Electron Diffraction

Quantum Physics

Operating instructions

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1 Safety

1.1 Personal safety

The electron diffraction tube will be connected to the power supplies and the electric circuit will be ready for you to start the experiment. You will be operating with high voltage, up to 7.5 kV. Before turning the power on, you should carefully inspect the apparatus. Ensure all wires are connected and there are no exposed cable ends. Additionally:

- Try to avoid unnecessarily touching the electron beam tube and electrical leads during the experiment.
- Do not apply any mechanical force on the electron beam tube to avoid possible cracking and implosion of this tube. This is for your safety and the safety of the equipment.

1.2 Responsible equipment use

The equipment should be handled carefully to prevent damage. Follow the personal safety directions above, and additionally take care with the electron beam tube:

- The bright spot at the centre of the screen can damage the phosphorescent layer at the front of the tube over time. Please don't leave the apparatus running any longer than is needed to complete your measurements to preserve tube life.
- Don't position anything above the electron beam tube that may fall on it.
- Be aware that high voltages are involved. Ensure there are no exposed cable ends and that all cables are plugged into their correct locations before turning on the power supplies. If in doubt, please ask a demonstrator.

2 Operating instructions

2.1 The experimental setup

High Voltage Equipment: Inspect the experimental apparatus (Figure 1) when you begin the experiment to check it is correctly wired up. If it is not correctly connected as shown in Figure 1, please speak to a demonstrator.

Warning re: equipment damage: When used with a high accelerating voltage >2 kV, the Wehnelt voltage G1, which limits the current, is to be kept at -50 V otherwise the anode current will exceed safe limits.

Familiarise yourself with the experimental setup for electron diffraction shown in Figure 1. The pieces of equipment are labeled as follows:

1. High voltage power supply (0-10 kV).
2. Multi-function power supply (0-600 V DC, 6.3 V AC) that provides the current to heat the cathode and to focus the electron beam.
3. Electron beam tube with an electron gun, graphite thin film target and a luminescent screen.
4. Vernier calipers for measuring the radii of the diffraction rings.

