User's Manual

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FRANK HERTZ EXPERIMENT
Model: FH-3001
(Rev.: 23/07/2020)

Manufactured by

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INTRODUCTION

From the early spectroscopic work it is clear that atoms emit radiations at discrete frequencies. From Bohr's model the frequency of the radiation ν is related to the change of energy levels through $\Delta E = h\nu$. It is then to be expected that transfer of energy to atomic electrons by any mechanism should always be in discrete amounts. One such mechanism of energy transfer is through inelastic scattering of low-energy electrons.

Frank and Hertz in 1914 set out to verify these considerations.

(i) It is possible to excite atoms by low energy electron bombardment.

(ii) The energy transferred from electrons to the atoms always had discrete values.

(iii) The values so obtained for the energy levels were in agreement with spectroscopic results.

Thus the existence of atomic energy levels put forward by Bohr can be proved directly. It is a very important experiment and can be performed in any college or University level lab.

OPERATING PRINCIPLE

The Frank-Hertz tube in this instrument is a tetrode filled with the vapour of the experimental substance Fig. 1 indicates the basic scheme of experiment.

The electrons emitted by filament can be accelerated by the potential V_{G_2K} between the cathode and the grid G_2. The grid G_1 helps in minimising space charge effects. The grids are wire mesh and allow the electrons to pass through. The plate A is maintained at a potential slightly negative with respect to the grid G_2. This helps in making the dips in the plate current more prominent. In this experiment, the electron current is measured as a function of the voltage V_{G_2K}. As the voltage increases, the electron energy goes up and so the electron can overcome the retarding potential V_{G_2A} to reach the plate A. This gives rise to a current in the ammeter, which initially increases. As the voltage further increases, the electron energy reaches the threshold value to excite the atom in its first allowed excited state. In doing so, the electrons lose energy and therefore the number of electrons reaching the plate decreases. This decrease is proportional to the number of inelastic collisions that have occurred. When the V_{G_2K} is increased further and reaches a value twice that of the first excitation potential, it is possible for an electron to excite an atom halfway between the grids, loose all its energy, and then again gain enough energy to excite atoms and this lead to a second dip in the current. The advantage of this type of configuration of the potential is that the current dips are much more pronounced, and it is easy to obtain five fold or even larger multiplicity in the excitation of the first level.

Experiment consists of the following :

- Argon filled tetrode
- Filament Power Supply : 2.6 - 3.4V continuously variable
- Power Supply for V_{G_1K} : 1.3 - 5V continuously variable
- Power Supply for V_{G_2A} : 1.3 - 12V continuously variable
- Power Supply for V_{G_2K} : 0 - 95V continuously variable
- Saw tooth waveform for CRO display
  Scanning Voltage : 0 - 95V
  Scanning Frequency : 115 ± 20Hz.
- Multirange Digital Voltmeter
  Range : 0 - 100V, with 100% over
  Display: 3 ½ digit 7-segment LED with auto polarity and decimal indication
- Multirange Digital Ammeter
  Range : 0 – 100, 0-10 μA & 0-1μA
  Display: 3 ½ digit 7-segment LED with auto polarity

All the above are housed in a single cabinet and operates at 220V ±10%, 50Hz power source.

The instrument can not only lead to a plot of the amplitude spectrum curve by means of point by point measurement, but also directly display the amplitude spectrum curve on the oscilloscope screen. This instrument can thus be used as a classroom experiment as well as for demonstration to a group of students.

ANALYSIS OF THE DATA

Data obtained for the excitation potential point by point are shown in Fig. 3. The readings are taken for 1V changes on grid 2 (V_{G_2K}). A significant decrease in electron (collector) current is noticed every time the potential on grid 2 is increased by approximately 12V, thereby indicating that energy is transferred from the beam in (bundles) quanta of 12 eV only. Indeed, a prominent line in the spectrum of argon exists at 1048 Å corresponding to eV=11.83.

The location of the peaks is indicated in Fig. 3. Average value of spacing between peaks is 11.75 eV compared with the accepted value of 11.83V.

