PAPER-A: CONDENSED MATTER PHYSICS

(B.Sc. Semester-V)

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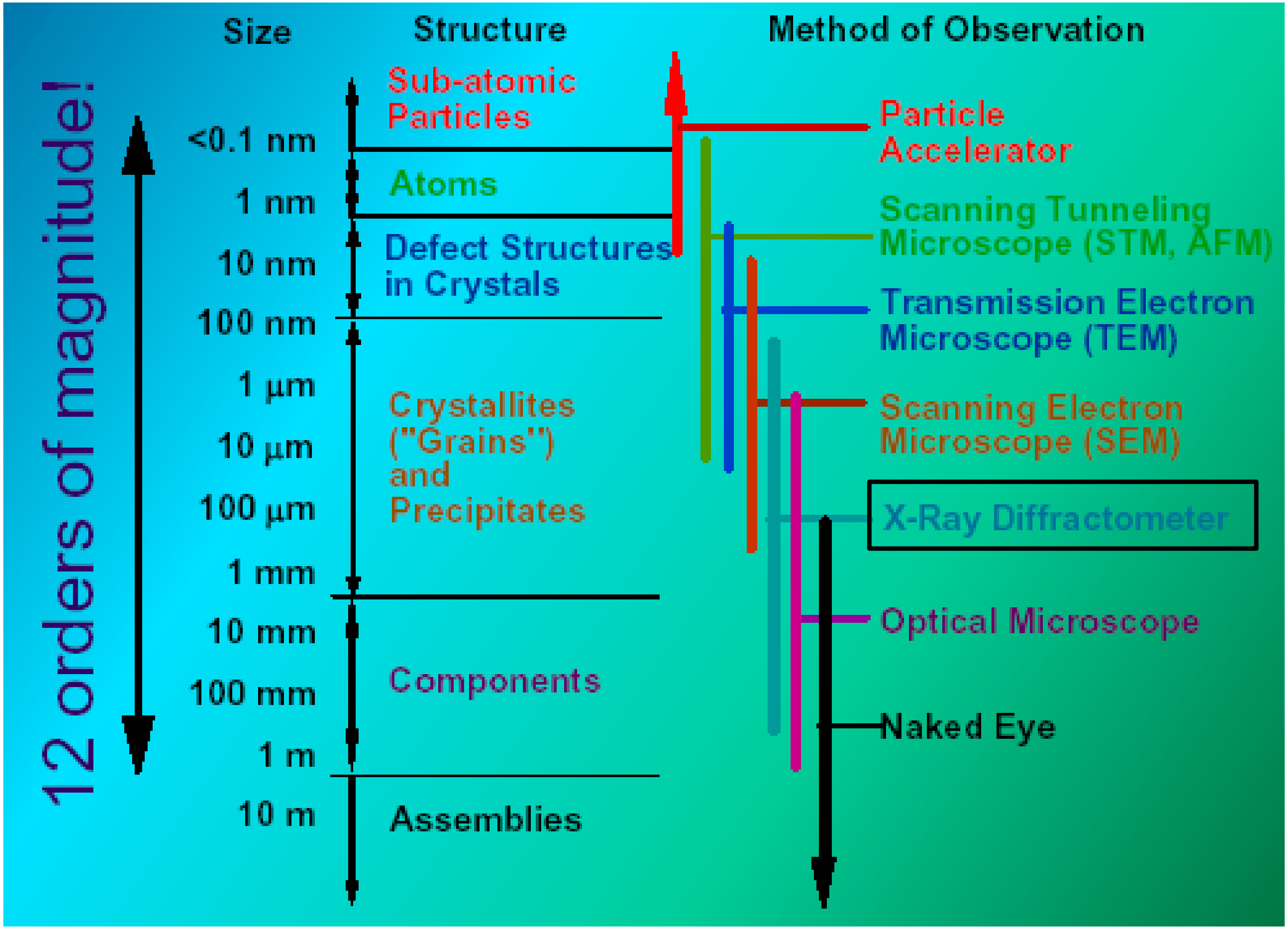
CONTENTS

