

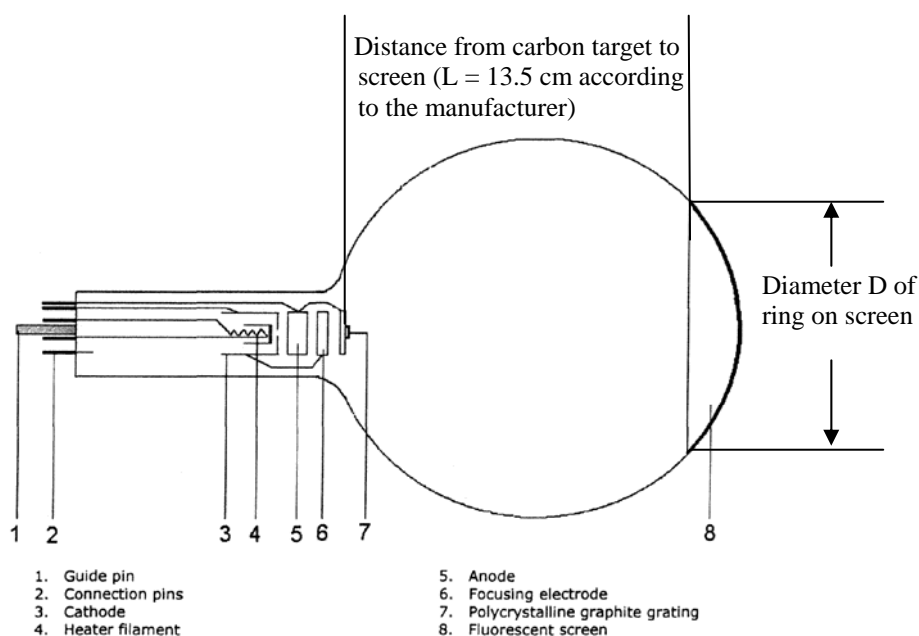
EXPERIMENT 13 ELECTRON DIFFRACTION

I. THEORY

In this experiment you will observe the wave-nature of electrons. A beam of electrons will be accelerated through a potential difference V_{ac} and each gain a kinetic energy $K = eV_{ac}$. The beam of electrons will then strike a micro-mesh nickel grating onto which a thin layer of polycrystalline graphitized carbon has been deposited. As the beam passes through this carbon target the electrons are diffracted by different layers of atoms. This is similar to the diffraction of x-rays from a crystal as discussed when studying diffraction of light.

The electrons will strike a luminescent screen causing it to glow. You should see two rings centered on a bright spot. The bright spot is caused by electrons that travel straight through the target. The rings are caused by electrons that diffract from different planes of atoms in the crystal. As with x-ray diffraction the Bragg condition $d \sin\theta = m\lambda$ where d is the spacing between the different layers of atoms will be applied. The two rings here are both first order ($m = 1$) maxima and d in each case one of the lattice plane spacings of the carbon crystal. The two values of d for this experiment are 0.213 nm and 0.123 nm.

In this experiment, you will measure the diameters of the two rings for a variety of values of the accelerating potential. You will then graph the results and from the slope of the two lines determine the spacing of the layers of atoms in the carbon target and compare them to the given values.



II. LABORATORY PROCEDURE

CAUTION: Hot cathode tubes are thin-walled, highly evacuated glass tubes. Treat them carefully as there is a risk of implosion. Do not subject the tube to mechanical stresses.

Do not exceed the stated operating parameters. If voltage or current is too high or the cathode is at the wrong temperature, it can lead to the tube being destroyed.

Anode current should not exceed 0.20 mA during the operation of the tube. Monitor the anode current carefully on the meter connected in the circuit.

If the anode current exceeds 0.20 mA or the graphite target starts to glow, immediately turn the voltage control knob on the high voltage power supply to zero and turn it off.

1. The following circuit will be set up for you before lab. The high-voltage source may look somewhat different from the one shown in the diagram, but its function is the same. It provides both the anode voltage and the accelerating voltage. The 0...50 V DC label refers to a low-voltage source that will be used to produce a bias voltage to be used in focusing the rings. The circle labeled I_A represents an ammeter which will be used to monitor the anode current.