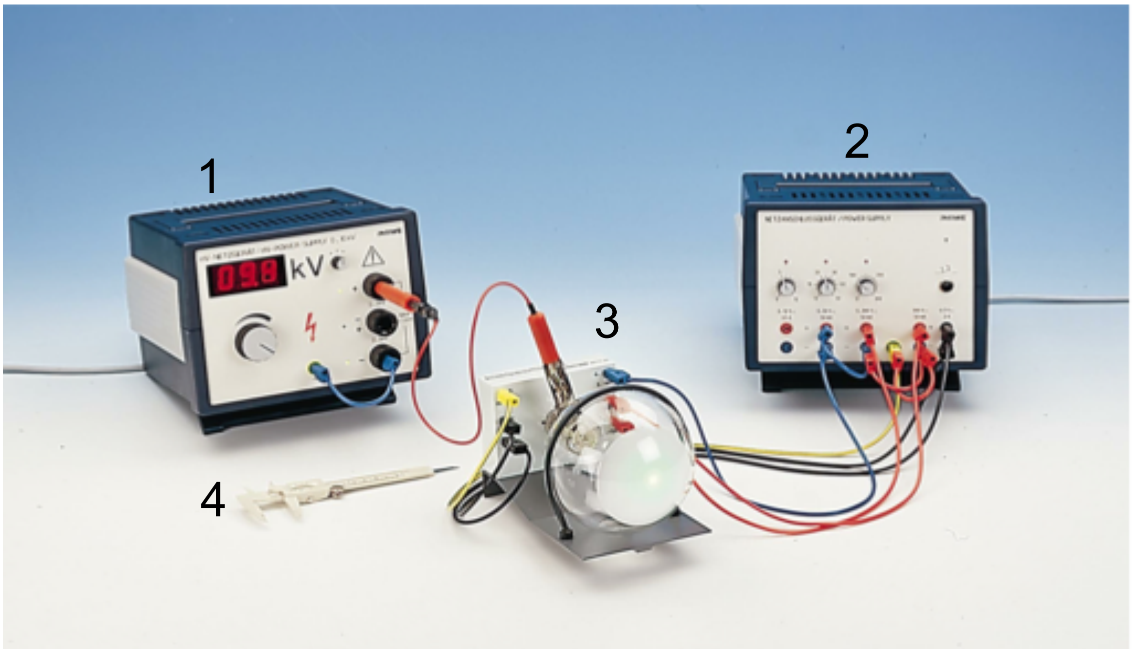

Figure 1: Experimental equipment for the Electron Diffraction Experiment. (1) is the high voltage power supply, (2) provides the voltages to the electrodes within the electron diffraction tube (3), and (4) is the plastic Vernier callipers you will use to measure the diameter of the diffractions rings. See Figure 2 for more information on the electron diffraction tube.

The main action happens within the electron beam tube (3). Electrons are ejected from an anode (a Wehnelt cylinder) and then accelerated in the electron beam tube through a high potential difference, gaining kinetic energy before being scattered from the target. The target is a polycrystalline layer of graphite powder on a copper mesh. Graphite behaves as a two-dimensional diffraction grating for the electron beam. The electrons are diffracted by the graphite crystals and demonstrate their wave nature by generating an interference pattern of concentric circles, known as Debye-Scherrer rings, on the phosphorescent layer of the glass tube (see Figure 2).

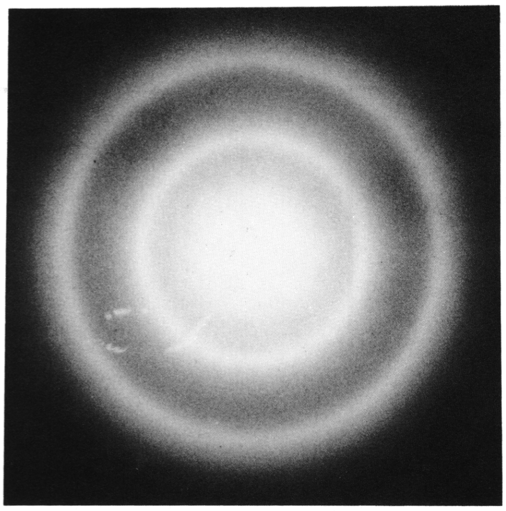

Figure 2: An example of an interference pattern of concentric circles, known as Debye-Scherrer rings, on the phosphorescent layer of a glass electron beam tube.

A schematic diagram of the electron beam tube assembly is shown in Figures 3 and 4. The electron beam is generated by the electron gun. To avoid collisions between electrons and air molecules, the tube is evacuated. Electrons are ejected by thermionic emission from the incandescent heater H. They are accelerated through the electric field generated by the electrode system K, G1 -- G4. The Wehnelt cylinder electrode G1 focuses electrons into a narrow beam [1], which is subjected to preliminary acceleration through the grid G2. The electrons are then strongly accelerated through the highly positive potential of the anode G3. The resulting beam is directed at a copper mesh with graphite powder on it, and thereafter into the main body of the electron beam tube. The diffracted electrons traverse the electron beam tube, striking a phosphorescent coating on the front of the electron beam tube. A phosphorescent material is one that emits light in response to incident high energy electrons.

