Physics 122
Winter 2012

Franck-Hertz Experiment

Introduction:

The Franck-Hertz experiment is one of the experiments that showed quantization of energy levels in atoms. In previous experiments, we have observed that a photon could lose all of its energy to excite an atom. In this experiment we will demonstrate that electrons can lose their kinetic energy in quantized amounts to excite atoms.

A schematic diagram of the Franck-Hertz experiment is depicted on Figure 1. When electrons are accelerated due the applied voltage between the filament and grid, they gain enough kinetic energy to cross the retarding potential and record in the electrometer, ammeter. This is of course if they don't lose of any of their energy due to collision with the mercury vapor.

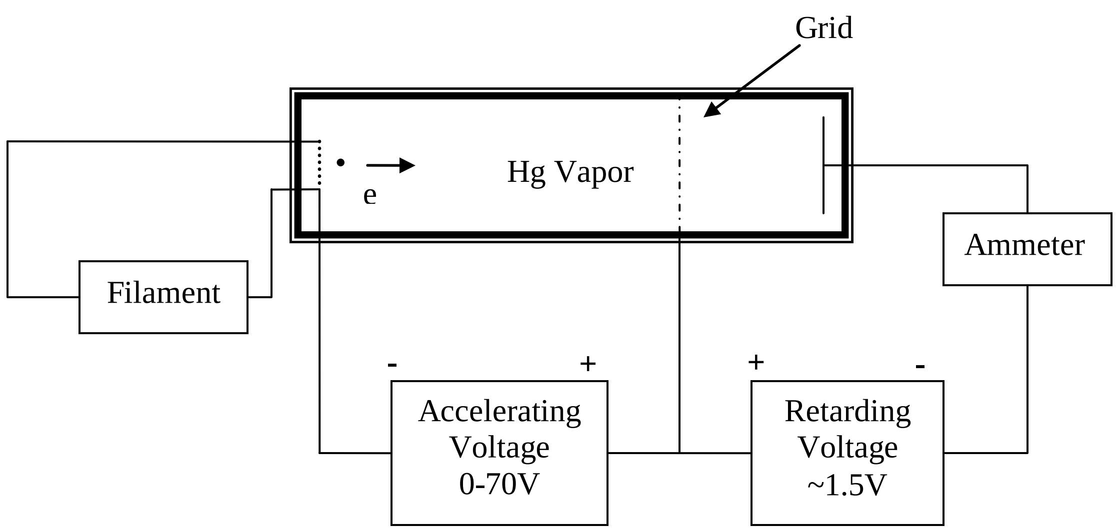

Figure 1. *Schematic drawing of Franck-Hertz apparatus and setup. (Drawing not to scale)*

However, the current registered for certain accelerating voltages, e.g. about 5V, is found to be smaller than for an accelerating voltage less than 5V. This drop of current was initially interpreted as a result ionization of the Hg atoms. Further increase in the accelerating voltage, on the other hand, resulted in an increase in the current with another decrease for accelerating voltage around 10V. This predictable pattern of decrease in current with respect to the accelerating voltage can be explained by invoking the quantization of the energy levels of the atom.

Most of the collisions between the electrons and the Hg atoms are elastic. The Hg atoms being heavier than the electrons don't gain kinetic energy from recoil during the collision. The electrons, thus, do not lose kinetic energy and are able to reach the collector. However, when the electrons have enough energy to excite the Hg atoms, they lose part of their energy. This precludes them from reaching the collector and hence a decrease in current is observed.

In this experiment we will determine the excitation energy of Hg atoms from the corresponding drop in the current. We will use a time varying accelerating voltage. By recording simultaneously both the accelerating voltage and the current using an oscilloscope, we will be able to determine the excitation energy.

Procedure:

Caution: The setup could get HOT and uses Hg vapor tube. Care must be taken all the times

1. Make sure all of the knobs in the power supply are set to zero, i.e. all the way counter-clockwise.
2. Connect the Franck-Hertz tube according to Figure 2.
3. Set the oven temperature to 150°C. The apparatus may take few minutes to equilibrate at the set temperature. Avoid overheating the apparatus. It is advised to start with the lower temperature setting.
4. Switch the accelerating voltage to a saw-tooth mode. Although, the output is supposed to be a saw-tooth, it is not. It is a half sine wave.
5. Increase the accelerating voltage until the amplitude is about 70V. You can measure this using the cursors on the oscilloscope, channel 2 according to Figure 2 (remember the output is /10). Although, we are suppose to use the accelerating voltage as x-sweep. We are using YT mode on the oscilloscope.
6. Adjust the horizontal scale just to see only one half wave. You can measure the width of the wave to satisfy yourself that this indeed is a half wave of 60 Hz.
7. Increase the current in the emitter, heater filament, **slowly** until you get a signal.

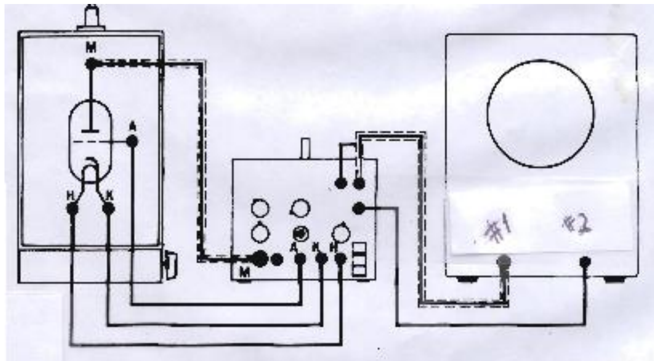

Figure 2. *Franck-Hertz Experimental setup. Image copied from NEVA manual.*

8. Adjust the retarding voltage to approximately 1.9 V, until the peaks start to resolve.
9. Adjust the gain in such a way that the peaks at lower accelerating voltage, ca. 15V, are resolved. If you need to, increase the filament current and reduce the retarding voltage. An example what you should expect is depicted in Figure 3.

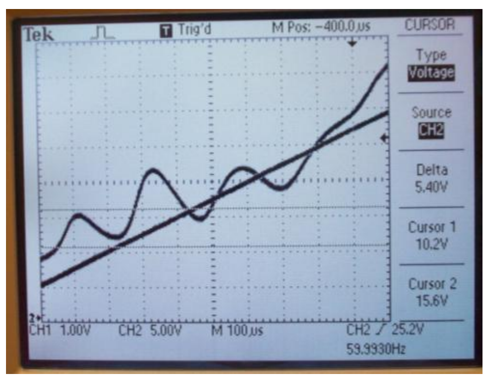

Figure 3. *Example of Franck-Hertz experimental result. Channel 1 is used for the current signal while Channel 2 is used for the accelerating voltage.*

10. Once you have resolved about 4 peaks, measure the accelerating voltage, channel 2, that corresponds to the minima in the current, channel 1.
11. Find the average change in accelerating voltage that caused a successive reduction in current and estimate the errors in your measurements.