5.1.03-15 Franck-Hertz experiment with Ne-tube

What you can learn about ...

→ **Energy quantum**
→ **Quantum leap**
→ **Electron collision**
→ **Excitation energy**

Principle:

Electrons are accelerated in a tube filled with neon vapour.

The excitation energy of neon is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

What you need:

Franck-Hertz operating unit	09105.99	1
Franck-Hertz neon-tube with housing	09105.40	1
5-pin connecting cable, for Ne tube	09105.50	1
Shielded BNC-cable, l = 75 cm	07542.11	1
RS232 data cable	14602.00	1
Franck-Hertz software	14522.61	1
PC, Windows® 95 or higher		
Optional equipment:		
Oscilloscope, 30 MHz, 2 channels	11459.95	1
Adapter, BNC-socket/4mm plug pair	07542.27	2
Screened cable, BNC, l = 75 cm	07542.11	2

Complete Equipment Set, Manual on CD-ROM included
Franck-Hertz experiment with Ne-tube   P2510315
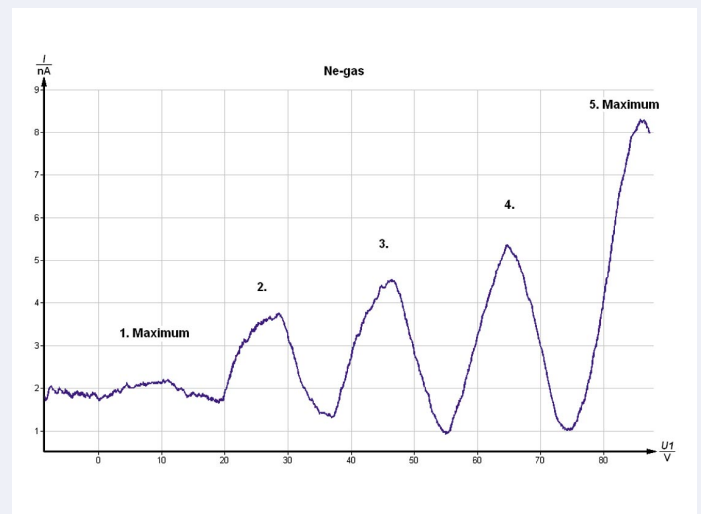
Example of a Franck-Hertz curve for Ne-gas.

Tasks:

1. To record the counter current strength Is in a Franck-Hertz tube as a function of the anode voltage U_a.

2. To determine the excitation energy E_a from the positions of the current strength minima or maxima by difference formation.

Related topics

Energy quanta, quantum jumps, electron collision, excitation energy, Bohr's shell model.

Principle

Electrons are accelerated in a tube filled with neon gas. The excitation energy of neon is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

Equipment

Franck-Hertz operating unit	09105.99	1
Franck-Hertz neon-tube with housing	09105.40	1
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Tasks

Record the countercurrent strength I in a Franck-Hertz tube as a function of the anode voltage U. Determine the excitation energy E from the positions of the current strength minima or maxima by difference formation.

Set-up and procedure

Set up the experiment as shown in Fig. 1. For details see the operating instructions of the unit 09105.99. Connect the operating unit to the computer port COM1, COM2 or to USB port (use USB to RS232 Adapter Converter 14602.10). Start the measure program and select Cobra3 Franck-Hertz experiment Gauge. Select the parameters given in Fig. 2 and press continue button.

Theory and evaluation

Niels Bohr introduced the planetary model of the atom in 1913: An isolated atom consists of a positively charged nucleus about which electrons are distributed in successive orbits. He also postulated that only those orbits occur for which the angular momentum of the electron is an integral multiple of $h/2\pi$, i.e. $n*h/2\pi$, where n is an integer and h is Planck's constant.

Bohr's picture of electrons in discrete states with transitions among those states producing radiation whose frequency is determined by the energy differences between states can be derived from the quantum mechanics which replaced classical mechanics when dealing with structures as small as atoms. It seems reasonable from the Bohr model that just as electrons may make transitions down from allowed higher energy states to lower ones, they may be excited up into higher energy states by absorbing precisely the amount of energy representing difference between the lower and higher states. James Franck and Gustav Hertz showed that this was, indeed, the case in a series of experiments reported in 1913, the same year that Bohr presented his model. Franck and Hertz used a beam of accelerated electrons to measure the energy required to lift

Fig.1: Set-up for the Franck-Hertz experiment with PC.