- Crystal Diffraction: Bragg’s law,
- Experimental methods for crystal structure studies,

Scale of Structure Organization



Today **X-ray diffraction** supplemented by **electron** and **neutron** diffration

Energies **X-ray**, **electrons** and **neutrons** wave-particle

X-ray:

$$\begin{tikzcd} E = h\upsilon = \frac{hc}{\lambda} \arrow[r, leftrightarrow] & \lambda = \frac{hc}{E} & \\ & \lambda \approx 1\,\mathring{A} \arrow[u] \arrow[r, Rightarrow] & \boxed{E \approx 12\,k\,eV} \end{tikzcd}$$

Electrons:

$$\begin{tikzcd} & \lambda \approx 1\,\mathring{A} \arrow[d] & m_e = 9.1\ 10^{-31}\ kg \\ p = \hbar k = \frac{h}{\lambda} \arrow[r, leftrightarrow] & \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \arrow[r, Rightarrow] & \boxed{E \approx 150\ eV} \end{tikzcd}$$

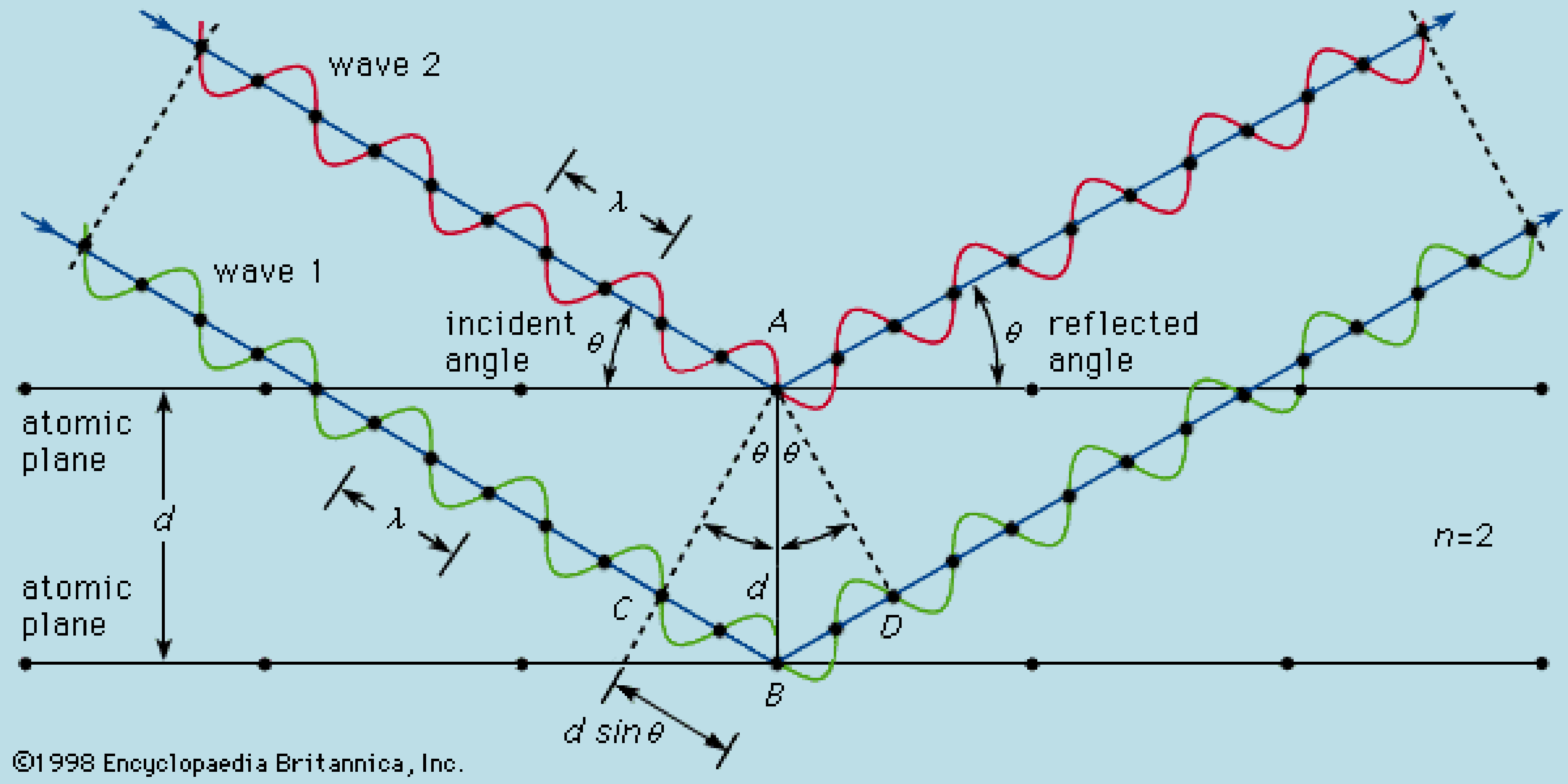
Neutrons:

