2. Theory

According to Bohr's theory, atoms can only remain stable in some specific states (i.e. steady-states). Each of which corresponds to a certain amount of energy, and the steady-state energy is discrete. Atoms can only absorb or release energy equivalent to the energy difference between two discrete states. To excite an atom from the ground state to the first excitation state, the impact energy must be greater than the energy difference between the two states. Franck-Hertz experiment implements the energy exchange for state transitions through the collisions of atoms with electrons of certain energy, which is obtained by applying an accelerating electric field. The process can be represented by using the equation below:

$$\frac{1}{2}m_e v^2 \geq eV_1 = E_1 - E_0$$

where e, m_e, and ν are the charge, mass and speed (before collision) of an electron, respectively; E_1 and E_0 are the energy of the atom at the first excitation and the ground states, respectively; V_1 is the minimum voltage of an accelerating field required to excite the atom from the ground state to the first excitation state, called the first excitation potential of the atom. eV_1 is therefore called as the first excitation potential energy.

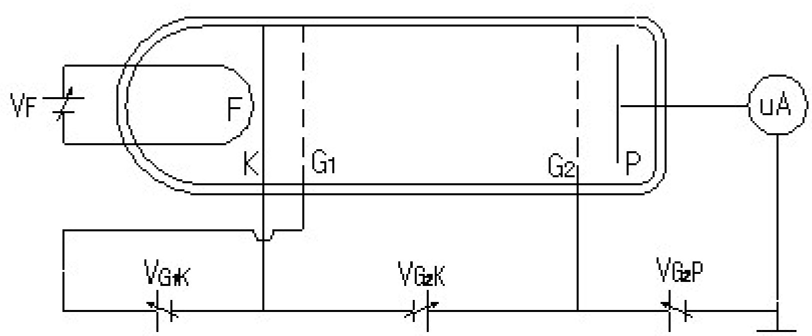

Figure 1 Schematic of Franck-Hertz experiment

The principle of Franck-Hertz experiment is shown in Figure 1. In an argon-filled Franck-Hertz tube (F-H tube), electrons are emitted from hot cathode *K*. A relatively low voltage V_{G1K} is applied between cathode *K* and grid G_1 to control the electron flow entering the collision region. An adjustable accelerating voltage V_{G2K} is applied between grid G_2 and cathode *K* to accelerate electrons to desired energy. A braking voltage V_{G2P} is applied between anode *P* and grid G_2. The electric potential distribution in the F-H tube is shown in Figure 2. When electrons pass through grid G_2, if their energy is higher than eV_{G2P}, they can arrive at anode *P* to form current I_P.

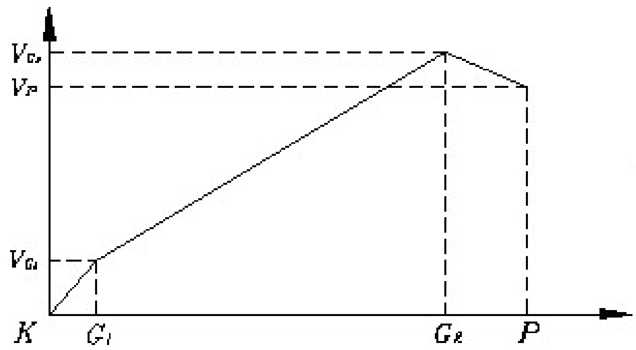

Figure 2 Schematic of potential distribution in the F-H tube

At the beginning, accelerating voltage V_{G2K} is relatively low and the energy of electrons arriving at grid G_2 is less than eV_{G2P}, so the electrons cannot reach anode P to form a current. By increasing V_{G2K}, the electron energy increases accordingly (the number of electrons with energy higher than eV_{G2P} increases too), so current I_p rises to the point that electron energy is higher than the first excitation potential energy eV_1 and electrons pass energy eV_1 to atoms by inelastic collisions. As a result, electron energy is less than eV_{G2P}, leading to a reduced anode current I_p.

By continuously increasing V_{G2K}, anode current I_p rises again until the electrons regain energy eV_1. Due to the inelastic collisions of electrons and atoms for the second time, anode current reduces again.

By increasing V_{G2K} from low to high, multiple inelastic collisions occur between electrons and Argon atoms leading to multiple rise/fall cycles on $I_p \sim V_{G2K}$ curve, as shown in Figure 3.

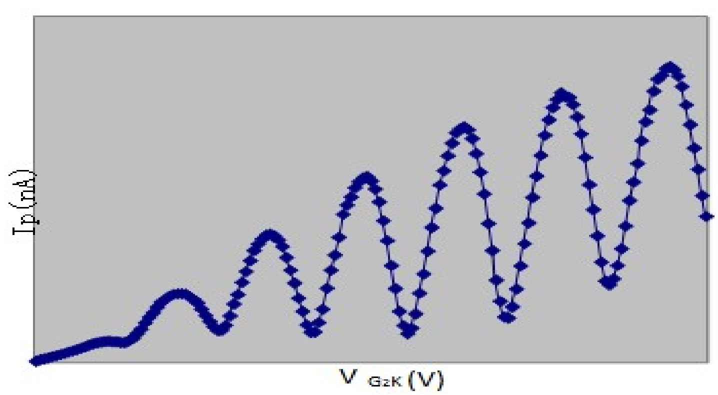

Figure 3 Relationship curve of anode current I_p and accelerating voltage V_{G2K}

For argon atoms, the voltage difference between adjacent valleys or peaks as shown in Figure 3 is the 1st excitation potential of an argon atom, which proves the discontinuity of argon atomic energy states.

The absorbed energy of the argon atom will be released through electron transition to lower state, and therefore a strong emission spectral line can be found that is corresponding to an energy of eV_1. According to published literatures, the measured argon atom resonance line is 106.7 nm (or 11.62 eV). Using the acquired 1st excitation potential, Planck's constant h can be calculated based on the formula: $h = eV_1\lambda / c$, where e=1.602×10^{-19} C, λ=106.7 nm, and c=3× 10^{8} m/s.