重庆大学-辛辛那提大学联合学院

学生实验报告

CQU-UC Joint Co-op Institute (JCI)
Student Experiment Report

实验课程名称 Experiment Course Name College Physics Experiment II

开课实验室（学院）Laboratory (School) CQU-UC

学院 School JCI 年级专业班 Student Group 2018 ME01

学生姓名 Student Name 易弘睿 学号 Student Number 20186103

学年 Academic Year 2019——2020 学期 Semester Spring

成绩 Grade	
教师签名 Signature of Instructor	

批改说明 Marking instructions:

指导老师请用红色水笔批改，在扣分处标明所扣分数并给出相应理由，在封面的平时成绩处注明成绩。

Supervisors should mark the report with a **red ink pen**. Please write down **the points deducted** for each section when errors arise and specify the corresponding reasons. Please write down **the total grade** in the table on the cover page.

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JCI ____Experiment Report

学院 School Chongqing University 年级专业班 Student Group 2018ME01

姓名 Name 易弘睿 学号 Student Number 20186103

开课学院、实验室 Academic School/ Laboratory CQU-UC

实验时间 Date of Experiment 2020 年 Year 4 月 Month 9 日 Day

报告时间 Date of Report 2020 年 Year 4 月 Month 12 日 Day

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<tr><td rowspan="2">课程名称
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Experiment Project</td><td rowspan="2">Frank Hertz Experiment</td><td colspan="5">实验项目类型
Type of experiment project</td></tr>
<tr><td>验 证
Verification</td><td>演 示
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实验目的 Description/Instruction:

1. Understanding the principle of Frank-Hertz experiment.
2. Measure the basic charge.
3. The first excitation potential of argon atom is measured by experimental method. It is proved that the atomic energy level is pure.

原理和设计 Principle and Design:

Bohr's atomic energy level theory:

(1) The atom can only stay in some stable state for a long time (referred to as steady state). When atoms are in these states, they do not emit or absorb energy; each state has a certain amount of energy, and its values are separated from each other. No matter how the energy of an atom changes, it can only transition from one state to another.

(2) The atom emits or absorbs a certain amount of energy from one stationary state to another, and the radiation frequency is certain and satisfied:

$$hv = E_m - E_n \tag{1}$$

h is Planck constant, equals to $6.63 \times 10^{-34} J/s$

One of the ways in which atoms can achieve energy level transitions is through the collision of electrons with a certain energy with atoms. An electron with an initial velocity of zero is obtained by an accelerating electric field with a potential difference of U. The energy obtained is eU. When an electron having such energy collides with an atom in a rare gas, energy exchange occurs, such as an E band. The ground state energy of the mercury atom, E_2 represents the energy of the first excited state of the mercury atom, then the energy transmitted from the electron by the mercury atom happens to be:

$$eU_0 = E_2 - E_1 \tag{2}$$

At this time, the argon atoms will transition from the ground state to the first excited state. The corresponding potential difference is called the first excitation potential of argon.

In the mercury-filled Frank-Hertz tube, as *figure 1*, electrons are emitted from the cathode K, and the accelerating voltage U_{G1K} between the cathode K and the gate G_1 accelerates electrons. A repellent voltage U_{AG2} is applied between the A and the G. When electrons enter the GA space through the G_1G_2 space, if there is a large energy ($\geq eU_{AG2}$), the reverse repulsive electric field can be passed to reach the plate forming current, which is detected by the micro ammeter IP. If electrons collide with mercury atoms in the KG space and give some of their own energy to the mercury atoms to excite the latter, the electrons themselves have little energy left, so that they are folded back after the gate is insufficient to overcome the repulsive electric field. Gate. At this time, the current through the micro galvanometer will be significantly reduced.

