

5. Experimental Contents

- 1) Measure the $V_{G2K}-I_P$ curve of the F-H mercury tube, observe the quantization of atomic energy, and acquire the first excitation potential of mercury atoms;
- 2) Use different furnace temperature T , retarding voltage V_{G2P} , filament voltage V_F and other parameters to study the influence of these parameters on the F-H experimental curve, such as curve shape, peak number, etc.
- 3) Measure the potential of higher excited states of mercury atoms and observe the 6^3P_1 , and 6^1P_1 states.

6. Experiment Procedures

Experiment 1: Measurement of the first excitation potential of mercury atoms

- 1) Set the temperature of furnace

Make sure the probe of the temperature sensor is well inserted into the hole on the back side of the furnace. Turn on the power of the temperature controller; use the “Up” and “Down” buttons to set the temperature of the furnace (usually set at 220 °C). It takes about 15-20 minutes to reach the set temperature. After reaching the set temperature, wait a few more minutes to let it stabilized. Pay attention to the display value of the temperature controller.

- 2) Connect wires

Refer Figure 6 to connect wires.

Note: 1. Do not turn on the power of the instrument while doing wire connections.

2. Do not use the two BNC terminals on the rear panel (They are reserved terminals).

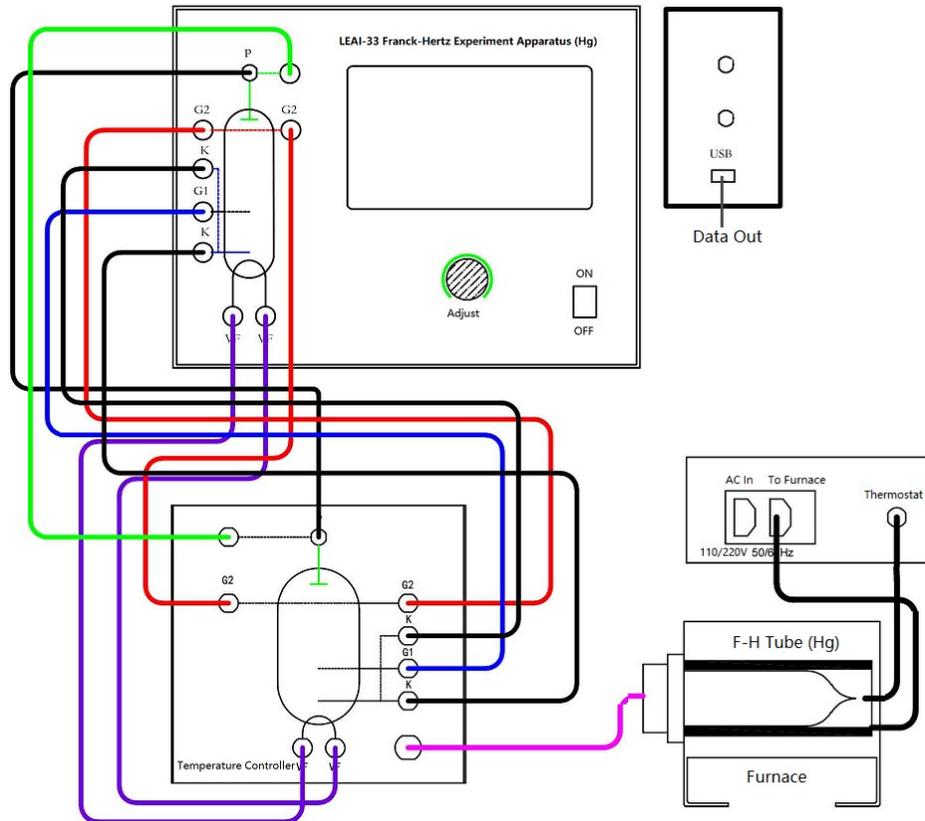


Figure 6 Wiring diagram for measurement of the 1st excitation potential of mercury atoms

3) Measure the 1st excitation potential of mercury atom

* Refer Appendix I to operate the touch screen for setting parameters and doing measurements.

- a) When the furnace temperature reaches the set value, turn on the power of the main experimental unit;
- b) According to the recommended working voltages of the mercury tube shown on the label attached on the back panel of the main unit, set V_F , V_{G1K} , and V_{G2K} respectively.
- c) Qualitative observation: use “automatic” mode to observe the F-H curve;
- d) Manual measurement: adjust voltages of the F-H tube appropriately. Starting from 0 V, gradually increase the accelerating voltage V_{G2K} . With interval 1.0 V, record plate current I_p at each voltage. After 4.0 V, change voltage interval to 0.5 V till to 60 V. In addition, around each peak or valley, finely adjust V_{G2K} with minimum interval to

achieve the local maximum/minimum value of the plate current I_p and record the corresponding V_{G2K} value.

- e) Change parameters such as furnace temperature, retarding voltage, and/or filament voltage (note: do not exceed the allowed maximum filament voltage given to the apparatus. Each time changing V_F , wait a few minutes before acquiring data), measure the relationship between $V_{G2K} - I_p$ under different parameters.

4) Analyze data

Plot $V_{G2K} - I_p$ curve. Based on the curve, by determining the voltage values at peaks/valleys, the 1st excitation potential of mercury atoms is calculated.

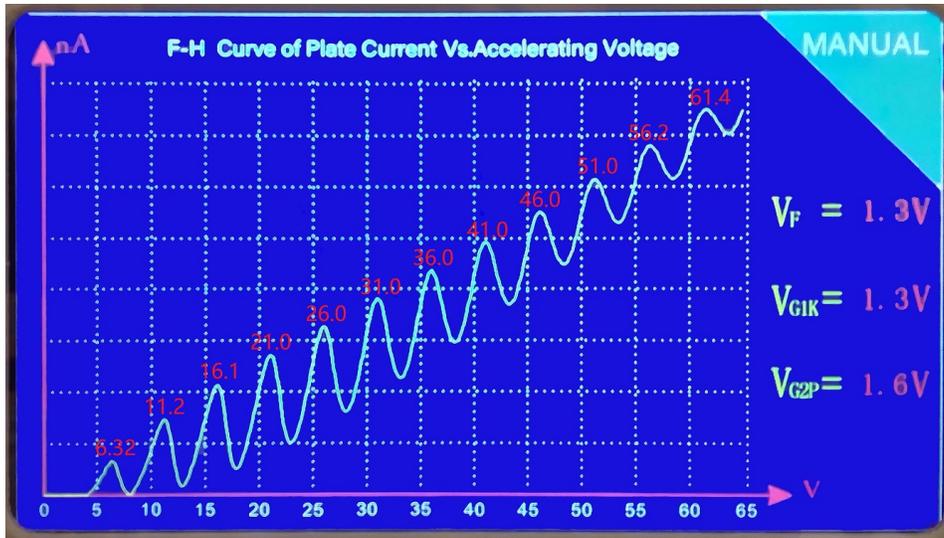


Figure 7 A sample of actually measured $V_{G2K} - I_p$ curve
(filament 1.3 V, V_{G1K} 1.3 V, V_{G2P} 1.6 V, furnace temperature 220 °C)

To determine the location of each local minimum (valley) or maximum (peak) with a better accuracy, the data segment around each local minimum or maximum should be curve-fitted to a quadratic polynomial function using software (e.g. Excel), as shown below

$$I_p = aV_{G2K}^2 + bV_{G2K} + c$$

Thus, the location of each local minimum or maximum can be determined as

$$(V_{G2K})_{\min/\max} = -\frac{b}{2a}$$

Using the derived locations of local valleys and peaks, the mean with standard deviation of the the 1st excitation potential of mercury atoms can be calculated.

Discuss the influence of furnace temperature, retarding voltage, filament voltage and other parameters on the $V_{G2K} - I_p$ curve.

