UNIVERSITY OF BIRMINGHAM

Lecture 1 – Atomic Structure
Lecture 2 – The Ultraviolet Catastrophe
Lecture 3 – Particle Nature of Light
Lecture 4 – Atomic Energy Levels and Spectra
Lecture 5 – X-ray Production and Diffraction
Lecture 6 – X-ray Spectra

Lecture 7 – Matter Waves

Lecture 8 – Wave-Particle Duality
Lecture 9 – Wave functions for Quantum Particles
Lecture 10 – A Quantum Mechanical Wave Equation
Lecture 11 – Applications of Schrödinger's Equation

Recap of Lecture 6

- Spectra produced by X-ray sources
  - Brehmsstralung
  - Discrete lines (K_α and friends)

- Absorption – exponential inside a material plus absorption edges when we hit high enough energy to ionise electrons from a shell

In this lecture

- Particles acting as waves – de Broglie wavelength

- Proof – Davisson & Germer experiment

de Broglie Wavelength

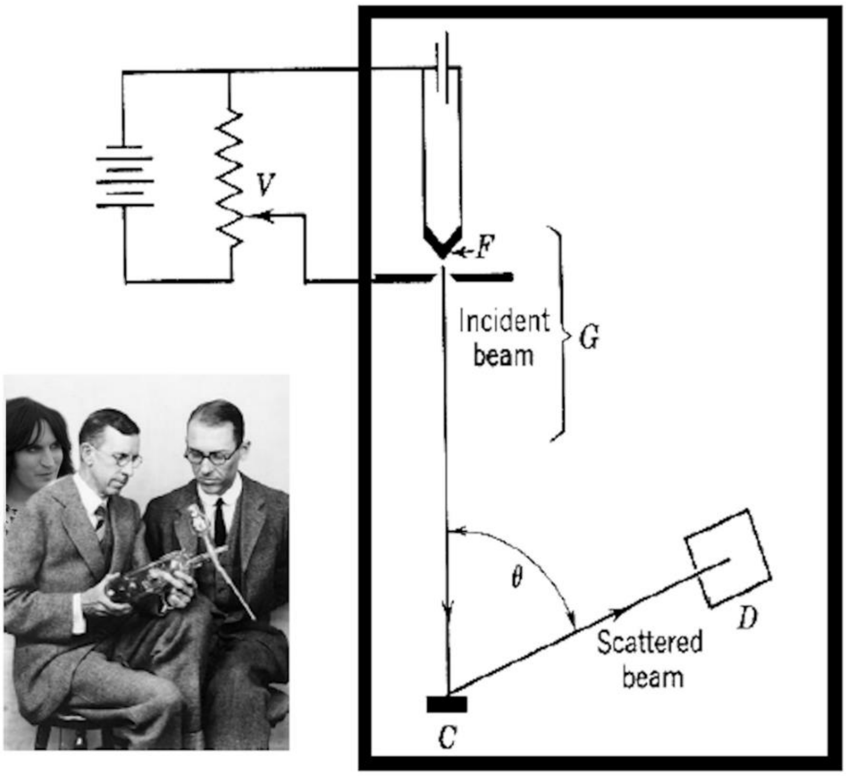
Louis de Broglie
(1892-1987)

In 1924, Louis de Broglie argued that classical particles should also have wave-like properties – in his PhD thesis. He was awarded a Nobel Prize for his hypothesis in 1929

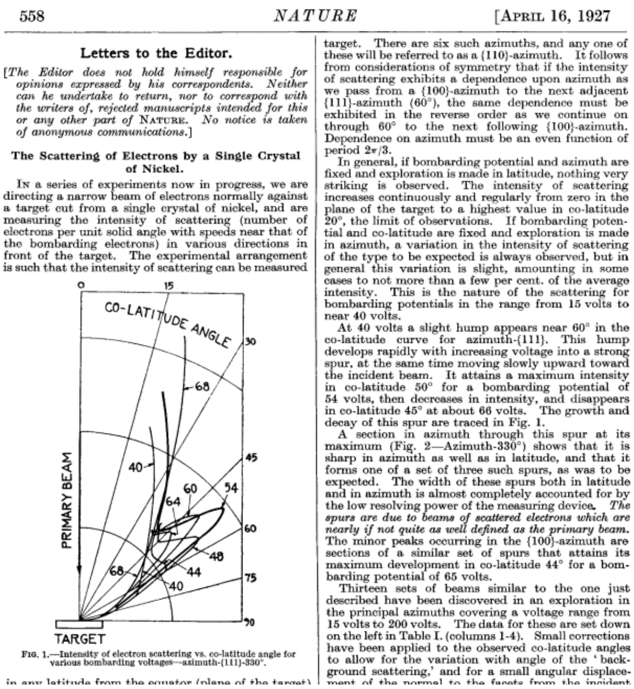
Davisson & Germer experiment

In 1925 Elsasser predicted that electrons would be diffracted by crystalline materials

- This was observed experimentally in 1927 by Davisson & Germer, and independently by G.P. Thomson
- de Broglie’s hypothesis appeared in his PhD thesis in 1924. He was awarded a Nobel Prize for his hypothesis in 1929
- Davisson and Thomson shared a Nobel Prize for their experimental work in 1937



Davisson & Germer experiment - Results



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Letters to the Editor.

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The Scattering of Electrons by a Single Crystal of Nickel.