$$\begin{tikzcd} \lambda \approx 1\,\mathring{A} \arrow[d] & m_n = 1.6749\ 10^{-27}\ kg \\ \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \arrow[r, Rightarrow] & \boxed{E \approx 0.08\ eV} \end{tikzcd}$$

Bragg Diffraction Law

Law describing the *necessary condition* for diffraction

Applicable for photons, electrons and neutrons



Bragg's law

Condition for efficient specular reflection

(click for java applet)

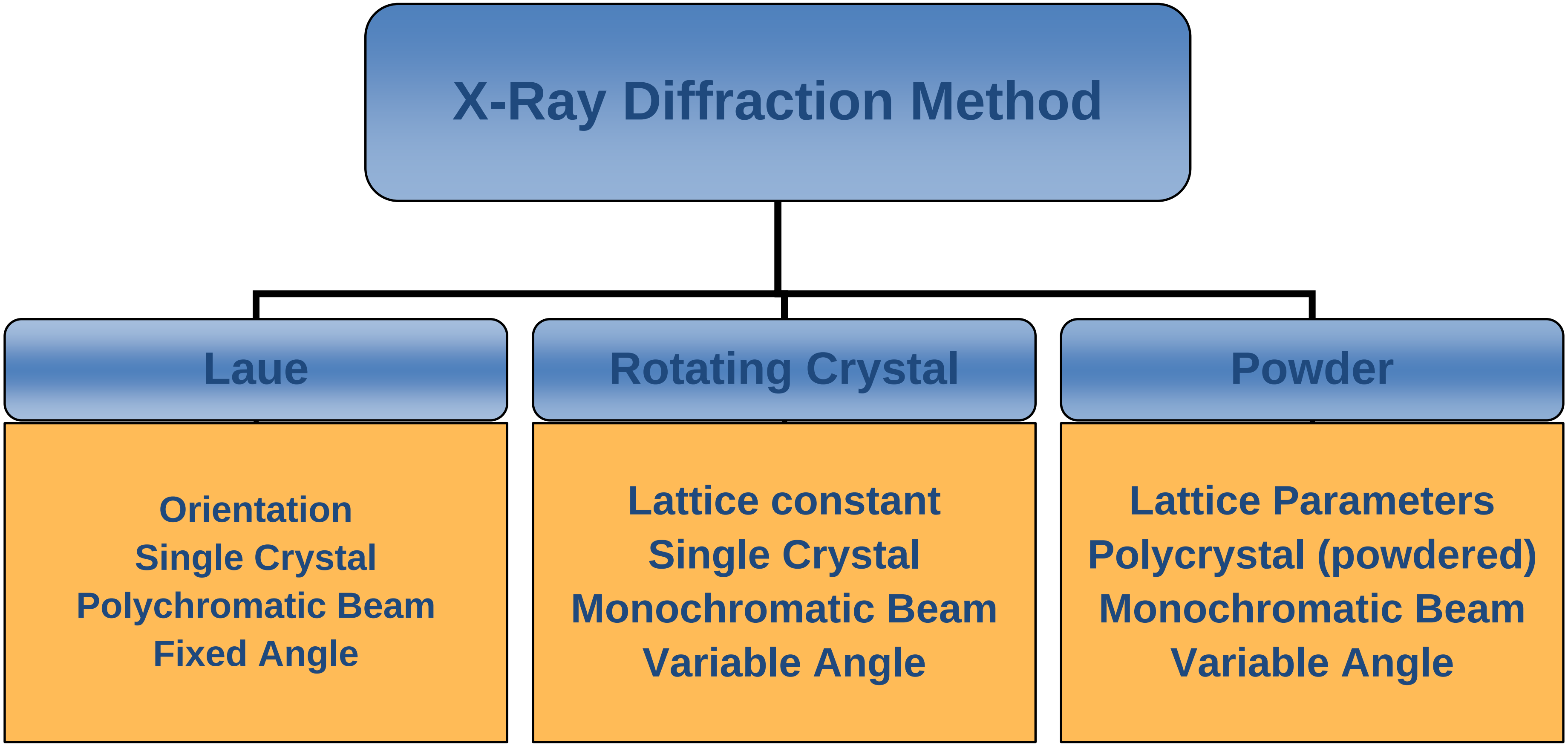
$$\boxed{2d\sin\theta = n\ \lambda}$$

$$2d_{hkl}\sin\theta = n\lambda$$

n: integer

Significance of Bragg’s law

- Bragg’s law is a consequence of periodicity of the lattice