UNPACKING

Unpack the instrument carefully and check the accessories with the packing list. The instrument is checked thoroughly before dispatch, damage/shortage, if any should be reported immediately.

Take out the Frank-Hertz Tube from its window-marked 'Frank-Hertz Tube Window' by removing its cover.

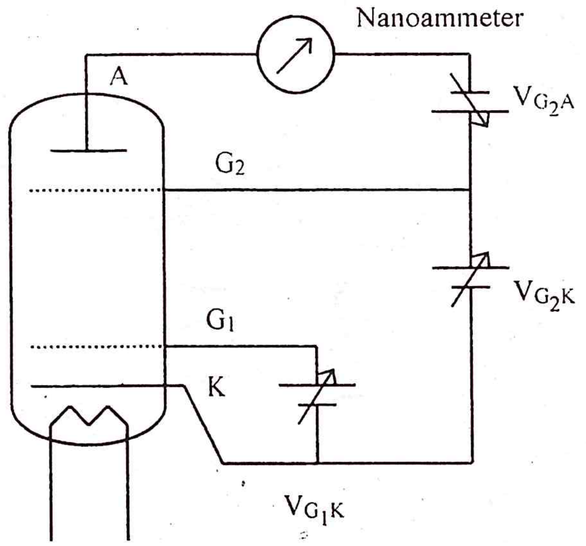

Fig. 1 : Circuit diagram of Frank – Hertz experiment

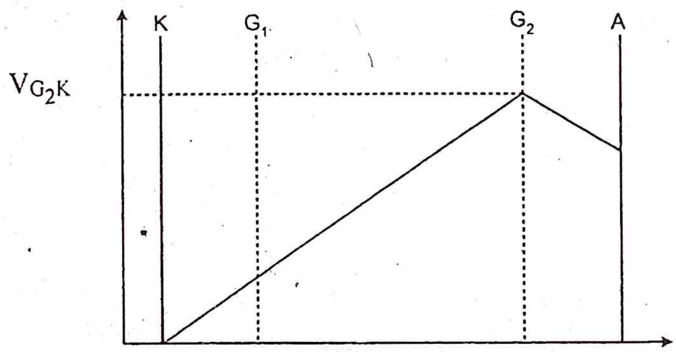

Fig. 2 : Configuration of the Potential in Frank-Hertz Experiment

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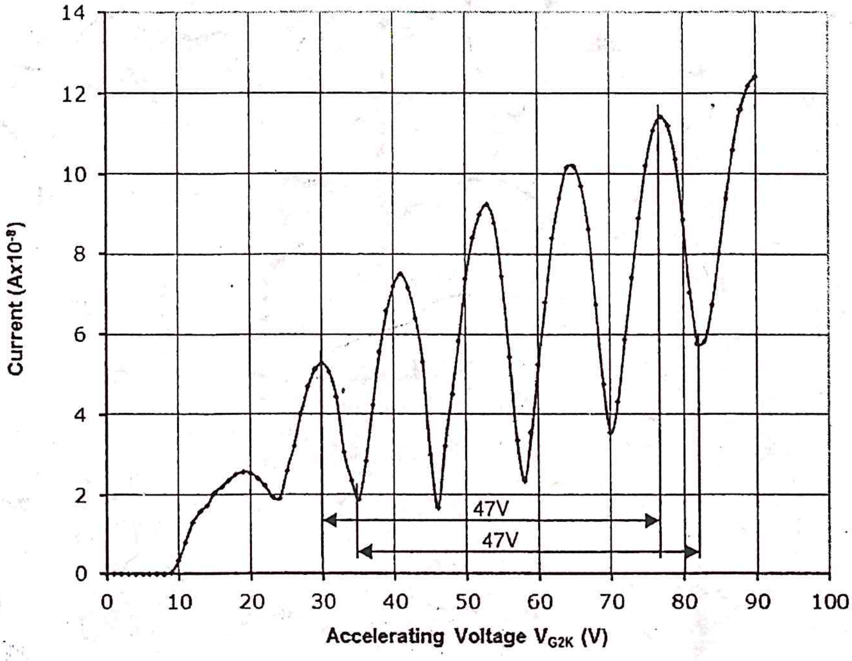