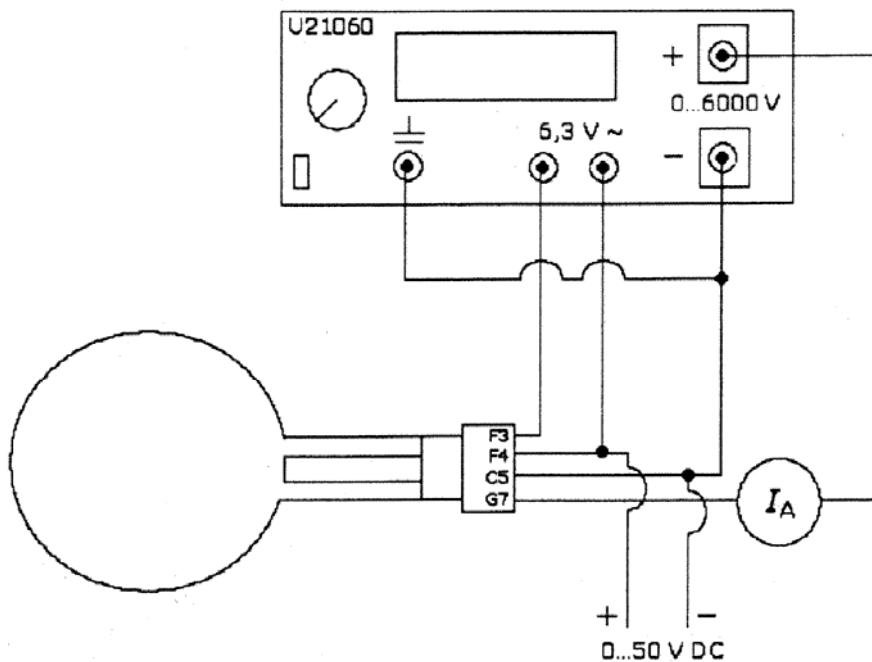


Fig. 2 Circuit diagram for the diffraction tube, 0 - 50 V DC focussing voltage (optional)

2. Turn on the high voltage power supply and wait about one minute for the filament to be heated before applying the accelerating potential. Turn on the bias voltage power supply, which will be used to focus the rings.

3. Apply an accelerating voltage of about 2.5 kV as read on the meter on the power supply. Darken the room. Have a flashlight handy and be sure to monitor the anode current carefully. Two rings should be visible now. You may want to adjust the bias voltage to get a sharper image.
4. Use the optical calipers and a meterstick to measure the diameters of the two rings. The rings have a finite thickness. Where should you measure the diameter? Why?
5. Record both of the diameters and the accelerating voltage in a table. Record the reading of the accelerating voltage after adjusting the bias voltage.
6. Repeat the above for accelerating voltage of approximately 3.0 kV to 5.0 kV in 0.5 kV increments.
7. Turn both power supply knobs to the zero position (full counterclockwise) and turn off the power supplies. Do not try to dismantle the circuit.

III. CALCULATIONS

1. Make a table containing the values of V_{ac} , $V_{ac}^{-1/2}$, and D for each ring.
2. Graph D vs. $V_{ac}^{-1/2}$ for each ring on one set of axes. Use a different symbol or color for data for each ring. Does each set of data appear to be linear? Draw in the best fit straight line through each set of data points.
3. Use the modified method of least squares to calculate the slope of each line. The modified method of least squares is required since the data should pass through the origin. The modified least squares method is included in section IV on the following page.
4. Relate the slope of your line to the lattice spacing d . Assume angles are small enough that $\sin \theta = \tan \theta = \theta$. Show that the maximum speed of the electrons is small enough that relativistic effects do not need to be taken into account. Calculate the values of the two lattice spacings and find the percent error in each.

IV.

MODIFIED LEAST SQUARES

In some cases, we will encounter a relation that is not only linear, but a direct proportion. If x and y are related by a direct proportion, then $y = mx + b$ with $b = 0$.

With this constraint, the sum S is given by

$$S = \sum_{i=1}^n (\Delta y_i)^2 = \sum_{i=1}^n (y_i - mx_i)^2 = \sum_{i=1}^n y_i^2 + m^2 \sum_{i=1}^n x_i^2 - 2m \sum_{i=1}^n x_i y_i$$

For this case, the sum S depends on only one unknown, m . We can find the value of m that makes S minimum by setting the derivative of S with respect to m equal to 0.

$$0 = \frac{dS}{dm} = 2m \sum_{i=1}^n x_i^2 - 2 \sum_{i=1}^n x_i y_i$$

Solving for m ,

$$m = \frac{\sum_{i=1}^n x_i y_i}{\sum_{i=1}^n x_i^2}$$

Since there are no subtractions in this formula, one does not tend to get zero divided by zero with the Modified Least Squares.