

## 5. Experimental Contents

- 1) Observe anode current versus accelerating voltage curve on an oscilloscope
- 2) Understand the process of electron-atom collisions and energy exchange
- 3) Record data, plot curve, and calculate the 1<sup>st</sup> excitation potential of Argon atom

## 6. Experimental procedure

**Note:** the voltage values provided on the label attached to apparatus are only for reference purpose. You may finely adjust these values to achieve optimal results during experiment. Especially, the filament voltage can significantly influence the output current  $I_p$ . If the reading of the current (manual mode) is too high or the waveform acquired on the oscilloscope or on PC (auto mode) is saturated or distorted, it means the anode output current is too high. Under this case, the filament voltage should be decreased and/or the current multiple selector should be adjusted. The optimal filament voltages for manual mode and auto mode could be different. After changing filament voltage, allow one or two minutes to let the instrument stabilize. For auto mode, turn  $V_{G2P}$  to maximum to achieve the most peaks.

### A. Measurement with oscilloscope

- a. Plug in a power cord, and connect “ $V_{G2K}$  Output” and “ $I_p$  Output” from the main unit to the “X-Axis” and “Y-Axis” of an oscilloscope, respectively, using BNC cables.
- b. On the oscilloscope, set the scanning mode to “Auto”, set the “X” and “Y” voltage divisions to “1 V”, and “Format” to “Y-T” or “X-Y”, and all “DC/AC” to “DC”.
- c. Turn on the main machine and the oscilloscope.
- d. Adjust voltages of  $V_F$ ,  $V_{G1K}$  and  $V_{G2P}$ , respectively, to proper values, select 0.1  $\mu A$  from  $I_p$  multiplier switches, and gradually increase  $V_{G2K}$  (**caution:** not too high to avoid breakdown of the F-H tube) until a stable  $I_p \sim V_{G2K}$  curve of the Argon-filled F-H tube is displayed on the oscilloscope. Observe the quantization of atom energy states.

**Note:** the output voltage at the “ $V_{G2K}$  Output” terminal is attenuated by a factor of 10 from the actual  $V_{G2K}$  voltage which is applied on the F-H tube. Also, at “Auto” mode, the voltage reading on the voltmeter of the instrument front panel is an average value of the scanning  $V_{G2K}$  voltage rather than the peak-to-peak value. In this case, the peak-to-peak value of  $V_{G2K}$  voltage should be determined from the waveform on the oscilloscope (with a factor 10 $\times$ ).

- e. If the oscilloscope is a digital storage oscilloscope with a USB port, the experimental results (observed on the oscilloscope) can be displayed and processed with a PC using the software of the oscilloscope. An example graph is shown in Figure 6.