Fig. 3. Plot of Accelerating Voltage Vs Beam Current

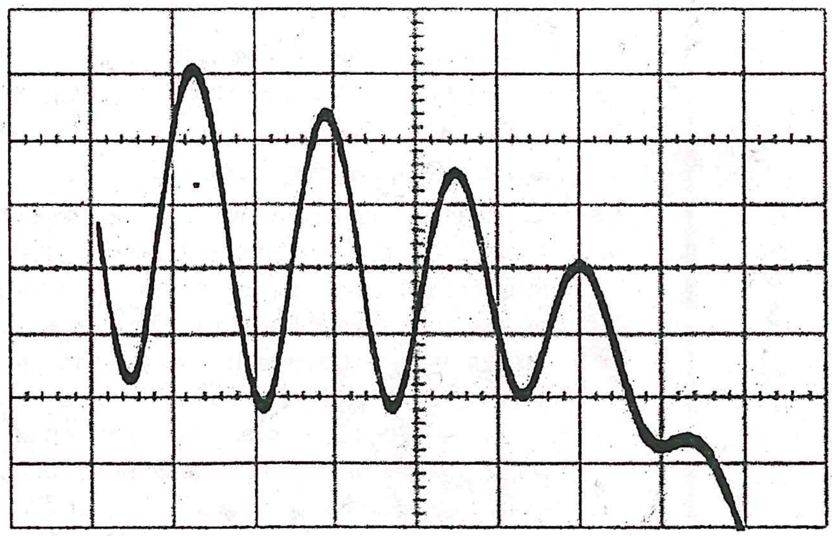

Fig. 4 Oscilloscope display of Frank-Hertz Experiment

OPERATING INSTRUCTIONS

1) Ensure that the Electrical power is 220V ±10%, 50Hz.

2) Before the power is switched 'ON' make sure all the control knobs are at their minimum position and Current Multiplier knob at 10^{-7} position.

3) Switch 'ON' the power.

4) Turn the Manual-Auto Switch to Manual, and check that the Scanning Voltage Knob is at its minimum position.

5) Turn Voltage Display Selector to V_{G_1K} and adjust the V_{G_1K} knob until voltmeter reads 1.5V.

6) Turn Voltage Display Selector to V_{G_2A} and adjust the V_{G_2A} knob until the voltmeter read 7.5.

When you have finished step 1-5, you are ready to do the experiment with following parameters.

Filament voltage	: ~3.5 V (midway position on panel)
V_{G_1K}	: 1.5 V
V_{G_2A}	: 7.5 V
V_{G_2K}	: 0 V
Current multiplier	: 10^{-7}A

These are suggested values for the experiment. The experiment can be done with other values also.

7) Rotate V_{G_2K} knob and observe the variation of plate current with the increase of V_{G_2K}. The current reading would show maxima and minima periodically. The magnitude of maxima could be adjusted suitably by adjusting the filament voltage and the value of Current Multiplier. Now take the systematic readings, V_{G_2K} vs. plate current. For better resolution, the reading may be taken at a interval of 1V. Plot the graph with output current on Y-axis and accelerating voltage V_{G_2K} at X-axis.

8) Turn the Manual-Auto switch to 'Auto', connect the instruments Y, G, X sockets to Y, G X of oscilloscope. Put the Scanning Range switch of oscilloscope to X-Y mode/external 'X'. Switch on the power of oscilloscope, adjust the Y and X shift to make the scan base line on the bottom of screen. Rotate the 'Scanning Knob' of the instrument and observe the wave-form on the oscilloscope screen. Adjust the 'Y-gain' and 'X-gain' of oscilloscope to make wave-form clear and Y amplitude moderate. Rotate the scanning potentiometer clockwise to end. Then the maximum scan voltage is 85V. Measure the horizontal distance between the peaks. The distance of two consecutive peaks (count the grids) and multiply it by V/grid factor (X-gain) of oscilloscope. This would give the value of argon atom's first excitation potential in eV.