5) Export experimental data

This apparatus is equipped with a USB interface on the back panel, which can export experimental data to a computer or a storage device. The data format is a TXT text file. Students can use Excel or Origin software to plot and analyze $V_{G2K} - I_p$ curve. Note: USB drive and data export software need to be installed (see Appendix II).

Experiment 2 Measurement of the excitation potential of higher level of mercury atoms

After the experiment of measuring the 1st excitation potential, allow the furnace temperature cool from 220 °C to 100-135 °C. Refer Figure 8 to connect wires (i.e. in Figure 6, the plug at Socket G1 is moved to Socket G2 on the front panel of the main electric unit).

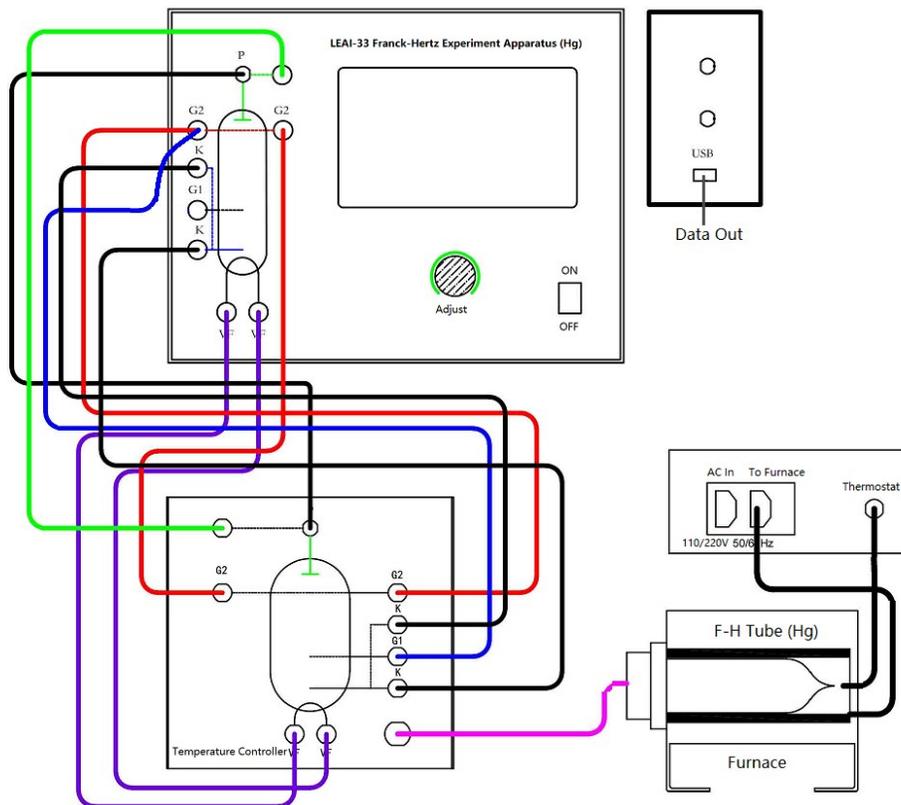


Figure 8 Wire connections for measurement of higher excitation potential of mercury atoms

Turn on the power of the apparatus. Set appropriate voltages for V_F and V_{G2P} (the optimal working conditions of each F-H tube should be determined carefully by experiments).

In the configuration of this experiment, terminals G_1 and G_2 of the tube are short-circuited to form an equipotential space between them. The F-H tube is now divided into three regions: acceleration zone ($K-G_1$), collision zone (G_1-G_2) and collection zone (G_2-P).

The vapor density of mercury atom can be controlled by adjusting the temperature of the heating furnace. Usually for measurement of the 1st excitation potential, high atom density is desired, which can be achieved by applying a relatively high furnace temperature (e.g. 200-220 °C). The collision zone and the acceleration zone are shared, so the path length for electron acceleration is much larger than its mean free path. This can almost only cause excitation of 6^3P_1 energy level.