- The law does not refer to the arrangement of atoms in the basis associated with each lattice point
- The composition of the basis determine the relative intensity of the various orders n of diffraction
- Since $\lambda \sim 1A^o$ is inevitable, we can’t use visible light for such studies



X-Ray Diffraction Method

Laue

Orientation
Single Crystal
Polychromatic Beam
Fixed Angle

Rotating Crystal

Lattice constant
Single Crystal
Monochromatic Beam
Variable Angle

Powder

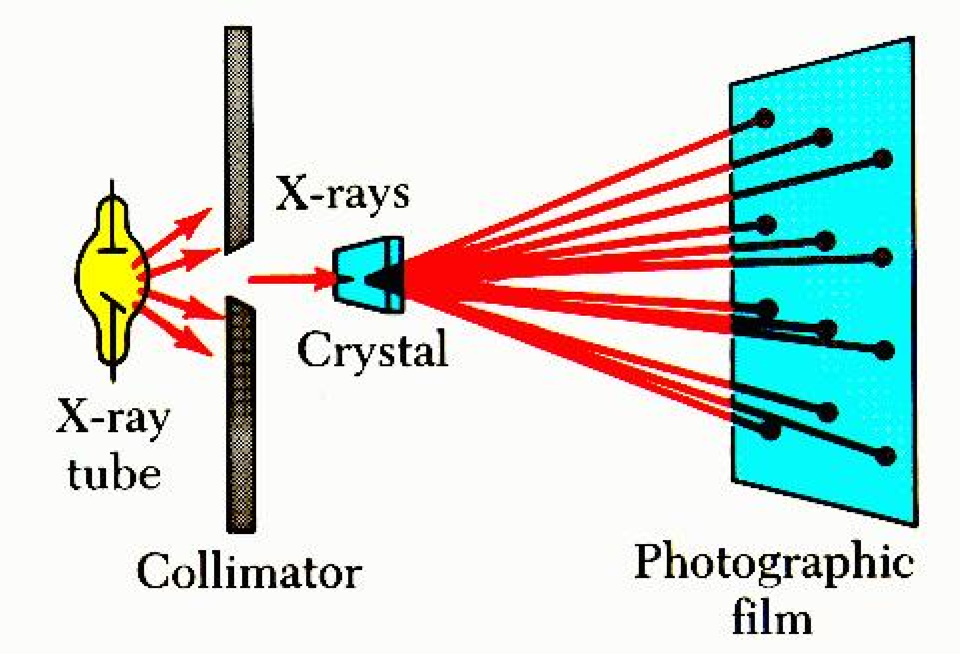
Lattice Parameters
Polycrystal (powdered)
Monochromatic Beam
Variable Angle

