Expt. 25 Franck-Hertz experiment

Ⅰ. Purpose

Verify the existence of atomic energy level through the Franck-Hertz experiment.

Ⅱ. Principle

When an atom makes a transition from one stable state to another stable state under external actions, it absorbs or emits electromagnetic waves of a certain frequency, ν, given by:

$$h_\nu = E_n - E_m$$

Where E_n and E_m are the nth and mth excited state energies of the atom respectively and h is Planck's constant.

The diagram of the experiment is shown as Figure 25 – 1. The Franck-Hertz Tube is a kind of tetrode, filled with argon gas. This experiment verifies the existence of atomic energy levels by investigating slow electrons colliding with atoms of argon. The hot cathode emits electrons and after being accelerated by the accelerating voltage U_{G_2K} between the cathode K and the second grid G_2, they cross the grid G_2. The decelerating voltage U_{G_2P} is applied between the plate and second grid G_2. If the electron has enough energy, it can overcome U_{G_2P} to reach the plate, forming the plate current I_P. The main purpose of this experiment is to observe the variation of the plate current with accelerating voltage.

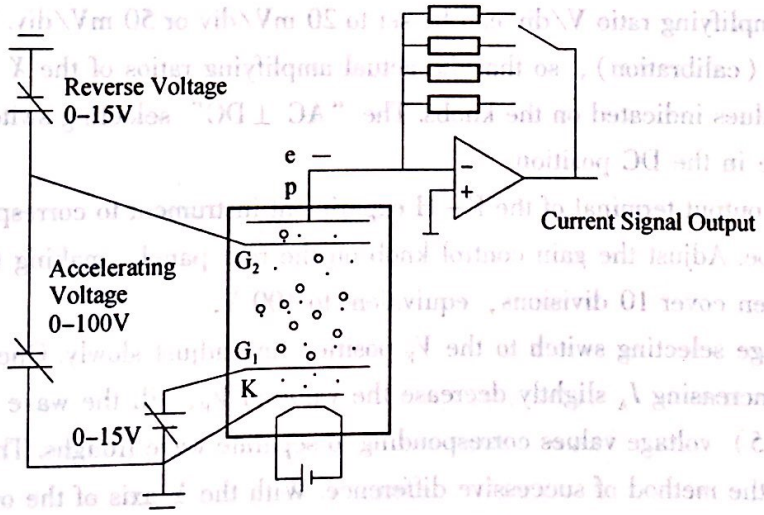

Figure 25 – 1 Schematic Diagram for Franck-Hertz Experiment

On gradually increasing the voltage U_{G_2K}, if the atomic energy level does exist, then the curve

$U_{G_2K} - I_P$ should be of form depicted in Figure 25 – 2. This curve shows the energy exchange between the argon atoms and the electrons in the space of K – G_2. The difference between two U_{G_2K} values corresponding to the two neighbouring minimum values of I_P equals the first excitation potential U_0 of the argon atom. When $U_{G_2K} = nU_0$, the plate current will decrease to a minimum value.

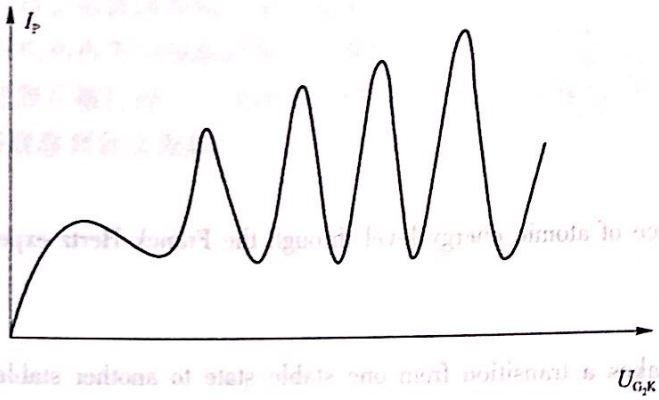

Figure 25 – 2 V – I Characteristic Curve in F – H Experiment

Ⅲ. Experimental

1. Preheating

Before the start of experiment switch the measurement range to 10^{-6}, turning all potentiometers fully anticlockwise, to make the voltage to decrease to the minimum value. Then switch it on, setting the voltage selecting switch on the V_{G_1K} position and adjust (usually about 1.5V), and then switch to the V_{G_2P} position and adjust (usually about 7.5V). Begin observations after the F – H tube has preheated for three minutes.

2. Oscilloscope mode

① Switch the oscilloscope to the X – Y mode. Set the *X* axis amplifying ratio knob V/div to 0.2 V/div. The *Y* axis amplifying ratio V/div can be set to 20 mV/div or 50 mV/div. Then put the knobs to the CAL position (calibration), so that the actual amplifying ratios of the *X* axis and *Y* axis accurately equal the values indicated on the knobs. The "AC ⊥ DC" selecting switches for both *X* axis and *Y* axis should be in the DC position.

② Connect the output terminal of the F – H experiment instrument to corresponding input terminal of the oscilloscope. Adjust the gain control knob on the rear panel, making the horizontal scanning line in the screen cover 10 divisions, equivalent to 100 V.

③ Set the voltage selecting switch to the V_F position and adjust slowly. Once some wave crests are found with fast increasing I_A slightly decrease the value of V_F, till the wave form is stable.

④ Read 6 (or 5) voltage values corresponding to separate wave troughs. Then find the first excitation potential by the method of successive difference. With the Y axis of the oscilloscope standing for the plate current, you need to record the number of divisions to get your reading.

3. Manual mode

Observe the F – H curve, and adjust to find out the optimal filament voltage V_F. Switch the

voltage selecting switch to the position of "Accelerating Voltage", and adjust the accelerating voltage knob slowly. When the first peak value appears, record I_A and V_{G_2K}, and then measure two nearby points of $V_{G_2K} \pm 2V$; then, increase V_{G_2K}, and when the first valley value appears, record I_A and V_{G_2K}, then measure two nearby points of $V_{G_2K} \pm 2V$. Totally measure 6 (or 5) peak values and 6 (or 5) valley values. Record the current value and the voltage value on the experiment instrument.

From the F – H experimental curve determine the first excitation potential.

4. Wave form of the accelerating voltage

Observe the wave form of the accelerating voltage on the second grid of the F – H tube, measuring its amplitude and frequency. Notice that the oscilloscope should be in the Y – t mode.

Notes: after the experiment is finished, turn the filament voltage V_F to the minimum (anticlockwise), and then switch it off.

Ⅳ. Questions

1. In the condition of decelerating voltage $V_{G_2P} = 0$, can you record a fluctuation of I_P?

2. Consider the third wave trough of the F – H curve. At what location in the F – H tube does the relevant electron argon inelastic collision happen?

3. Based on the speed of the electrons emitted from the cathode, explain the form of the I_P wave crest? In the case of the initial velocity of all electrons being zero, would I_P decrease vertically? Draw the F – H curve for this situation?

4. For the manual mode and oscilloscope mode detail separately the characteristics of the voltage change on the second grid.

实验二十五　弗兰克—赫兹实验

一、实验目的

通过弗兰克—赫兹实验证明原子能级（分立态）的存在。

二、实验原理

当原子受外界作用而从一个稳定态过渡到另一个稳定态时，就吸收或放出一定频率的电磁波：

$$h_\nu = E_n - E_m$$

式中，E_n和E_m分别为第 n 和第 m 激发态，h 为普朗克常数。

实验原理如图 25－1 所示。弗兰克—赫兹管是一种四极管，内部充满氩气。本实验是用慢电子碰撞氩原子来证明原子能级的。电子从热阴极发出，阴极 K 和第二栅极 G_2 之间的加速电压 U_{G_2K}使电子加速，并能穿过第二栅极的栅网。在板极 P 和第二栅极 G_2 之间加有减速电压 U_{G_2P}。如果电子的能量较大，就能克服 U_{G_2P}到达板极，形成板极电流 I_P。实验的主要工作就是观察在一定的加速电压控制下，板流的变化情况。

当 U_{G_2K}电压逐渐增加时，如果原子能级确实存在，就能观察到如图 25－2 所示的 U_{G_2K}－I_P 规则变化曲线。该曲线反映了氩原子在 K－G_2 空间与电子进行能量交换的情形。当$U_{G_2K} = nU_0$时，板流都会出现极小值。相邻的两个极小值对应的 U_{G_2K}的差就等于原子的第一激发电位 U_0。

三、实验内容与步骤

1. 预热

实验前将量程置于 10^{-6}挡，所有电位器都逆时针旋转到头，使得各挡电压分别降低到最小值。然后开电源，将电压选择开关置于 V_{G_1K}挡并适当调节（一般为 1.5V 左右），再拨到 V_{G_2P}挡并调节（一般 7.5V 左右）。预热 F－H 管 3min 后开始观测。

2. 观测

（1）将示波器置于 X－Y 工作方式。X 轴的放大倍率旋钮 V/div 置于 0.2 V/div。Y 轴的放大倍率 V/div 可置于 20mV/div 或 50mV/div。然后把 X 轴和 Y 轴放大倍率定标，即微调旋钮置于 CAL（校准）处，这时，X 轴和 Y 轴的实际放大倍率才准确等于旋钮指示值。X 轴和 Y 轴的“AC⊥DC”选择开关都置于 DC 处。

（2）将 F－H 实验仪的输出端与示波器的对应输入端连接。调节后面板上的增益调节旋钮，使屏上的水平扫描线径迹正好为 10 格，相当于 100V。

（3）将“选择”开关置于示波器挡将“电压”选择开关置于 V_F 挡并缓慢调节。一旦发现几个波峰增长较快时，再微微减小 V_F 值，直到波形稳定。

（4）分别读出 6（或 5）个波谷对应的电压值。然后用逐差法求第一激发电位。示波器的纵轴代表板极电流，读数时记录格数即可。

3. 手动方式观测

先用示波器方式观测 F－H 曲线，调出最佳的灯丝电压 V_F。然后将“选择”开关置于手动挡，电压选择开关拨到“加速电压”位置，缓慢调节加速电压旋钮。调出第一个峰值时，记录 I_P 和 V_{G_2K}，再测该点附近的 V_{G_2K} ±2V 的两个点；然后增大 V_{G_2K}，调出第一个谷值时，记录 I_P 和 V_{G_2K}，再测该点附近的 V_{G_2K} ±2V 的两个点。共测 6（或 5）个峰值和 6（或 5）个谷值。记录 F－H 实验仪上的电流和电压值。

作出 F－H 实验曲线，并求出第一激发电位。

4. 加速电压波形

观察示波器方式下 F－H 管第二栅极上加速电压的波形，测量其幅度和频率。注意此时示波器应改用 Y－t 方式。

注意：实验完毕后将灯丝电压 V_F 逆时针调到最小，再关电源。

四、思考题

1. 在减速电压 $V_{G_2P}=0$ 时，能否记录到 I_P 的有规则起伏？
2. 分析 F－H 曲线第三个波谷处，F－H 管中电子与氩原子发生非弹性碰撞的位置。
3. 根据阴极发射电子的速度分布来解释 I_P 峰顶的形状？若假设所有的电子的初速度都为零，那么 I_P 在下降时，是否会垂直下降？并画出此时的 F－H 曲线？
4. 手动方式和示波器方式，第二栅极上的电压变化各有什么特点？

都6组.

实验十二　弗兰克—赫兹实验

1. 用示波器观测

	波谷 1	波谷 2	波谷 3	波谷 4	波谷 5
I_A					
V_P					

用逐差法计算第一激发电位。

2. 手动记录：先找波峰或波谷，表格中右、左分别为波峰(谷)的 $V_P \pm 2V$

	左	波峰 1	右	左	波谷 1	右
I_A						
V_P						

	左	波峰 2	右	左	波谷 2	右
I_A						
V_P						

	左	波峰 3	右	左	波谷 3	右
I_A						
V_P						

	左	波峰 4	右	左	波谷 4	右
I_A						
V_P						

用坐标纸作图，用逐差法计算第一激发电位。

3. 加速电压

当 F—H 仪置于示波器位置时，根据所测加速电压的幅度和频率，在坐标纸上画出加速电压的波形。

思考题 1、3.