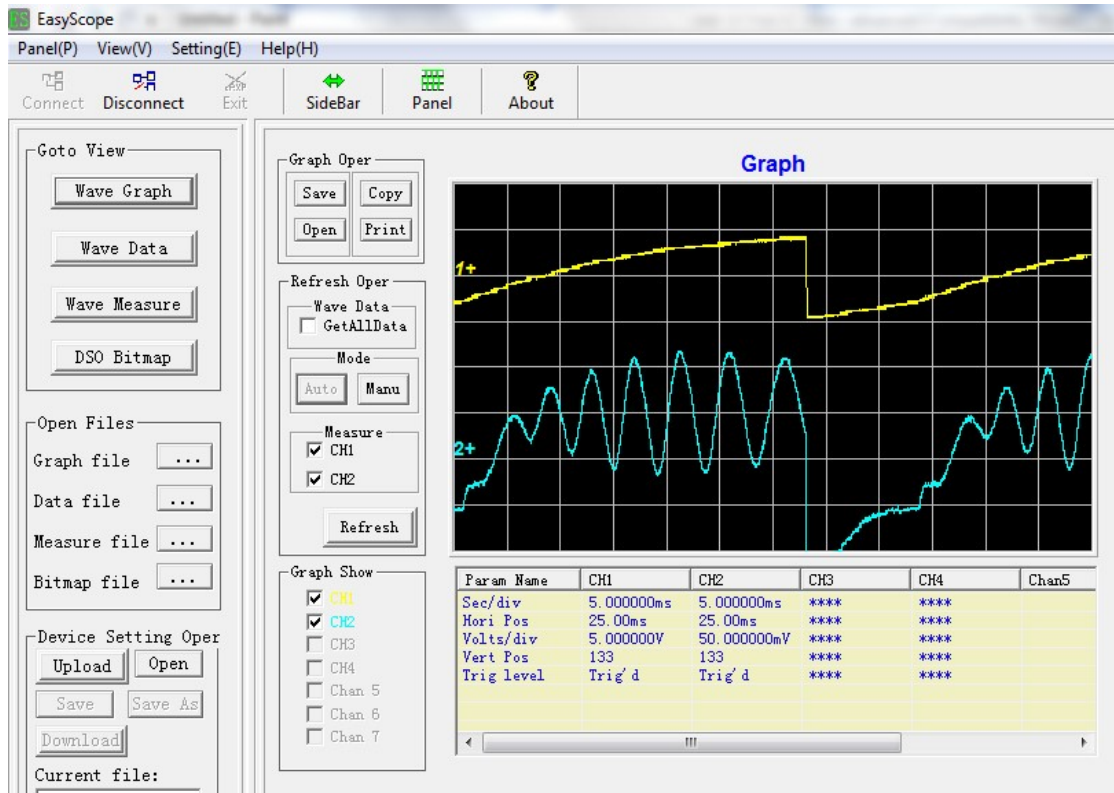


Figure 6 Experimental results acquired by PC from digital oscilloscope

### B. Measurement using manual mode

- Set  $V_{G2K}$  to minimum, set scanning switch to “Manual”, and turn on the main machine.
- Set proper experimental parameters, i.e. set  $V_F$ ,  $V_{G1K}$  and  $V_{G2P}$  to proper values (for example  $V_{G1K} \sim 1$  V,  $V_{G2P} \sim 8$  V,  $V_F \sim 2$  V), select the current scale to  $1.0 \mu\text{A}$ , and then manually and gradually increase  $V_{G2K}$  while monitoring  $I_p$  changes. Adjust  $V_F$ ,  $V_{G1K}$  and  $V_{G2P}$  properly, and increase  $V_{G2K}$  gradually to achieve 7 coda waves or more.
- Record  $I_p$  and  $V_{G2K}$  values with digital meters, and plot  $I_p \sim V_{G2K}$  curve. **Note:** the actual  $I_p$  reading should be multiplied by the selected scale factor, for example, if  $I_p$  meter displays a value of “3.23” with a current scale of  $1.0 \mu\text{A}$ , the actual value  $I_p$  should be  $3.23 \mu\text{A}$ .
- Calculate the 1<sup>st</sup> excitation potential  $V_I$  of Argon atoms based on the adjacent peaks or valleys on the  $I_p \sim V_{G2K}$  curve.
- Calculate Planck’s constant using formula:  $h = eV_I\lambda/c$ , where  $e = 1.602 \times 10^{-19}$  C,  $\lambda = 106.7$  nm, and  $c = 3 \times 10^8$  m/s, and compare it with the accepted value ( $h_0 = 6.626 \times 10^{-34}$  J•s).

### C. Measurement using software

Data acquisition software named “F-H DAQ” is provided with this apparatus for PC use via a USB port. By running this software, the relationship curve between plate current ( $I_p$ ) and accelerating voltage ( $U_{G2K}$ ) can be acquired by PC as shown in Figure 7, in XY mode or YT mode, respectively. An instruction for installing and using this program is given in Appendix.

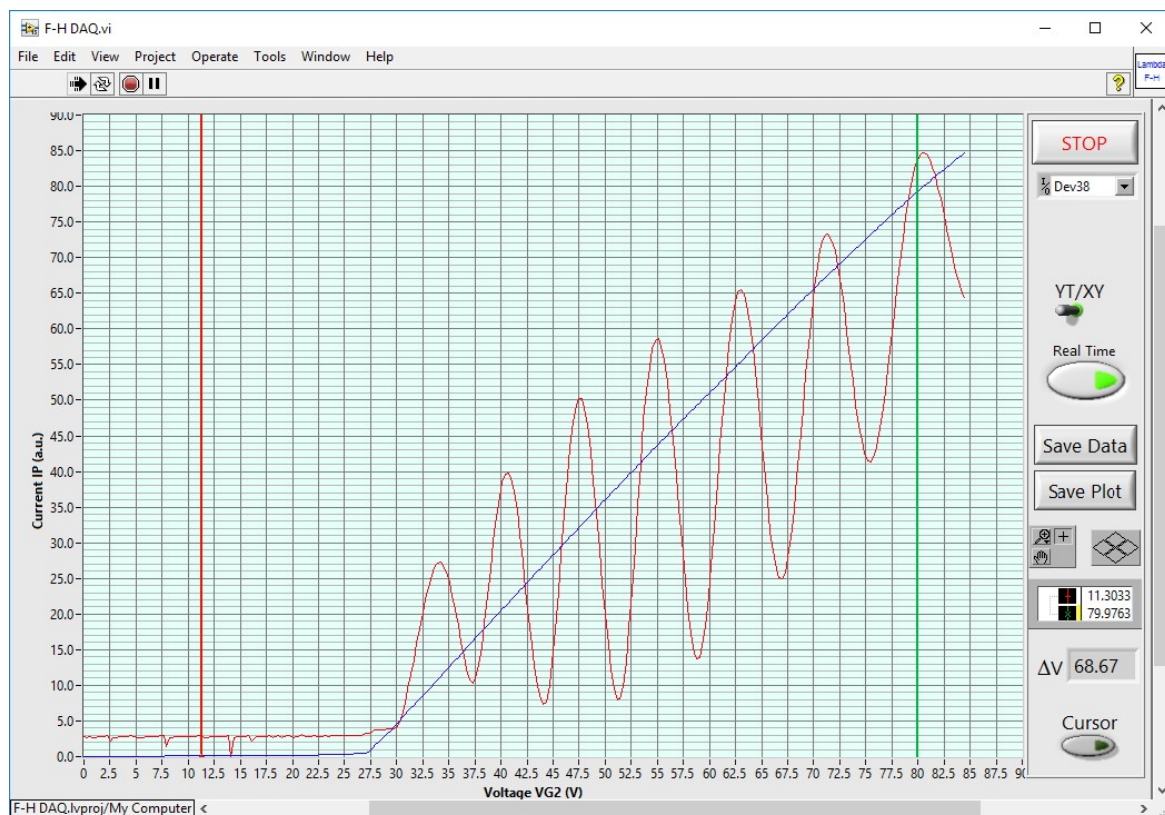
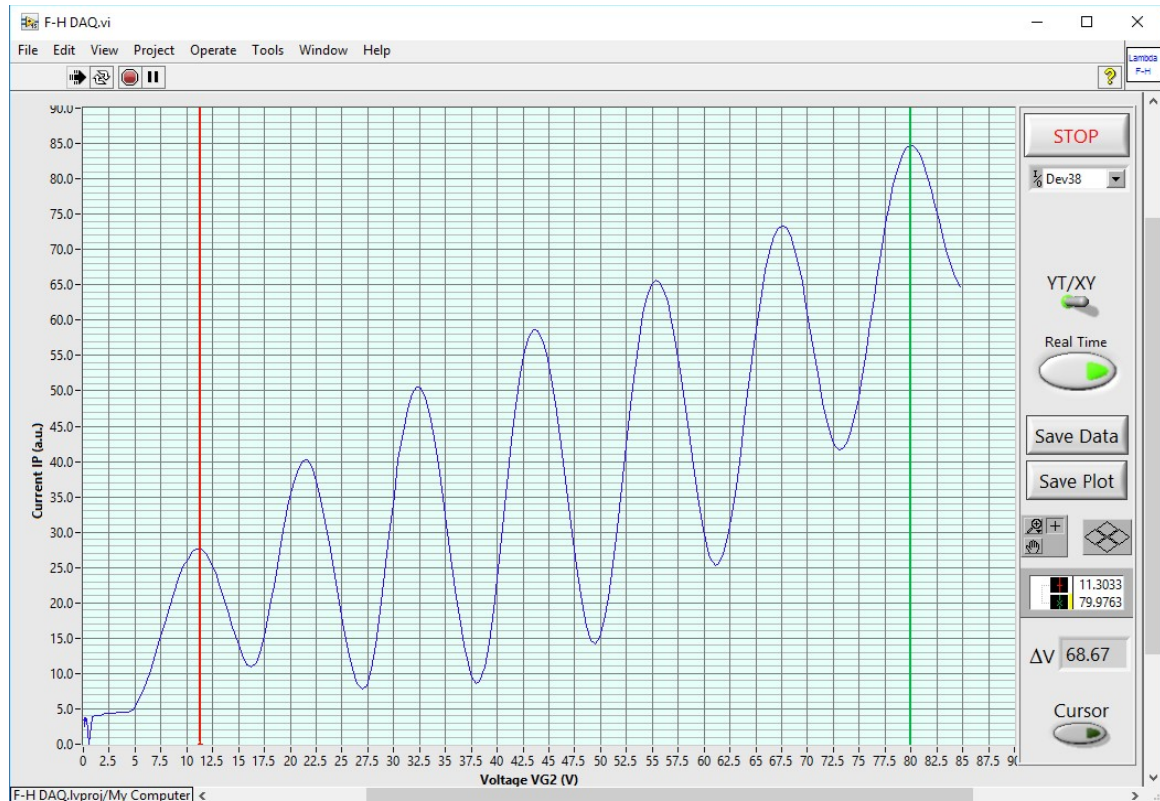