In a series of experiments now in progress, we are directing a narrow beam of electrons normally against a target cut from a single crystal of nickel, and are measuring the intensity of scattering (number of electrons per unit solid angle with speeds near that of the bombarding electrons) in various directions in front of the target. The experimental arrangement is such that the intensity of scattering can be measured

Fig. 1.—Intensity of electron scattering vs. co-latitude angle for various bombarding voltages—azimuth-{111}-330°.

in any latitude from the equator (plane of the target)

target. There are six such azimuths, and any one of these will be referred to as a {110}-azimuth. It follows from considerations of symmetry that if the intensity of scattering exhibits a dependence upon azimuth as we pass from a {100}-azimuth to the next adjacent {111}-azimuth (60°), the same dependence must be exhibited in the reverse order as we continue on through 60° to the next following {100}-azimuth. Dependence on azimuth must be an even function of period $2\pi/3$.

In general, if bombarding potential and azimuth are fixed and exploration is made in latitude, nothing very striking is observed. The intensity of scattering increases continuously and regularly from zero in the plane of the target to a highest value in co-latitude 20°, the limit of observations. If bombarding potential and co-latitude are fixed and exploration is made in azimuth, a variation in the intensity of scattering of the type to be expected is always observed, but in general this variation is slight, amounting in some cases to not more than a few per cent. of the average intensity. This is the nature of the scattering for bombarding potentials in the range from 15 volts to near 40 volts.

At 40 volts a slight hump appears near 60° in the co-latitude curve for azimuth-{111}. This hump develops rapidly with increasing voltage into a strong spur, at the same time moving slowly upward toward the incident beam. It attains a maximum intensity in co-latitude 50° for a bombarding potential of 54 volts, then decreases in intensity, and disappears in co-latitude 45° at about 66 volts. The growth and decay of this spur are traced in Fig. 1.

A section in azimuth through this spur at its maximum (Fig. 2—Azimuth-330°) shows that it is sharp in azimuth as well as in latitude, and that it forms one of a set of three such spurs, as was to be expected. The width of these spurs both in latitude and in azimuth is almost completely accounted for by the low resolving power of the measuring device. *The spurs are due to beams of scattered electrons which are nearly if not quite as well defined as the primary beam.* The minor peaks occurring in the {100}-azimuth are sections of a similar set of spurs that attains its maximum development in co-latitude 44° for a bombarding potential of 65 volts.

Thirteen sets of beams similar to the one just described have been discovered in an exploration in the principal azimuths covering a voltage range from 15 volts to 200 volts. The data for these are set down on the left in Table I. (columns 1-4). Small corrections have been applied to the observed co-latitude angles to allow for the variation with angle of the 'background scattering,' and for a small angular displacement of the normal to the facets from the incident

Diffraction peaks from a crystal, just like we found from X-rays:

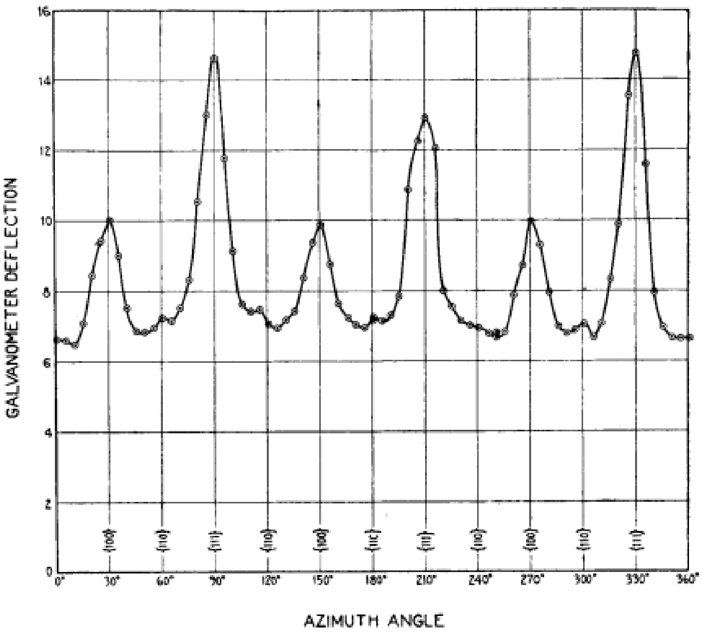
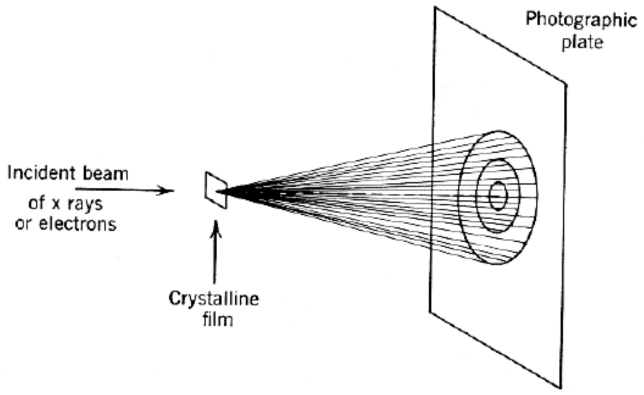
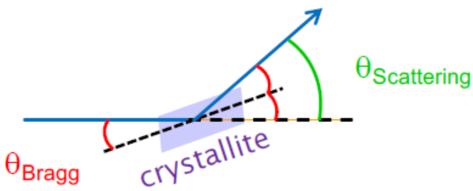


Fig. 2.—Intensity of electron scattering vs. azimuth angle—54 volts, co-latitude 50°.

GP Thomson experiment – powder electron diffraction





$$\theta_{Scattering} = 2 \times \theta_{Bragg}$$

G.P. Thomson was the son of J.J. Thomson – his father discovered the electron, and he established its wave behaviour – they both won Nobel Prizes (in 1906 and 1937)

Can use the same target to diffract both X-rays and electrons: