DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module 3- Lecture-13

Born Interpretation Of Wave Function, Verification of matter waves – Davisson and Germer’s diffraction experiment

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TOPICS OF THIS LECTURE

BORN INTERPRETATION OF WAVE FUNCTION
VERIFICATION OF MATTER WAVES – DAVISSON AND GERMER’S DIFFRACTION EXPERIMENT

BORN INTERPRETATION OF WAVE FUNCTION:

The Born interpretation of the Wave Function

- The Wave function
  - Contains all the dynamic information about the system
  - Born made analogy with the wave theory of light (square of the amplitude is interpreted as intensity – finding probability of photons)
  - Probability to find a particle is proportional to

$$|\psi|^2 = \psi^* \psi$$ **Probability Density**

Max Born

Interpretation of the wave function

The wave function of a particle is related to the *probability density* for finding the particle in a given region of space:

Probability of finding particle between x and x + dx:

$$\boxed{|\psi(x)|^2 dx}$$

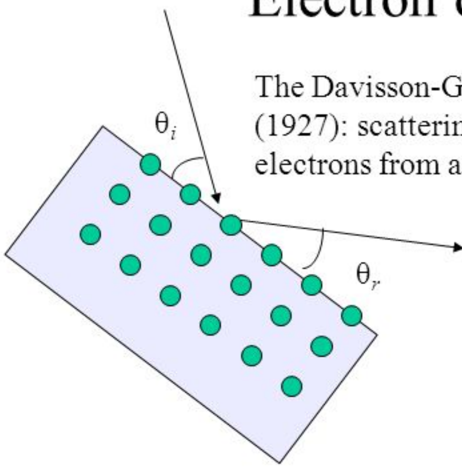
Probability of finding particle *somewhere* = 1, so we have the NORMALISATION CONDITION for the wave function:

Normalisation Condition

$$\boxed{\int_{-\infty}^{+\infty} |\psi(x)|^2 dx = 1}$$

VERIFICATION OF MATTER WAVES – DAVISSON AND GERMER'S DIFFRACTION EXPERIMENT

Electron diffraction from crystals

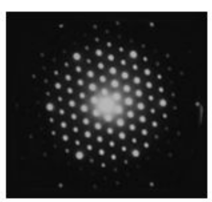


The Davisson-Germer experiment (1927): scattering a beam of electrons from a Ni crystal

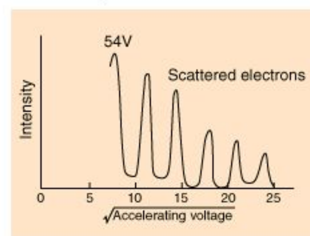
Davisson

G.P. Thomson

At fixed accelerating voltage (i.e. fixed electron energy) find a pattern of pencil-sharp reflected beams from the crystal



At fixed *angle*, find sharp peaks in intensity as a function of electron energy



Davisson, C. J., "Are Electrons Waves?," Franklin Institute Journal **205**, 597 (1928)

G.P. Thomson performed similar interference experiments with thin-film samples

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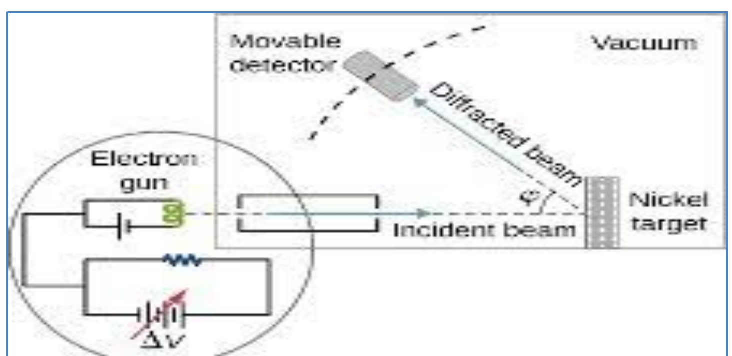
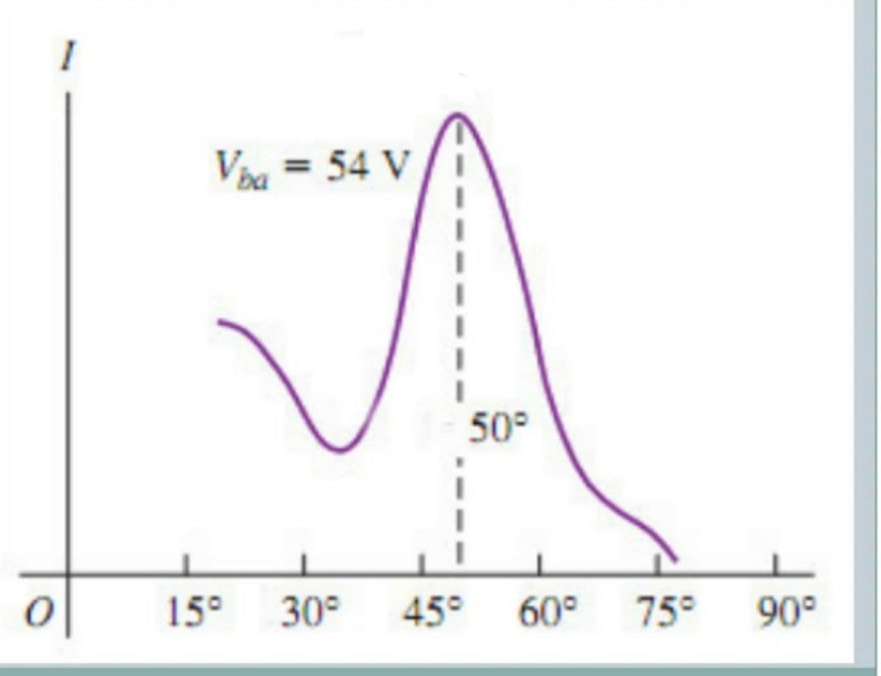
- The experiment consisted of firing an electron beam from an electron gun directed to a piece of nickel crystal at normal incidence (i.e. perpendicular to the surface of the crystal). The experiment included an electron gun consisting of a heated filament that released thermally excited electrons, which were then accelerated through a potential difference giving them a certain amount of kinetic energy towards the nickel crystal.



THE DAVISSON-GERMER EXPERIMENT

- If the electrons were reflecting off the nickel crystals as particles then the intensity of reflected electrons should be roughly equal at all angles.
- However Davisson & Germer saw a large peak in intensity at 50° when an accelerating potential difference of 54V was used.



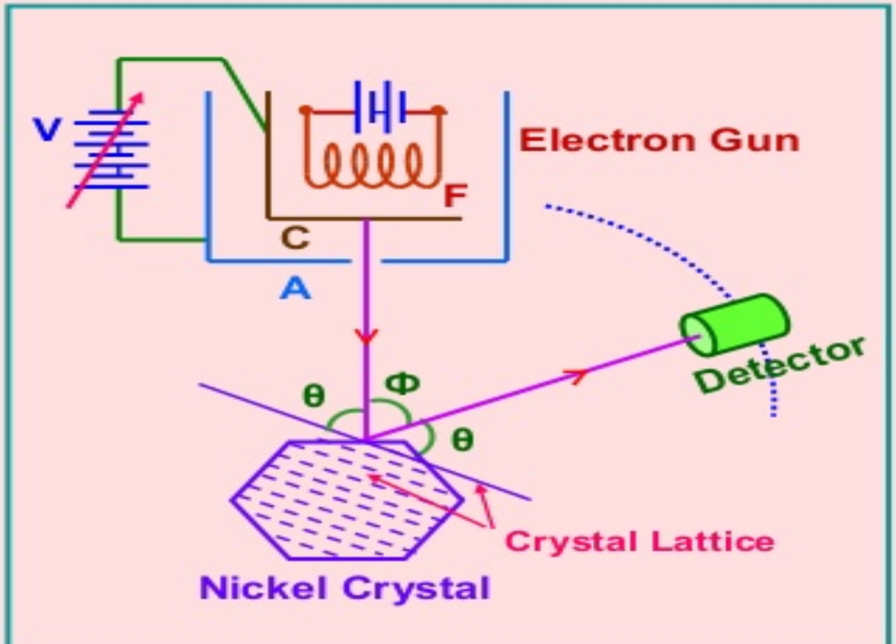
Davisson and Germer Experiment:

A beam of electrons emitted by the electron gun is made to fall on Nickel crystal cut along cubical axis at a particular angle.

The scattered beam of electrons is received by the detector which can be rotated at any angle.

The energy of the incident beam of electrons can be varied by changing the applied voltage to the electron gun.

Intensity of scattered beam of electrons is found to be maximum when angle of scattering is 50° and the accelerating potential is 54 V.



$\theta + 50° + \theta = 180°$ i.e. $\theta = 65°$

For Ni crystal, lattice spacing $d = 0.91$ Å

For first principal maximum, $n = 1$

Electron diffraction is similar to X-ray diffraction.

∴ Bragg's equation $2d\sin\theta = n\lambda$ gives

$\boxed{\lambda = 1.65 \text{ Å}}$

Diffraction of electrons

- Diffraction: Interference between waves caused by an object in their path
  Diffraction is a typical characteristic of wave
- Electrons are particles.
- In 1925, Davisson and Germer first observed the diffraction of electrons by a crystal.
- Conclusion: electrons have wave-like properties.
- The Davisson-Germer experiment has been repeated with other particles, including α particles and molecular H.

The wave character of particles