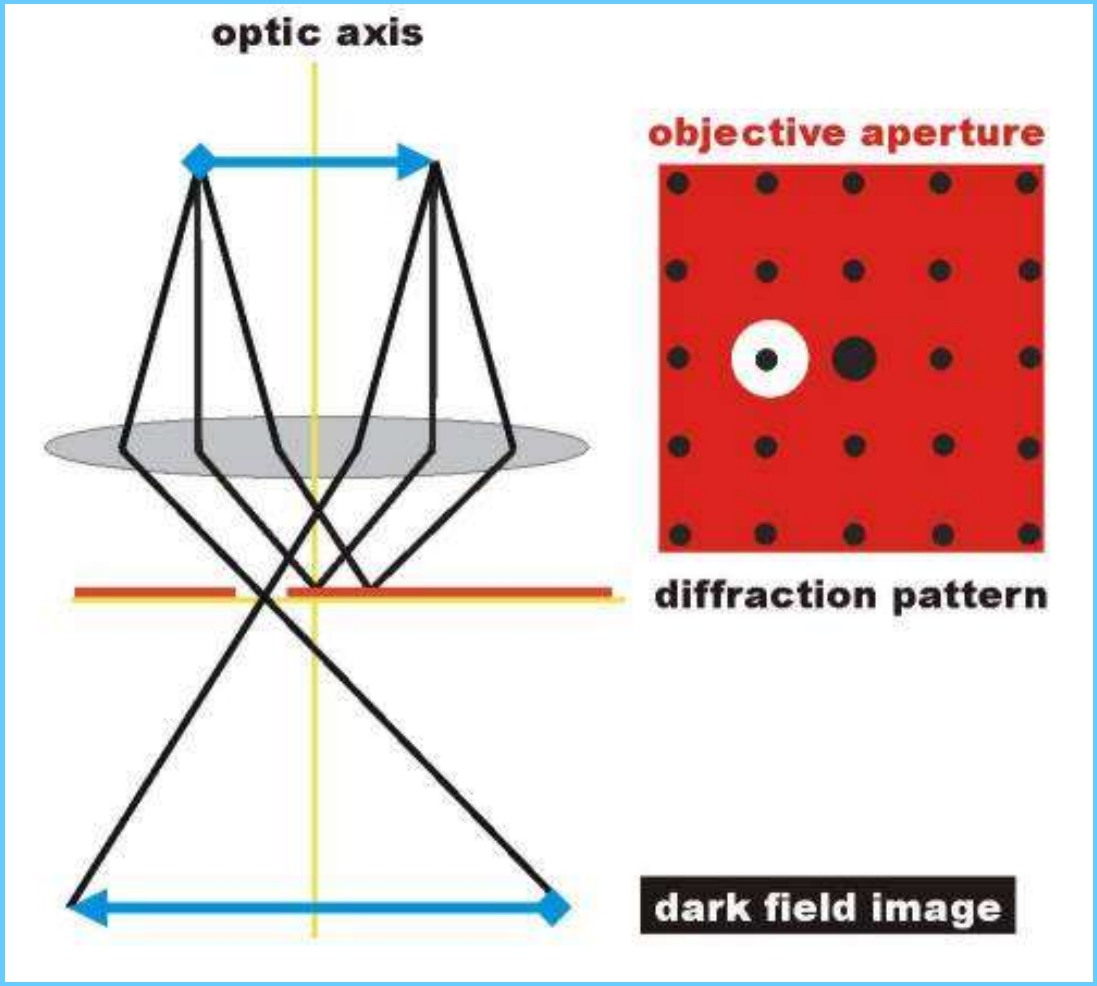




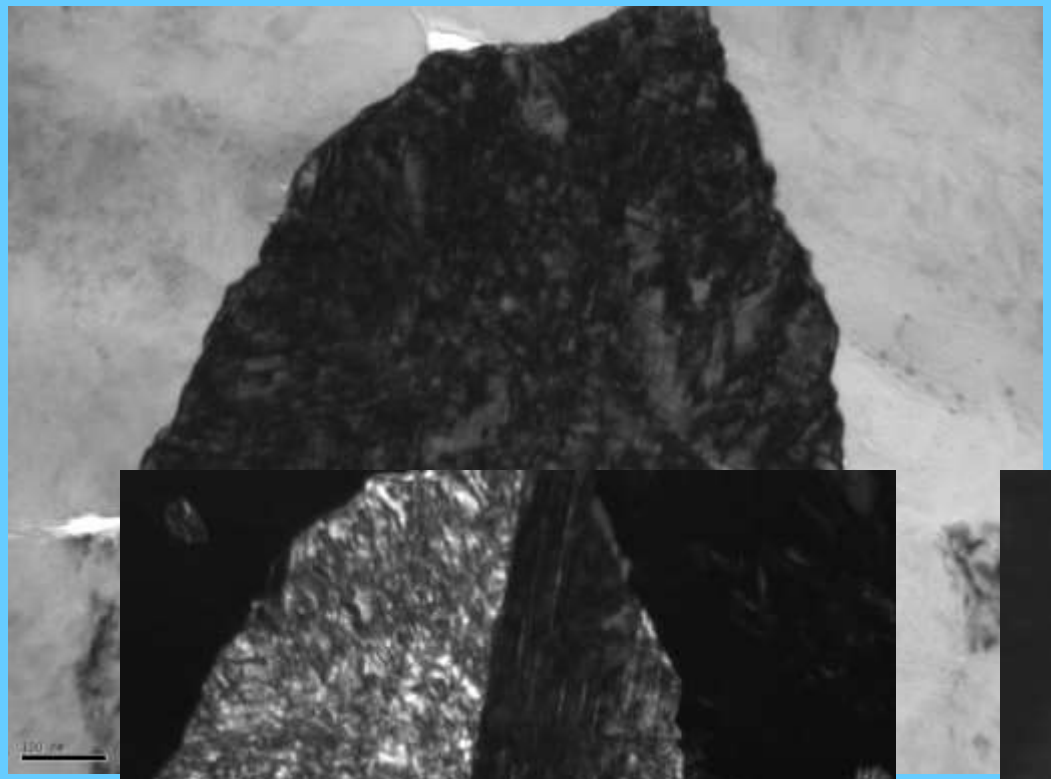
TEM Diffraction-
What can we infer?

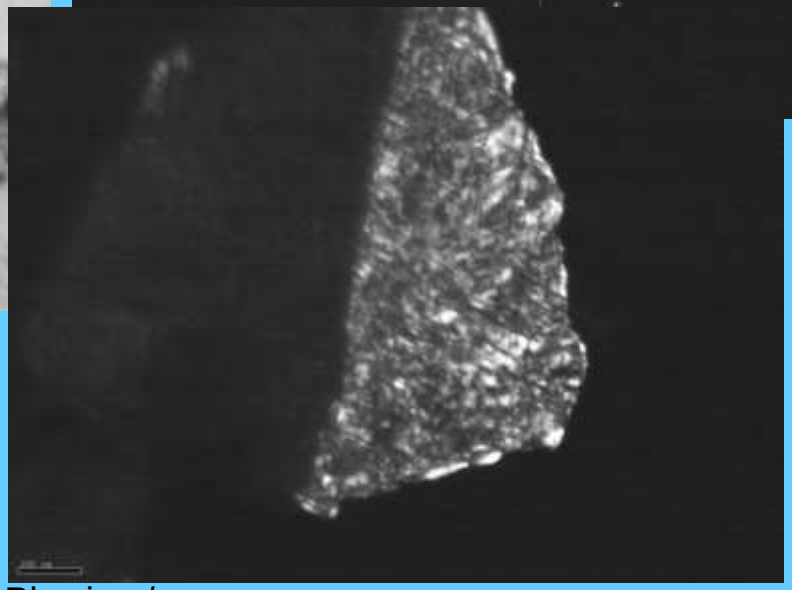
- Phases and crystal structure types
- Crystal symmetry and space group
- Orientation relationships between phases
- Determining growth directions, interface coherency
- Identifying defects , i.e. twinning, SFs, Dislocations
- Ordering behavior of crystal structures and the site occupancy preferences