LAUE'S METHOD

Max von Laue
(1879-1960)

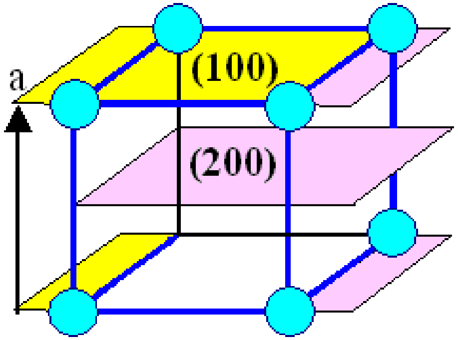
Laue 1912

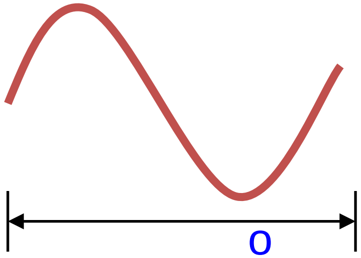
1914 Nobel prize



Lattice spacing typically

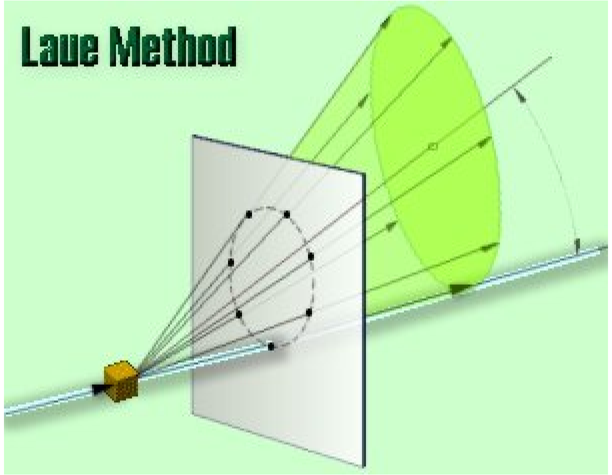
$$10^{-10}\,\mathrm{m} = 1\,\mathring{A}$$

