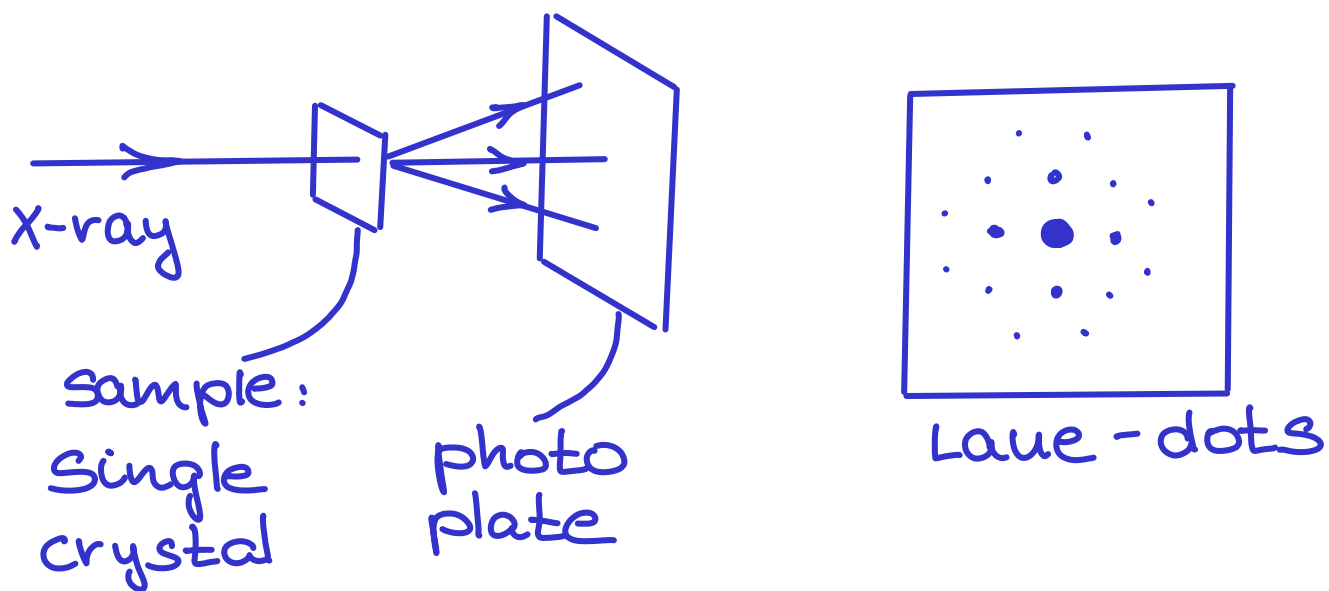


X-ray scattering

Max von Laue (Nobel, 1914) : x-ray diffraction by crystals

William Henry and William Lawrence Bragg (Nobel, 1915) : analysis of crystal structure by x-rays

Charles Barkla (Nobel, 1917) : characteristic x-rays of the elements.



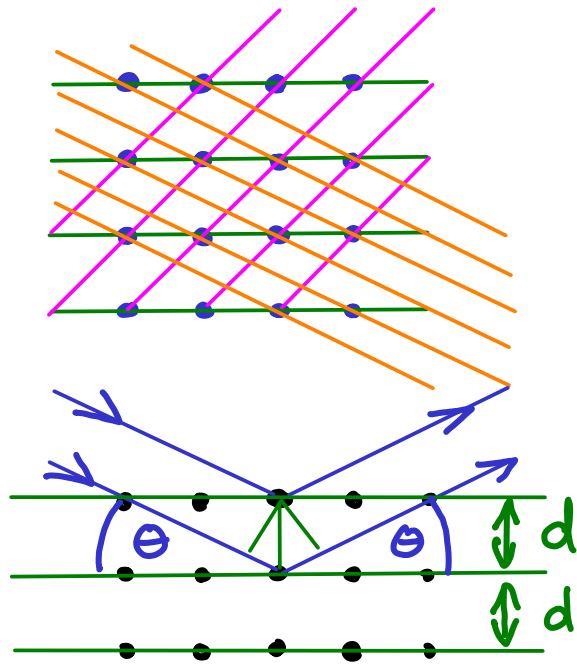
incoming x-ray: continuous

Laue:

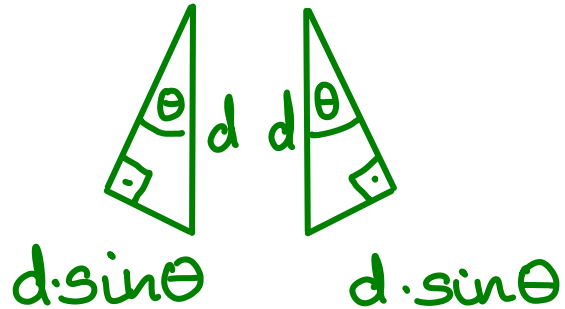
→ wave nature of x-rays

→ lattice structure of crystals

Bragg's law



Bragg planes



Bragg's law:

$$2d \cdot \sin\theta = n \cdot \lambda \quad n = 1, 2, 3, \dots$$

condition of constructive interference

Applications:

→ determination of crystal structures (APS: Advanced Photon Source)

Debye-Scherrer technique:
powdered crystal and monochromatic x-ray: rings

De Broglie waves

Prince Louis-Victor de Broglie
(Nobel, 1927):

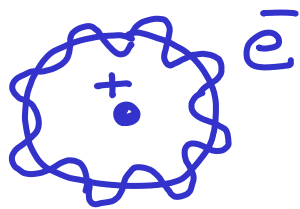
$$\begin{array}{l} E = hf \\ E = pc \end{array} \rightarrow \begin{array}{l} hf = pc = p\lambda f \\ h = p\lambda \end{array}$$

$$\boxed{\frac{h}{p} = \lambda}$$

Not only for photons, but also for electrons and later for other particles as well.

→ electron waves, matter waves

Bohr's condition for angular momentum:



$$2\pi r = n\lambda$$

$$n = 1, 2, 3, \dots$$

$$2\pi r = n \cdot \frac{h}{p}$$

$$pr = n \cdot \frac{h}{2\pi}$$

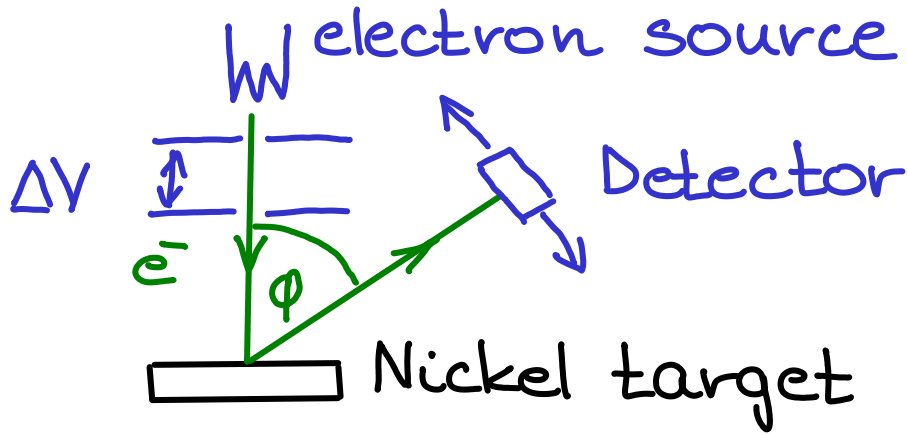
$$mvr = n \cdot \hbar$$

$$\boxed{L = n \cdot \hbar}$$

Electron around nucleus: a standing electron wave resonating.

Electron diffraction

Clinton Joseph Davisson and George Paget Thomson (Nobel, 1937).

