Diffraction des électrons par un cristal de graphite

Figure 1 – Dispositif de diffraction électronique

Le but de ce TP est double :

✘ Vérifier la relation de De Broglie :

$$\lambda_{DB} = \frac{h}{P}$$

où h est la constante de Planck et P est la quantité de mouvement de la particule (ici les électrons).

✘ Déterminer la constante de Planck dont la valeur théorique est :

$$h = 6.626\,070\,15 \times 10^{-34}\,\text{J·s}$$
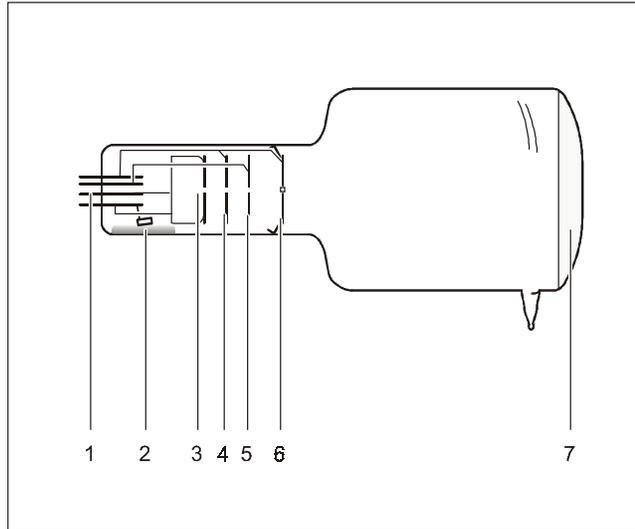
Pour cela vous avez à disposition deux documents :

✘ Un guide d'utilisation du matériel (Instruction sheet)

✘ Un guide pour la réalisation et l'exploitation des mesures (Introductory experiments)

Travail à faire

✘ Proposer un protocole permettant de vérifier la relation de De Broglie

✘ Proposer un protocole permettant de mesurer la constante de Planck connaissant les distances entres les plans réticulaires d_1 et d_2.

✘ Dans les deux cas, on procèdera à une validation.

Lehr– und Didaktiksysteme
LD Didactic GmbH
Leyboldstrasse 1 · D-50354 Huerth

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Instruction sheet 555 626

Electron diffraction tube (555 626)

1   Pin base (for electron gun contacting)
2   Getter mirror (for maintaining the vacuum)
3   Cathode cap
4   Anode plate 1
5   Focussing electrode
6   Anode plate 2, with graphite sample
7   Screen

Safety notes

When the electron diffraction tube is operated at high voltages over 5 kV, X-rays are generated.

- Do not operate the electron diffraction tube with high voltages over 5 keV.

The connection of the electron diffraction tube with grounded anode given in this instruction sheet requires a high-voltage enduring voltage source for the cathode heating.

- Use the high-voltage power supply 10 kV (521 70) for supplying the electron diffraction tube with power.

Danger of implosion: the electron diffraction tube is a high-vacuum tube made of thin-walled glass.

- Do not expose the electron diffraction tube to mechanical stress, and connect it only if it is mounted in the tube stand.
- Treat the contact pins in the pin base with care, do not bend them, and be careful when inserting them in the tube stand.

The electron diffraction tube may be destroyed by voltages or currents that are too high:

- Keep to the operating parameters given in the section on technical data.

1   Description

The electron diffraction tube enables the wave character of electrons to be demonstrated through their diffraction (Debye-Scherrer diffraction) at a polycrystalline graphite lattice. From the radii of the diffraction rings and the lattice plane spacings in graphite the wavelengths of the electrons for different anode voltages can be determined and compared with de Broglie's equation.

2   Scope of supply

1 Electron diffraction tube
1 Adjusting magnet

3   Technical data

Heating voltage U_F:	6-6.5 V~ (rec.: 6.3 V~)
Heating current I_F:	approx. 1.5 A at 6.3 V
Anode voltage U_A:	2.5-5 kV
Distance crystal-screen:	135 mm
Pressure:	$<10^{-6}$ hPa
Diameter:	90 mm
Total length:	270 mm
Mass:	250 g
Incandescent cathode:	heated directly
Lattice plane spacings in graphite:	123 pm, 213 pm

Atomic and Nuclear Physics

Introductory experiments
Dualism of wave and particle

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P6.1.5.1

Diffraction of electrons in a polycrystalline lattice (Debye-Scherrer diffraction)

Objects of the experiment

■ Determination of wavelength of the electrons

■ Verification of the de Broglie's equation

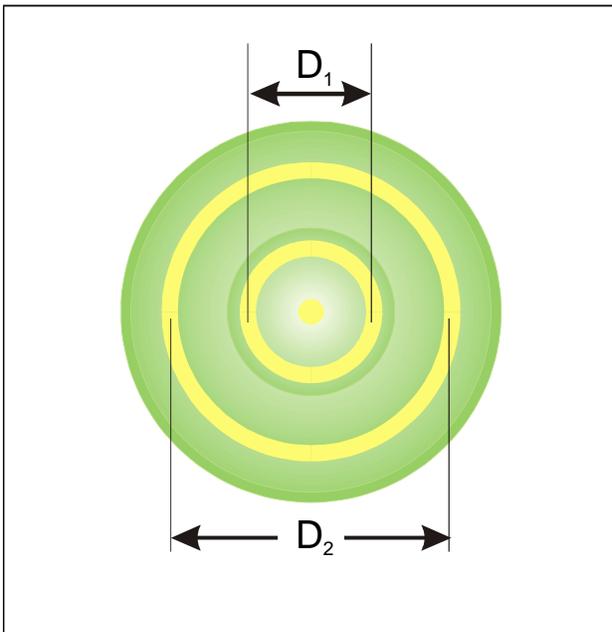■ Determination of lattice plane spacings of graphite

Fig. 1: Schematic representation of the observed ring pattern due to the diffraction of electrons on graphite. Two rings with diameters D_1 and D_2 are observed corresponding to the lattice plane spacings d_1 and d_2 (Fig. 3).

Principles

Louis de Broglie suggested in 1924 that particles could have wave properties in addition to their familiar particle properties. He hypothesized that the wavelength of the particle is inversely proportional to its momentum:

$$\lambda = \frac{h}{p} \qquad\qquad (I)$$

λ: wavelength

h: Planck's constant

p: momentum

His conjecture was confirmed by the experiments of Clinton Davisson and Lester Germer on the diffraction of electrons at crystalline Nickel structures in 1927.

In the present experiment the wave character of electrons is demonstrated by their diffraction at a polycrystalline graphite lattice (Debye-Scherrer diffraction). In contrast to the experiment of Davisson and Germer where electron diffraction is observed in reflection this setup uses a transmission diffraction type similar to the one used by G.P. Thomson in 1928.

From the electrons emitted by the hot cathode a small beam is singled out through a pin diagram. After passing through a focusing electron-optical system the electrons are incident as sharply limited monochromatic beam on a polycrystalline graphite foil. The atoms of the graphite can be regarded as a space lattice which acts as a diffracting grating for the electrons. On the fluorescent screen appears a diffraction pattern of two concentric rings which are centred around the indiffracted electron beam (Fig. 1). The diameter of the concentric rings changes with the wavelength λ and thus with the accelerating voltage U as can be seen by the following considerations:

LD Didactic GmbH · Leyboldstrasse 1 · D-50354 Huerth / Germany · Phone: (02233) 604-0 · Fax: (02233) 604-222 · e-mail: info@ld-didactic.de