For this experiment of measuring the excitation potential of higher energy levels, the acceleration path is very short and the density of mercury atoms is low (furnace temperature is 100 – 135 °C). In the acceleration zone, the probability of electrons collision with atoms has been greatly reduced, and electrons tend to accumulate relatively high energy. With the increase of accelerating voltage, the number of electrons with higher energy will increase accordingly. The G_1-G_2 space is a sufficiently long equipotential collision zone, where electrons and atoms collide with a greater probability, which improves the resolution and sensitivity of the experiment, and provides conditions for clearer spectral peaks.

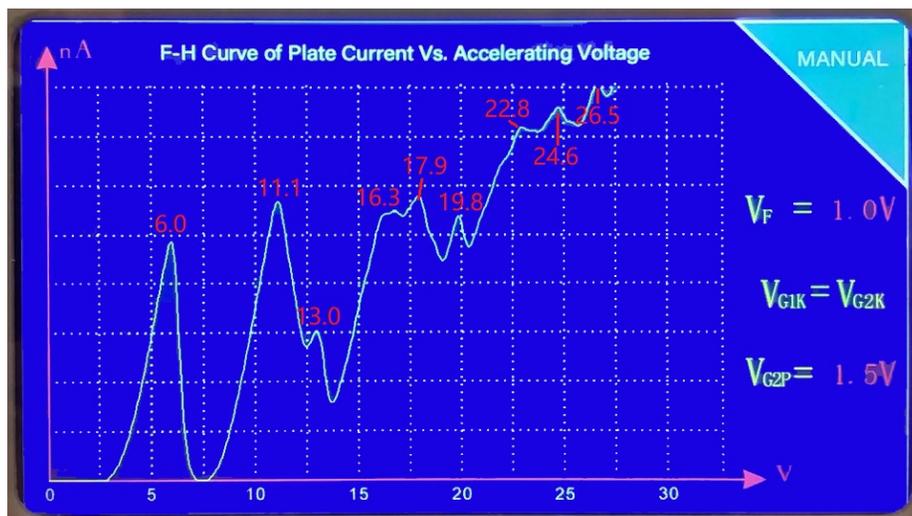


Figure 9 Example of $V_{KG1}-I_P$ curve (filament 1.0 V, V_{G2P} 1.5 V, furnace temperature 120°C)

Figure 9 shows a typical I_P-V_{KG1} curve, from which 6^3P_1 state 4.9 V (with some errors, 11.1 V - 6.0 V, 16.3 V-11.1 V, 17.9 V-13.0 V, 22.8 V-17.9 V), and 6^1P_1 state 6.7 V (with some errors, 13.0 V - 6.0 V, 19.8 V- 13.0 V, 24.6 V-17.9 V, 26.5 V-19.8 V) can be recognized.

Appendix I Operation Instruction of the Touch Screen

After turning on the main electric unit, the touch screen firstly displays the experiment name and company name. Then, it displays default interface as shown in Figure 10.