Figure 7 Experimental waveform acquired by software to PC

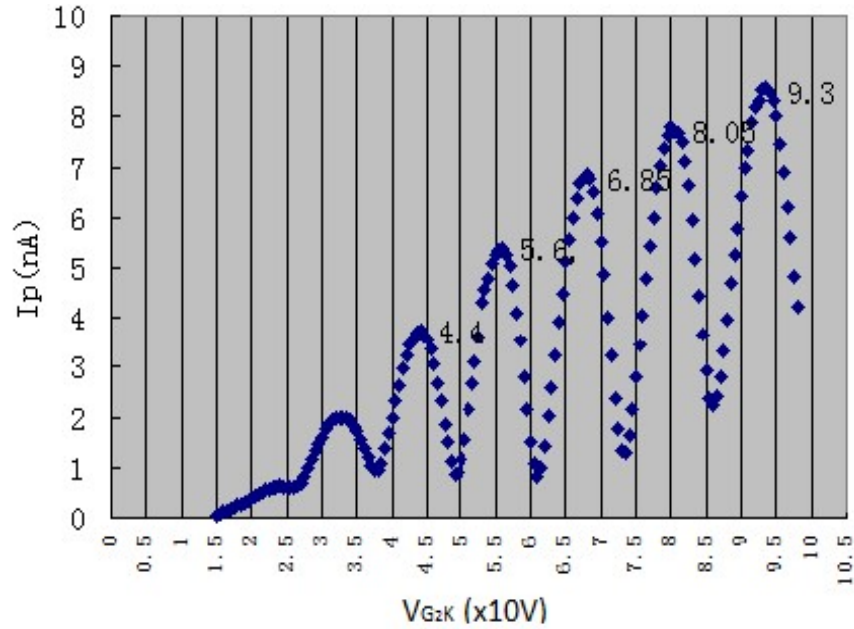
The waveform data shown in Figure 7 can be saved into a text file with a file extension of “txt”, which can be further imported to Excel for subsequent data processing and analysis.

## 7. An example for data recording and processing

An example of manually acquired data is shown in the following table (**Note:** it is only for reference purpose, not the criteria for apparatus performance):

$V_{G2K}$ (V)	15.0	16.0	17.0	18.0	19.0	20.0	.....
$I_p$ (nA)	0.4	1.1	1.8	2.1	2.4	3.1	.....

The corresponding  $I_p \sim V_{G2K}$  curve is plotted below:



Based on the curve, the 1<sup>st</sup> excitation potential of argon atoms is calculated as 12.25 V, leading to a measurement error of 5.5% by comparing with the theoretical value (11.62 V).

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 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 1<sup>st</sup> excitation potential of argon atoms can be calculated.

Using the acquired 1<sup>st</sup> excitation potential, calculate Planck's constant  $h$  based on the formula:  $h = eV_1\lambda/c$ , where  $e=1.602 \times 10^{-19}$  C,  $\lambda=106.7$  nm, and  $c=3 \times 10^8$  m/s, and compare it with the accepted value ( $h_0 = 6.626 \times 10^{-34}$  J•s).