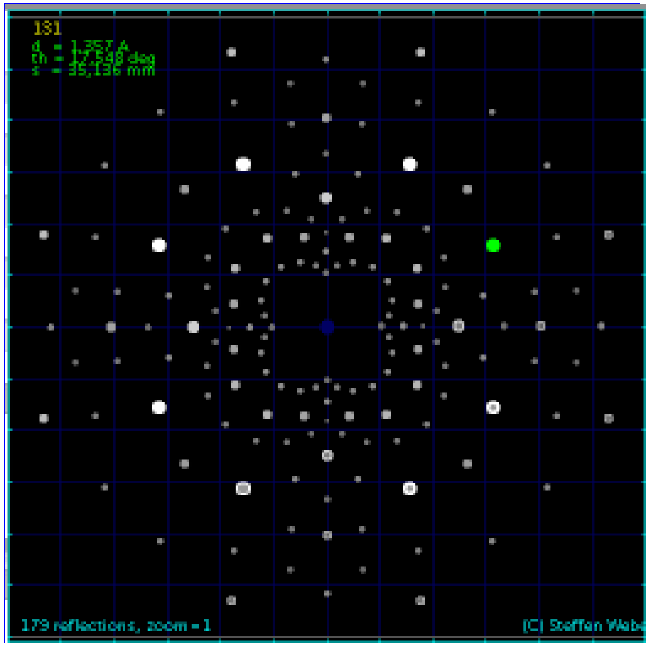




$$\lambda \approx 1\,\mathring{A}$$

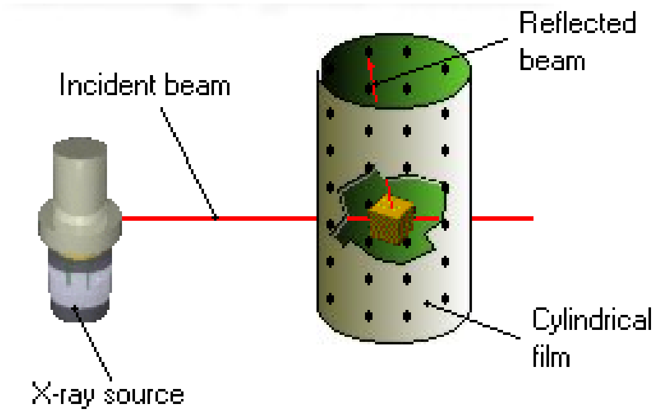
Laue’s Method : In this method a single crystal is held stationary in the path of a beam of e-m radiation (X-rays) or the Neutron radiation of continuous wavelengths. While θ is kept constant, the wavelength , λ is varied so that the Bragg law is satisfied. A plane film receives the diffracted beams. A developed film after its exposure shows a diffraction pattern that consists of series of spots.

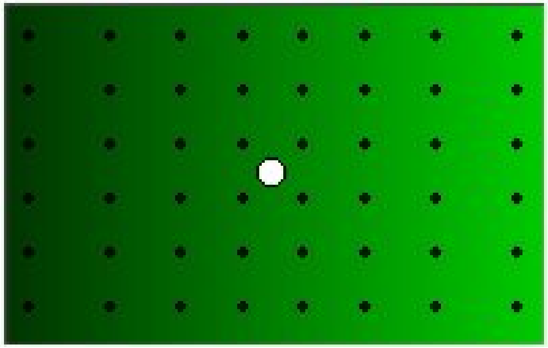




ROTATING CRYSTAL METHOD

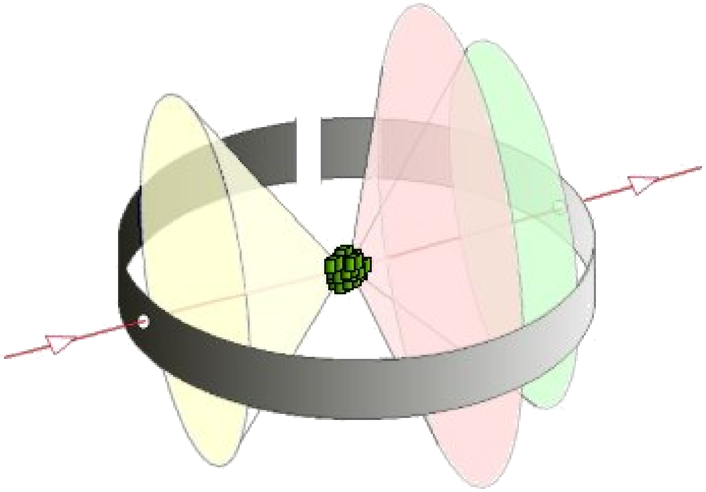
In this method , a single crystal is rotated about the fixed axis in a beam of monochromatic X-rays or neutrons. The angle θ is variable while the wavelength is kept constant. The variation of angle θ due to rotation of the crystal brings different atomic planes in the crystal into position for which Bragg’s reflection holds good. To record such reflections a film is mounted on a cylindrical holder that is concentric with a rotating spindle.





Powder Method

- ☐ If a powdered specimen is used, instead of a single crystal, then there is *no need to rotate* the specimen, because there will always be some crystals at an orientation for which diffraction is permitted. Here a monochromatic X-ray beam is incident on a powdered or polycrystalline sample.
- ☐ A sample of some hundreds of crystals (i.e. a powdered sample) show that the diffracted beams form continuous cones. A circle of film is used to record the diffraction pattern as shown. Each cone intersects the film giving diffraction lines. The lines are seen as arcs on the film.
- ☐ This method is useful for samples that are difficult to obtain in single crystal form



REFERENCES

- Introduction To Solid State Physics- Kittle
- Elementary Solid state Physics- Omar
- Solid state Physics- S. O. Pillai