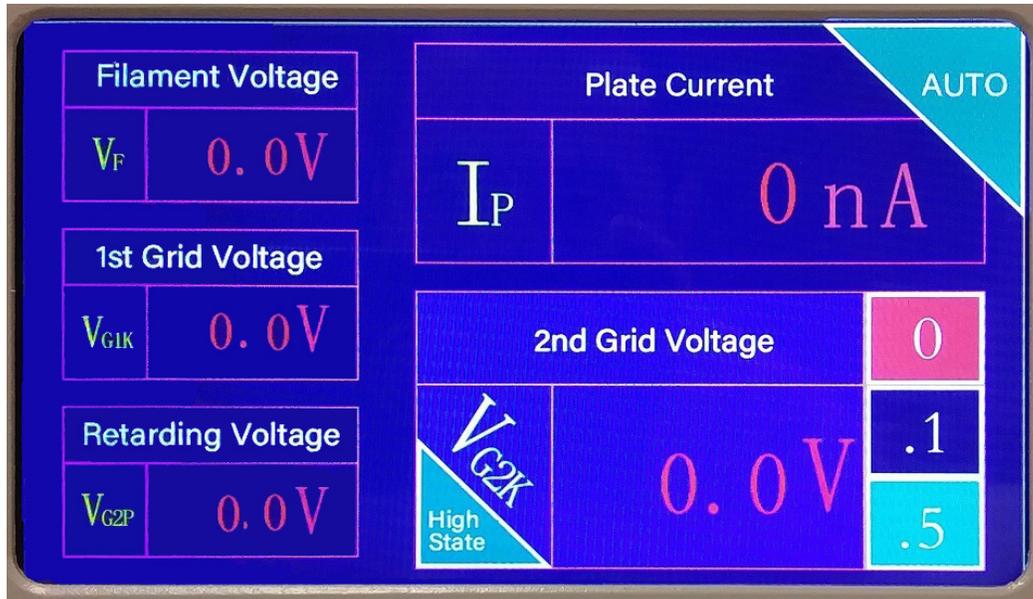


Figure 10 Default interface display.

Touch V_F , V_{G1K} and V_{G2P} to set these voltages by turning the “Adjust” knob (see reference settings shown on the back panel).

For manual measurement of 1^{st} excitation potential: touch the lower-right block to activate manual measurement mode. Touch “0.1” or “0.5” to select the adjustment step size of accelerating voltage. Then use the “Adjust” knob to adjust V_{G2K} (accelerating) voltage. Plate current I_p at corresponding V_{G2K} voltage is shown in upper-right block. To reset accelerating voltage to 0, please touch block “0” .

For automatic measurement of 1^{st} excitation potential: touch “0.1” or “0.5” to select the scan step size of accelerating voltage, then touch “Auto” in the upper-right corner to start scan. The screen will be changed to display $V_{G2K} - I_p$ Curve in real time, as shown in Figure 11. Touch “Manual” in the upper-right corner to return to the previous screen (i.e. Figure 10). Touch “0”

to reset accelerating voltage to 0.

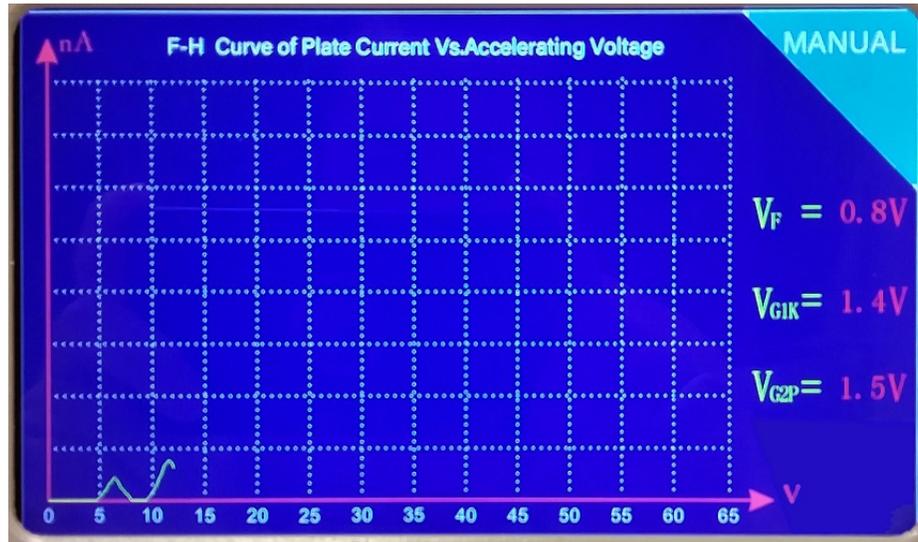


Figure 11 Automatic scan for V_{G2K} - I_p Curve of measuring 1st excitation potential.

