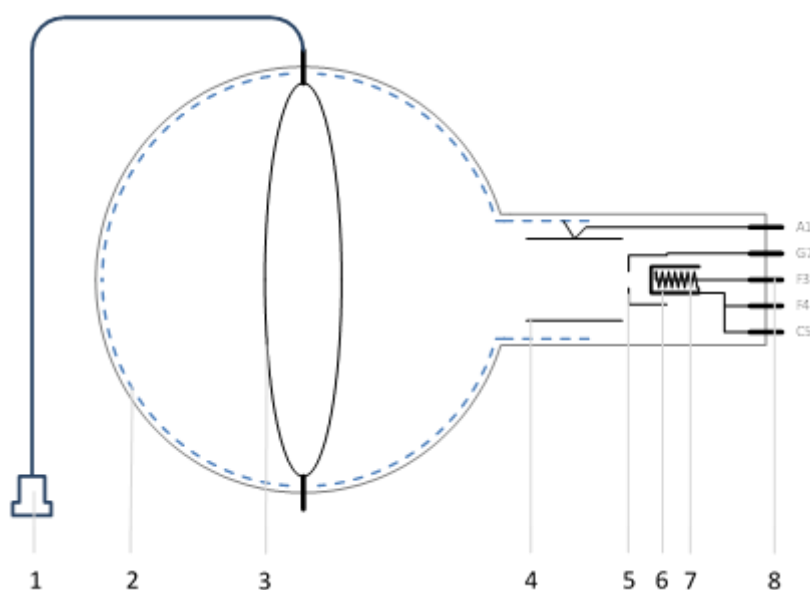


## Critical Potentials Tube S with He-Filling 1022131

### Instruction Sheet

07/ 22 GH/HB



- 1 BNC plug
  - 2 Glass coating on anode potential
  - 3 Ring collector
  - 4 Anode
  - 5 Grid
  - 6 Oxide cathode
  - 7 Heating coil
  - 8 Base with guide pin and contact pins
- A1 – Anode  
G7 – Grid  
C5 – Cathode  
F3, F4 – Cathode heating

### 1. Safety instructions

Electron tubes are thin-walled, evacuated glass bulbs. Handle with care: **Risk of implosion!**

- Do not subject the tube to mechanical stresses.
- Ensure that the connecting lead to the collector ring is not under any tension and there is no risk of it being accidentally pulled out.
- Insert the tube only in the tube holder S (1014525).

Excessive voltages, currents as well as reverse polarity connection can lead to destruction of the tube.

- Comply with the specified operating parameters.
- Carry out cabling only when the supply units are switched off.
- Only insert or remove the tube when the supply units are switched off.

Due to the cathode heating, the tube heats up during operation.

- Allow the tube to cool down before removing it from the tube holder.

Compliance with the EC Directive on electromagnetic compatibility is only guaranteed with the recommended power supply units.

### 2. Description

The critical potentials tube S with He filling is used for the quantitative investigation of inelastic collision of electrons with noble gas atoms, for the determination of ionization energy and for the identification of energy states of different principal and orbital quantum numbers.

The critical potentials tube has an electron gun with an indirectly heated oxide cathode and a cylindrical anode in an evacuated glass bulb filled with helium at low pressure. The inside of the glass bulb is coated with a transparent con-

ductive oxide (TCO), which is electrically connected to the anode. The milky appearance is due to the coating material. Small defects and uneven coating thickness do not impair the function.

To optimize the charge distribution in the electron beam, the grid, which is designed as a pin-hole, is placed in front of the cathode. The diameter and position of the collector are chosen in such a way that it cannot be directly hit by the divergent beam.

If the collector voltage is slightly positive with respect to the anode potential, exactly those electrons, which have transferred almost all their kinetic energy in the inelastic collision with a helium atom, drift to the collector and are collected. The current, which is generated by the collected charges, is measured. If this measured current is plotted as a curve over the anode voltage, the maxima positions correspond to the energies of the excited states of helium.

If the collector voltage is negative with respect to the anode, rather positively charged helium ions are deflected to the collector and neutralized there. If the current, which is measured here, is plotted against the anode voltage, the ionization energy of the helium can be read from the course of the curve.

With the chosen coating material, the use of an indirectly heated cathode and providing sufficient excitation probabilities during electron impact, energy levels down to 0.25 eV in distance can be resolved.

#### Critical potentials of helium:

If an electron is brought to a higher energy level in the helium atom, the spins of the two electrons no longer have to be antiparallel like in the ground state  $(1s)^2$ , before. This results in two clearly different spectra for the excitation energies.

The ground state of helium  $(1s)^2$  exists only as singlet  $1^1S_0$ .

	Triplet (Orthohelium)	Singulett (Parahelium)
1s2s	19,8 eV ( $2^3S_1$ )	20,6 eV ( $2^1S_0$ )
1s2p	21,0 eV ( $2^3P_{2,1,0}$ )	21,2 eV ( $2^1P_1$ )
1s3s	22,7 eV ( $3^3S_1$ )	22,9 eV ( $3^1S_0$ )
1s3p		23,0 eV
1s4s	23,6 eV ( $4^3S_1$ )	23,7 eV ( $4^1S_0$ )
1s5s		24,0 eV
1s6s		24,2 eV
Ionisation		24,6 eV

Despite the relatively high sheet resistance of  $\geq 1 \text{ M}\Omega$ , the total error of the measurements, which includes thermoelectric contact voltages and tolerances of the operating devices, is less than 1 eV.