electrons in the ground state of a gas of mercury atoms to the first excited state (see experiment 5.1.03-11). In present experiment a tube filled with neon gas is used.
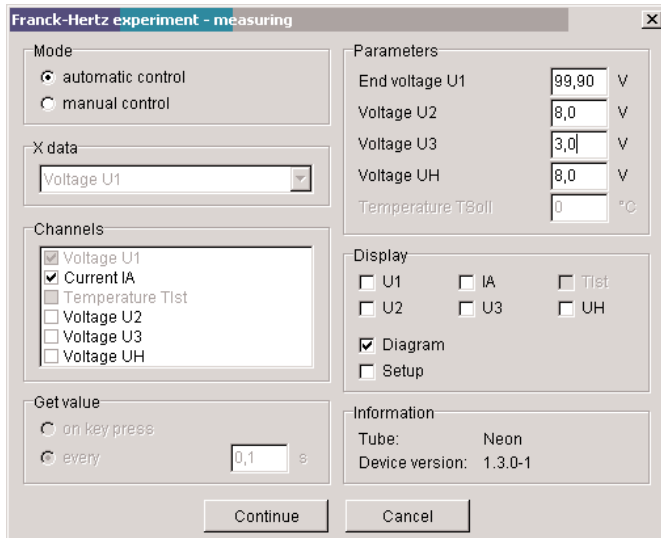
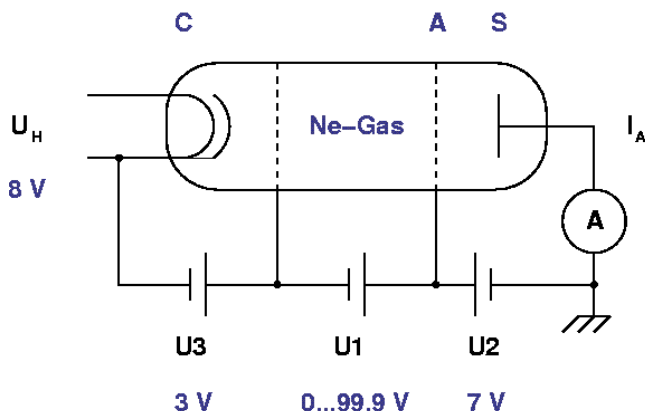

Fig. 2: Measuring parameters.

Fig. 3: Principle of the measurement.

The electrons emitted by a thermionic cathode are accelerated between cathode C and anode A in the tube filled with neon gas (Fig. 3) and are scattered by elastic collision with neon atoms.

From an anode voltage U_1 of 16,8 V, however, the kinetic energy of the electrons is sufficient to bring the valence electron of the neon to the first excitation level by an inelastic collision. Because of the accompanying loss of energy, the electron can now no longer traverse the opposing field between anode A and counter electrode S: the current I is at a minimum. If we now increase the anode voltage further, the kinetic energy of the electron is again sufficient to surmount the opposing field: the current strength I increases. When $U_1 = 2 \times 16.8$ V the kinetic energy is so high that two atoms in succession can be excited by the same electron: we obtain a second minimum (Fig. 4). The graph of I/U_1 thus shows equidistant maxima and minima.

These minima are not, however, very well-defined because of the initial thermal distribution of the electron velocities.

The voltage U_1 between anode and cathode is represented by

$$U_1 = U + (\phi_A - \phi_C),$$

where U is the applied voltage, and ϕ_A and ϕ_C the work function voltages of the anode and cathode respectively. As the ecxitation energy E is determined from the voltage differences at the minima, the work function voltages are of no significance here.

According to the classical theory the energy levels to which the mercury atoms are excited could be random. According to the quantum theory, however, a definite energy level must suddenly be assigned to the atom in an elementary process. The course of the I/U_A curve was first explained on the basis of this view and thus represents a confirmation of the quantum theory.

The excited neon atom again releases the energy it has absorbed, with the emission of a photon. When the excitation energy E is 16.8 eV, the wavelength of this photon is

$$\lambda = \frac{ch}{E} = 73.8 \text{ nm, where}$$

$$c = 2.9979 \cdot 10^8 \ \frac{\text{m}}{\text{s}}$$

and

$$h = 4.136 \cdot 10^{-15} \text{ eV.}$$

For our evaluation we determine the voltage values of the minima. From the differences between these values we obtain the excitation energy E of the neon atom by taking an average.

By evaluating the measurements in Fig. 4 we obtained the value
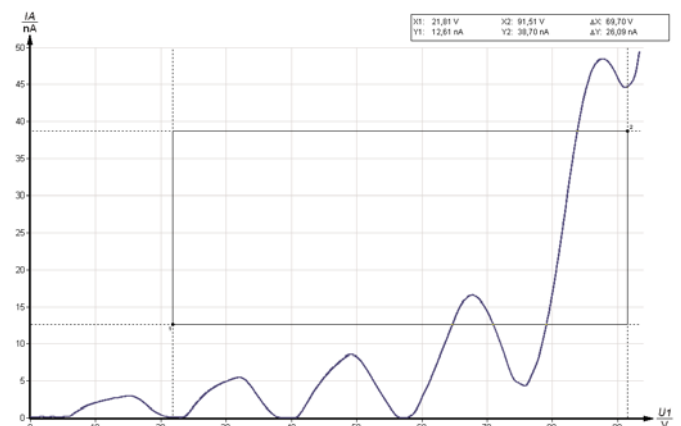
$$E = (17.4 \pm 0.7) \text{ eV.}$$

Fig. 4: Example of a Franck-Hertz curve recorded with Ne-tube.