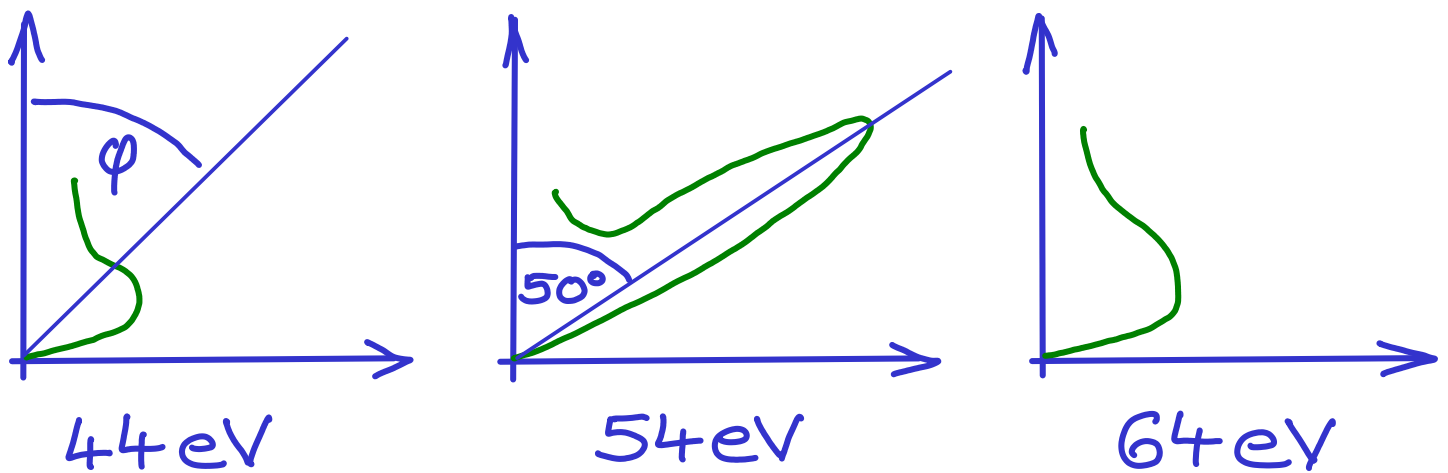


$$D \sin \phi = n \lambda$$

D : lattice constant

Nickel : $D = 2.15 \text{ \AA}$

Polar intensity plots:

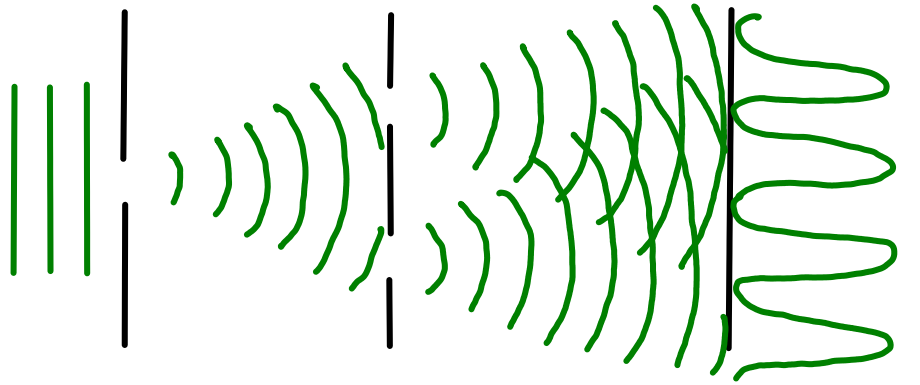


Later :

→ proton and neutron waves

→ atomic and molecular waves

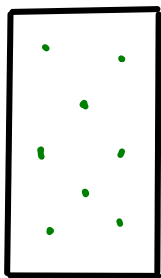
Double slit experiment



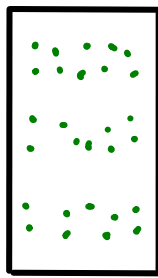
light wave $\longleftrightarrow$ intensity

electron or matter wave $\longleftrightarrow$ probability density

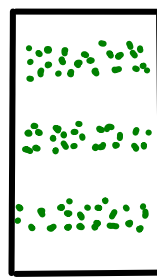
Single photon or single electron interference: there is only one photon or one electron in the interferometer at any given time.



1 minute



1 hour



1 day



The photon or electron interfered with itself !