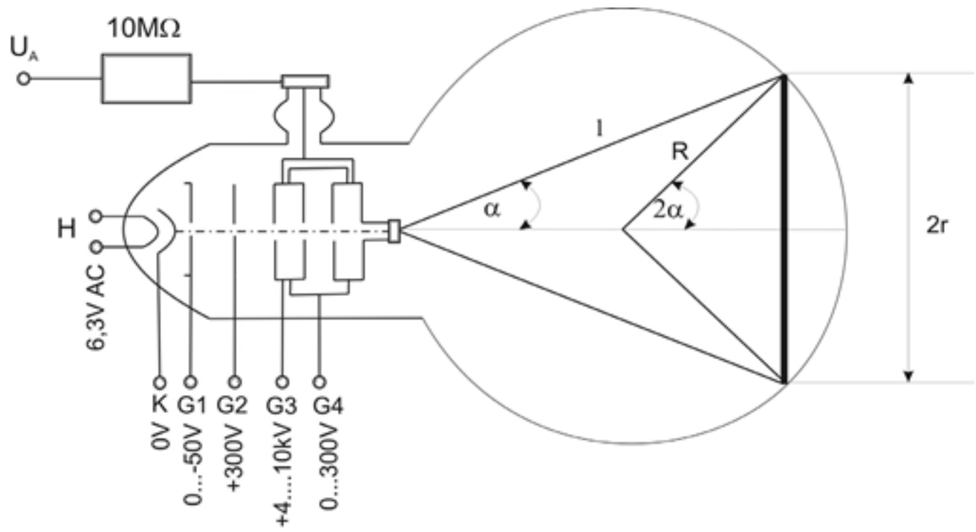

Figure 3: Set-up and power supply to the electron beam

2.2 Making your measurements – measuring the ring diameter

- Familiarise yourself with the Experimental set-up (Figure 1) and the circuit diagram of the electron diffraction tube and power supply (Figures 3 and 4).
- The high voltage power supply is connected to the anode G3 through a 10 MΩ protective resistor to limit the current draw (remember $I = V/R$).

- A low ac voltage is sufficient for heating the cathode for thermionic emission of electrons.
- Make sure that the power supplies are off (the switches on the rear side of the units) and all knobs on the power supplies are turned fully anticlockwise before turning anything on. The output voltages are electronically stabilised and can be read from the scales on the adjusting knobs.

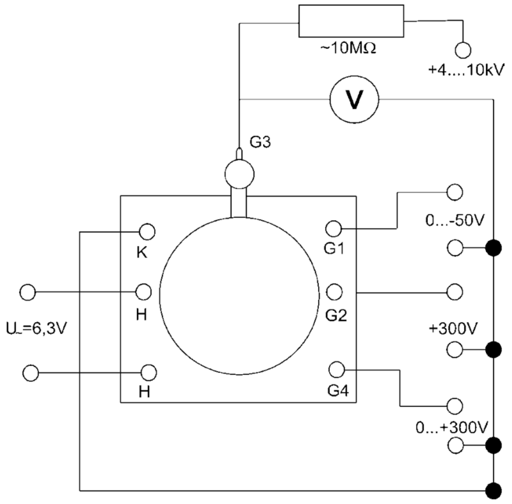

Figure 4: Circuit diagram showing the connections between the power supplies and the electron beam tube.

- Switch on the multi-function power supply (2 on Figure 1) from the back panel of the unit. Wait one minute for the cathode to heat up and achieve thermal stability.
- Set the voltage on the electrode G1 to -50 V using the second knob (from the left) on the multi-function power supply.
- Set the electrode G4 voltage to around 300 V.
- Slowly increase the accelerating voltage G3 (U_a) on the High Voltage Power Supply (read the anode voltage at the display of the high voltage power supply) until the concentric rings appear on the phosphorescent layer of the electron beam tube. This should happen at about 4 kV. Fast electrons are now diffracted from a polycrystalline layer of graphite.
- You may vary the accelerating voltage on G3 from 4 kV to 7.5 kV in this experiment.
- The diffraction rings can be diffuse and difficult to measure accurately. You can adjust G4 voltage to make the rings sharper.
- You should measure the ring radii using the plastic Vernier calipers provided (don't use metal calipers, they present an electric shock hazard and can damage the electron tube). You should think about how to accurately measure the ring diameter given how diffuse the rings are. (If you don't know how to use Vernier calipers, see Google).
- Think carefully about whether you want to measure the diameter of the rings directly and calculate the radius, or just measure the radius. The choice has an important impact on accuracy.
- After you have finished the experiment, first slowly decrease the voltage G3 on the High Voltage power supply, then the voltages on the electrodes G1 and G4 on the Multifunction power supply. Turn off the main switch at the back of each unit leave all electrical leads connected.

3 Background References

[1] https://en.wikipedia.org/wiki/Wehnelt_cylinder