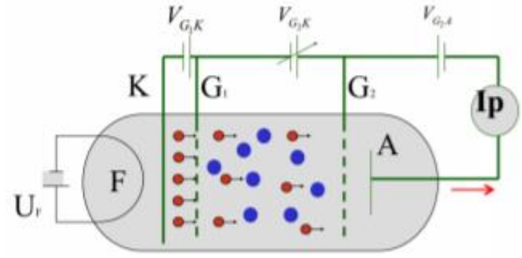

Figure 1 Mercury-filled Frank-Hertz Tube

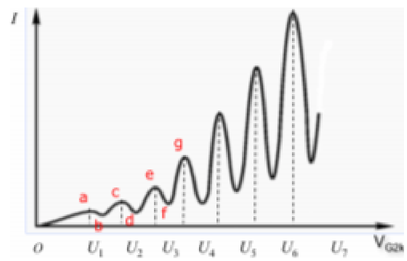

Figure 2 Excitation Curve

During the experiment, observe the phenomenon that the current of the galvanometer gradually increases with U_{GK1}. If the atomic energy level does exist, and there is a certain energy difference between the ground state and the first excited state, the curve as shown in *Figure 2* can be observed. When the voltage between KG reaches the first excitation potential U_0 of the mercury atom, the electron collides with the mercury atom near the gate, and all the energy obtained from the accelerated electric field is given to the latter, and the latter is excited from the ground state. To the first excited state. The electron itself is completely transferred to the mercury atom due to the energy, and even if it passes through the gate, it cannot be folded back to the gate by overcoming the repulsive electric field. Therefore, the plate current IA will be significantly reduced (*Figure 2-ab*). As the gate voltage increases, the energy of the electron increases, and after the collision with the mercury atom, enough energy is left to overcome the reverse repulsive electric field and reach the plate A. At this time, the current starts to rise (*Figure 2-bc*). Until the voltage between KG is twice the first excitation potential of the mercury atom, the electrons lose energy in the KG space due to the secondary collision, which in turn causes the first plate current to drop (*Figure 2-cd*). The latter part is also the same. The cathode and gate voltage difference $U_m - U_{m+1}$ corresponding to each plate current drop is the first excitation potential of the mercury atom.

Generally, the atom is in the micro-state for a short time, it will automatically transition back to the ground state, and release the energy value obtained at the same time. It radiates in the form of light, and its frequency is:

$$V = \frac{eU}{h} \tag{3}$$

It can be inferred that the radiation energy of mercury atom from the first excited state to the ground state should be eUe. The wavelength emitted in the form of photon quantum should be calculated by:

$$\lambda = \frac{hc}{eU_0} \tag{4}$$

where the propagation speed of light in vacuum C=3.00×10^8m/s. The electron charge e=1.6×10^{-19}C. The first excitation potential $U_0 = 4.9V$ of mercury atom.

实验器材 List of instruments and materials:

Franck-Hertz experiment instrument:

Current	V_F	V_{G1K}	V_{G2P}	V_{G2K}
1μA	2.57V	1.77V	9.0V	0-90V

Table 1 Instrument Parameter

实验步骤 Implementation:

1. According to the principle, connect the wires and turn on the switch after ensuring there is no mistake.
2. Turn each knobs as required as data shows in the *Table 1* above.
3. Use the working way of “Manual”.
4. Change the accelerating voltage from zero, record the value of current every 0.5V increase. Note how the value of current changes.
5. Draw the curve of accelerating voltage-current.
6. Calculate average V and wavelength of radiation use the data in diagram.

实验结果和数据处理 Results and Data processing:

1. Automatic Operation

When using the automatic operation mode, the excitation curve look like this:

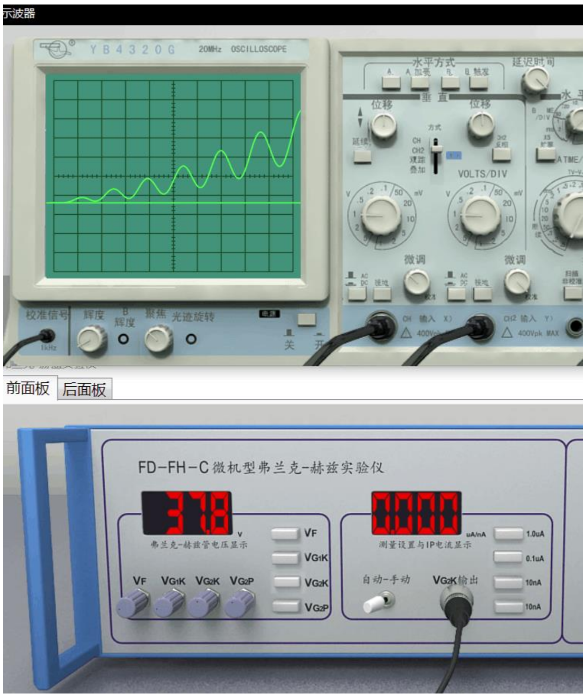

Figure 3 UG2K-IP Excitation Curve (Automatic Operation)

2. Manual Operation

Data is as below:

UG2K(V)	IP(μA)
0	0
15.8	0.0142
20.4	0.0036
25.8	0.0348
30.8	0.0096

36.4	0.0606
41.8	0.0186
47.8	0.0916
52.8	0.0324
60.4	0.127
65.4	0.0558
72.4	0.1698
78.2	0.0766

Draw the curve as below:

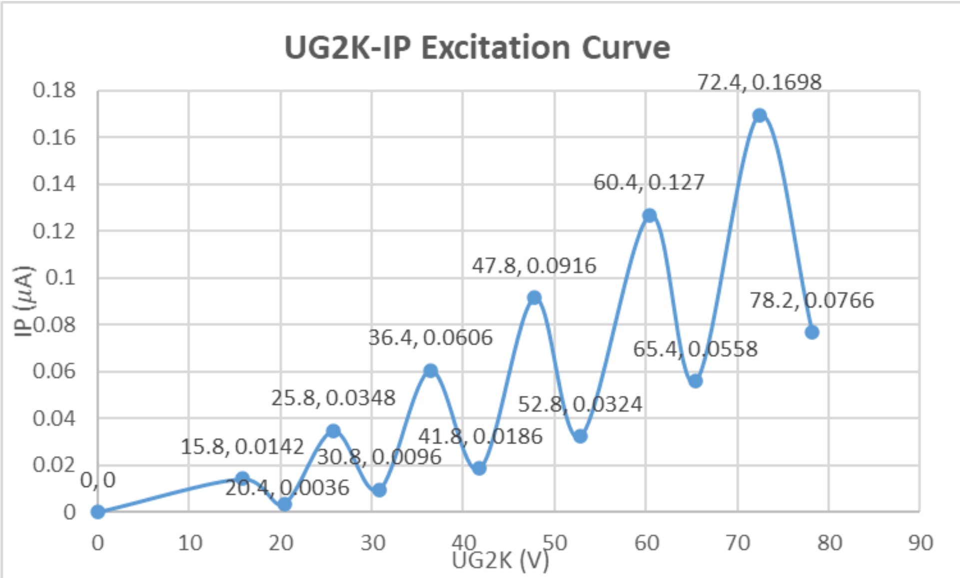

Figure 4 UG2K-IP Excitation Curve (Manual Operation)

$\bar{V}_0 = \frac{(47.8-15.8)+(52.8-20.4)+(60.4-25.8)+(65.4-30.8)+(72.4-36.4)+(78.2-41.8)}{3\times 6}$=11.44V

By formula (4):

$$\lambda = \frac{6.63\times 10^{-34}\times 3\times 10^{8}}{1.6\times 10^{-19}\times 11.44} m = 1.09\times 10^{-7} m = 109nm$$

According to the standard data, V0 should be 106.6 nm. So the error:

$E_r = \frac{|\lambda-\lambda_{Ar}|}{\lambda_{Ar}}\times 100\% = \frac{|109-106.6|}{106.6}\times 100\% = 2.25\%$, less than 5%, which can be accepted.

实验讨论 Discussions:

1. Errors

Errors may come from two parts: measurement errors and instruments errors.

(1) The data is obversely abnormal before VG2K increasing to 10V. I think it is not an operation error as current starts to appear even when VG2K =0. It may because that teacher used this instrument to demonstrate, so there was still current remaining in it.

(2) In the experiment, because the difference of voltage in each step are not continuous, the measured peak value will have some errors.

(3) Other errors may come from instruments, such as aging and abrasion.

2. Discussion

(1) I-U curve current is not very steep, what is the main reason?

Because the thermal electron energy emitted by the k-pole obeys the Maxwell statistical distribution law, the drop of the pole current is not abrupt, but the "peak" and "valley" near the maxima and minima have a certain width.

(2) Is the voltage corresponding to the first peak equal to the first excitation potential? Why?

Is not equal to. Because the thermal motion is excited, the number of electrons occupied in the lowest excited states is equal to or greater than the number of electrons in the base attitude. The voltage corresponding to the first peak is not equal to the first excited bit. In this experiment, in addition to the inelastic collisions of electrons and gaseous atoms, there are also elastic collisions and energy exchanges between gas atoms caused by collisions with each other due to heat weights.

物理实验 原始实验数据记录

Experiment Data

姓名 Name_____易弘睿_____学号 Student Number_____20186103_____实验时间_2020.4.9_

实验名称 Name of experiment: Frank Hertz Experiment

仪器名称	量程	最小量	估读误差	仪器误差	零位误差
Digital ammeter	0~10 V	0.001	0.001		
Digital Voltage	0~100	0.5	0.5		

实验数据 Experiment Data （表格自拟）

以加速栅电压VG2K为横坐标，阳极电流Ip为纵坐标，绘制氩的UG2K~Ip激发曲线，用逐差法计算出氩原子的第一激发电位。

(1)测量峰值、谷值及对应的IP输出值，填入数据表格：

注：IP输出值：弗兰克-赫兹实验仪显示读数*"测量设置与IP电流显示"档位，例如：显示读数：1.32，档位：0.1uA档，填入数据表格数值：1.32*0.1=0.132

谷)	第1个波峰(波谷)	第2个波峰(波谷)	第3个波峰(波谷)	第4个波峰(波谷)	第5个波峰(波谷)	第6个波峰(波谷
V	15.8	25.8	36.4	47.8	60.4	72.4
值/uA	0.01422	0.0348	0.0606	0.0916	0.1270	0.1698
V	20.4	30.8	41.8	52.8	65.4	78.2
值/uA	0.0036	0.0096	0.0186	0.0324	0.0558	0.0766

(2)逐差法处理峰值、谷值：

波谷)	(第4个波峰(谷)-第1个波峰(谷))/3.0	(第5个波峰(谷)-第2个波峰(谷))/3.0	(第6个波峰(谷)-第3个波峰(谷
值/V	10.67	11.53	12
值/V	10.8	11.53	12.13

(3)根据数据表格，计算Ar原子第一激发电位平均值(单位：V)= 11.44

关闭

指导教师：边立功