Dark field imaging

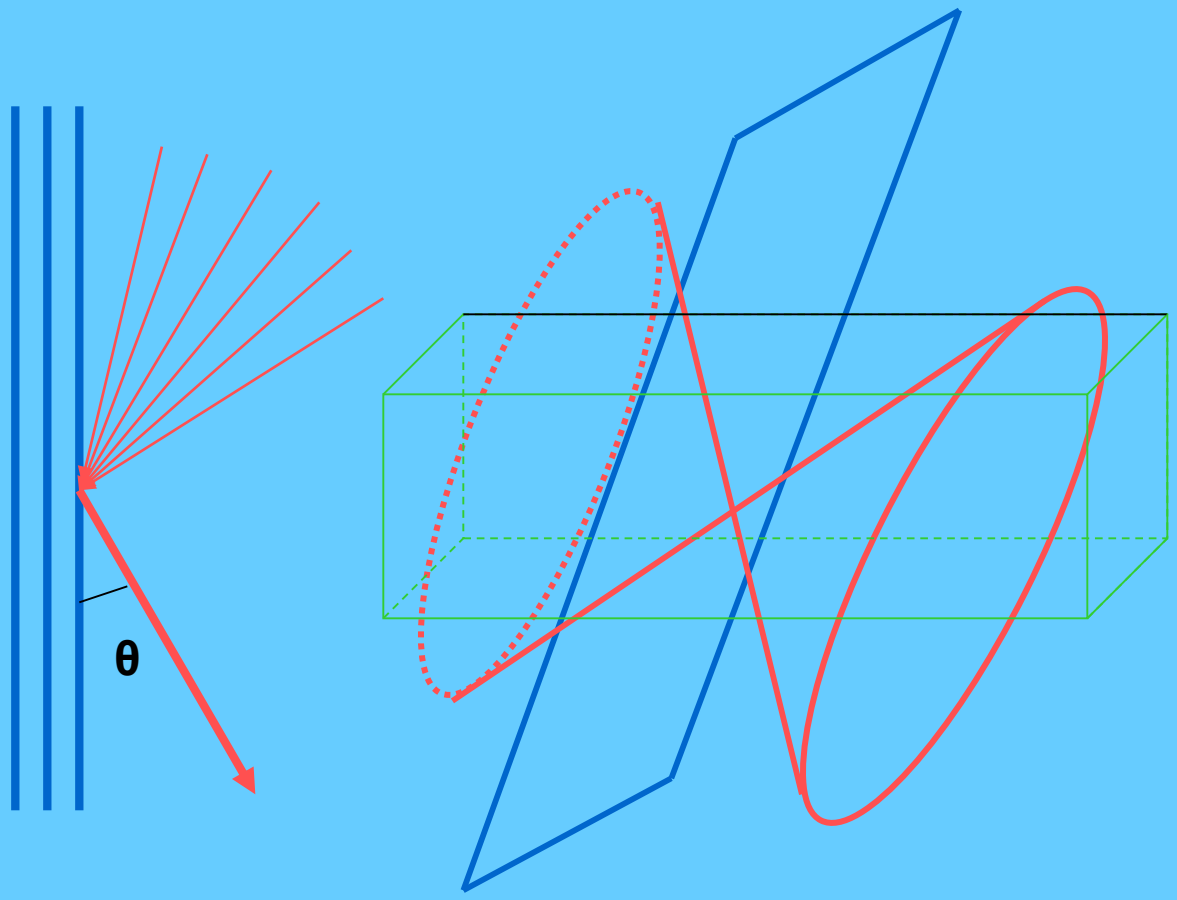


Dark field imaging



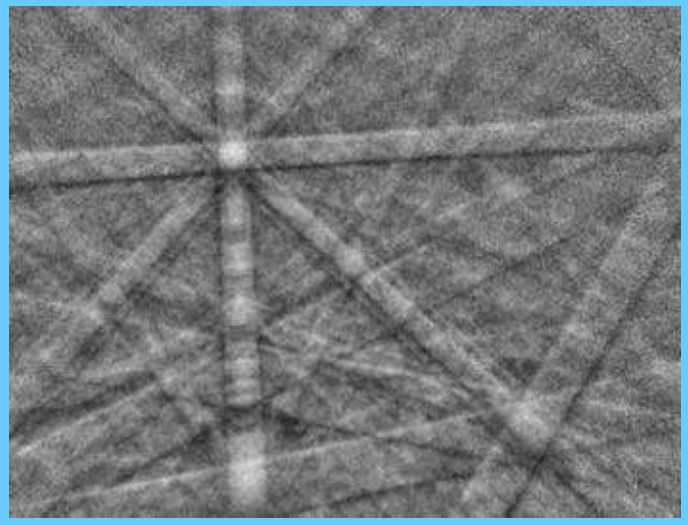


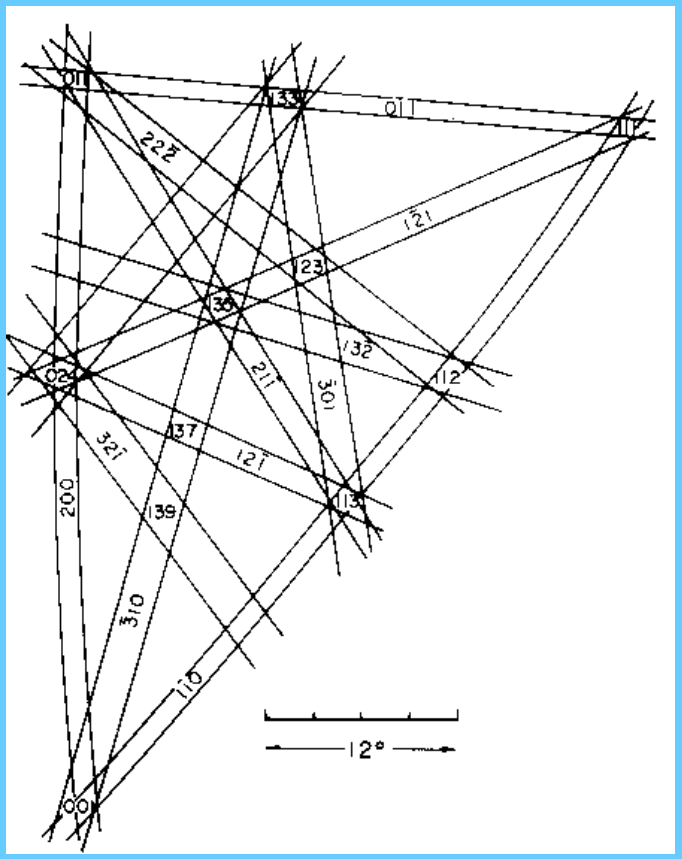
Kikuchi lines

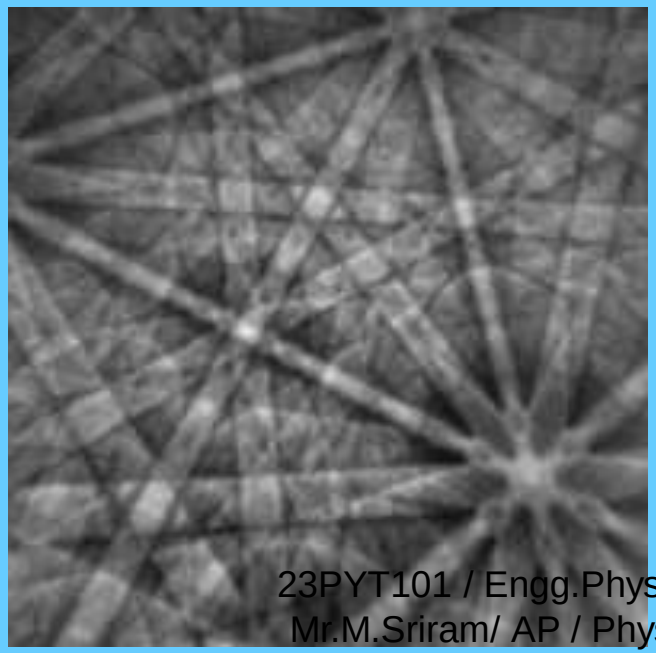


Inelastic scattering without significant wavelength change leads to formation of Kikuchi lines by diffraction. Incoming beam has every possible direction. Outgoing strong beam is at Bragg angle. This is particularly seen in thick samples

Kikuchi Maps







More….

- Transmission Electron Microscopy- Dr. Vasudevan's Graduate Course
- Transmission Electron Microscopy – David B. Williams and C. Barry Carter
- Transmission Electron Microscopy – Ludwig Reimer