For measuring excitation potential of high energy level: on the screen shown in Figure 10, touch “High State” in the lower-left corner of V_{G2K} block, the screen will change to that one as shown in Figure 12. Other settings and measurements (auto or manual) are same as that for measurement of 1st excitation potential. The screen display for automatic scan measurement is shown in Figure 9. Touch “Return” to switch back to mode of measuring 1st excitation potential. Note: to adjust V_F and V_{G2P} , you need to return to the screen shown in Figure 10 for parameters setting by touching “Return”.

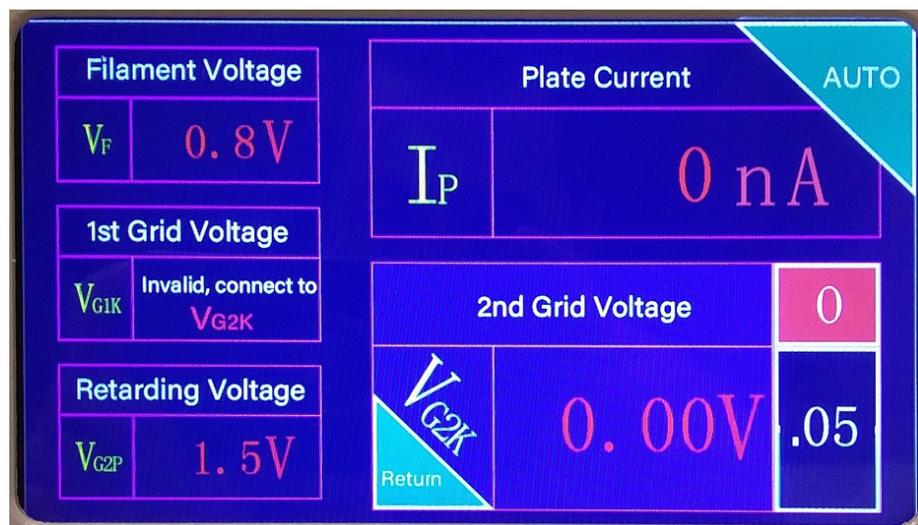


Figure 12 Screen for measuring excitation potential of high energy level.

Appendix II Steps for Software Installation

Step 1: Install USB serial port driver

In folder “CH340 USB Drive”, run (double click) “SETUP.EXE” to install USB driver.



Step 2: Install F-H Experiment Data Export Software

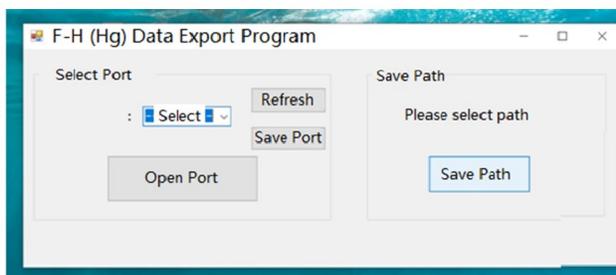
Run “F-H Data Export.msi” to install.



After successful installation, an icon will appear on desktop:



Step 3: Click on the F-H (Hg) Data Export icon, the following window will pop up:



Step 4: Connect the USB port on the back panel of the LEAI-33 Franck-Hertz Apparatus (Hg) to the computer and click **Refresh** button of the program to refresh port. Select Port 3 or Port 4 (do not select Port 1 and Port 2). Click **Save Port** button to save port.

Step 5: Click **Save Path** button and set a folder to save experimental data.

Step 6: Click **Open Port** button, the software is ready to acquire data.

Set all voltage values on the screen of the Franck-Hertz Apparatus, and then click **Auto** button on the screen, the voltage V_{G2K} will scan from low to high with specified step size automatically. At the same time, the experimental data set (V_{G2K} , I_p) will be automatically stored in the designated folder (set in Step 5). Data of each scan will be saved in a separated file named in chronological order.

The stored data is in txt format. Use data process and analysis software (e.g. Origin) to process data. An example of data imported to Excel is shown below.