### 3. Scope of delivery

- 1 Critical Potentials Tube S with He-Filling
- 1 Test report
- 1 Screening frame
- 1 Instruction sheet

### 4. Technical Data

Cathode heating *:	$U_F$	ca. 7 V DC
Anode voltage:	$U_{A \text{ max}}$	= 80 V;
	$U_{A \text{ typ}}$	= 18...26 V
Anode current:	$I_A$	$\leq 1 \text{ mA}$ ;
	$I_{A \text{ typ}}$	= 0,2...1,5 $\mu\text{A}$
Grid voltage*:	$U_{G \text{ max}}$	= 6 V;
	$U_{G \text{ typ}}$	= 0,1...3,0 V
Grid current:	$I_G$	$\leq 200 \mu\text{A}$ ;
	$I_{G \text{ typ}}$	= 0,2...5,0 $\mu\text{A}$
Collector voltage*:	$\pm U_{E \text{ max}}$	= 5 V;
	$U_{E \text{ typ}}$	= $\pm 0,5... \pm 2,5 \text{ V}$
Collector current:	$I_R$	$\leq 400 \text{ nA}$
Dimensions:	$\varnothing$ bulb approx.	130 mm
	total length approx.	260 mm

\*) maximum and typical values are listed; see optimum parameters in the test report

## 5. Additionally required equipment

### For Operation of the tube:

1 Tube holder S	1014525
1 Franck-Hertz Experiment Power Supply (115 V or 230 V)	1012819 / 1012818
1 Set of 15 Safety Experiment Leads	1002843

### For data acquisition:

1 2-Channel-Oscilloscope, e.g..	1020910
2 HF Patch Cord, BNC/4 mm Plug	1002748

### alternative data acquisition:

1 VinciLab	1021477
or	
1 Wilab	1022284
2 Differential Voltage Sensor 10 V	1022539
2 Sensor cable	1021514
1 Coach 7 Licence	
1 Computer	

## 6. Operation

### 6.1 Insert the tube into the tube holder

- Only insert or remove the tube when the supply units are switched off.
- Push the tube with slight pressure into the socket of the tube holder until the pin contacts are fully seated in the socket, making sure that the guide pin is clearly positioned.

### 6.2 Removing the tube from the tube holder

- Allow tube to cool before removing.

To remove the tube, press the guide pin from the back until the contact pins are released. Then remove the tube.

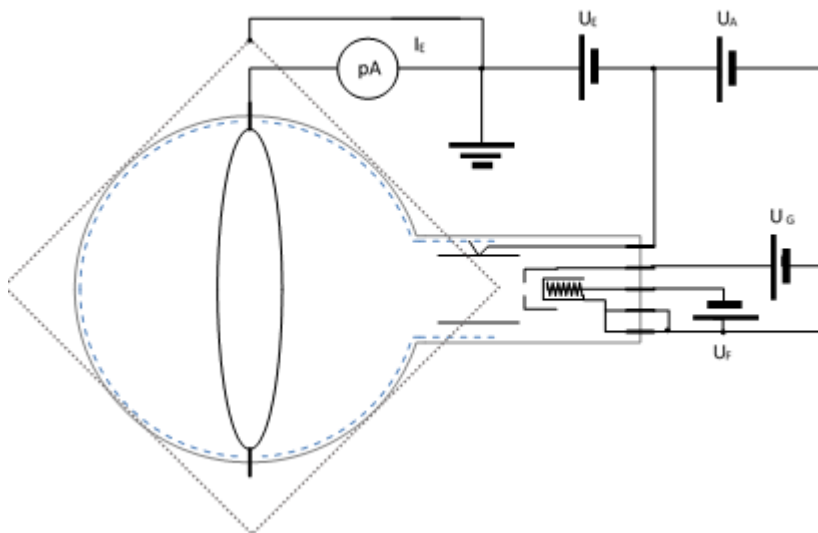


Fig. 1: Circuit diagram (the polarity of the reverse voltage  $U_E$  for the measurement of the electron current is shown; it corresponds to a negative sign in the display of the power supply)

## 7. Experiment example

### Determination of excitation and ionization energies of the helium atom

#### 7.1 General information

The experimental setup with the critical potentials tube is very sensitive to sources of electromagnetic disturbance (computer, fluorescent tubes, mobile phones etc.).

- Select the experiment site in such a way that electromagnetic sources of disturbance are minimized.
- For operation of the Franck-Hertz Experiment Power Supply power sockets should be used, where no strong sources of disturbance are plugged at the same time.
- Lay the experiment cables as closely in parallel as possible so that the coupling of external electromagnetic fields is minimized.

#### 7.2 Experiment set-up (Fig. 2, Fig. 3)

- Insert the tube into the tube holder.

##### Applying the heat voltage $U_F$ :

- Connect socket F3 of the tube holder to socket F of the 'Franck-Hertz' power supply.
- Connect socket F4 of the tube holder to socket K of the power supply.

##### Applying the accelerating voltage $U_A$ :

- Connect socket A1 of the tube holder to socket A of the power supply.
- Connect socket C5 of the tube holder to socket K of the power supply.

##### Applying the grid voltage $U_G$ :

- Connect socket G7 of the tube holder to socket G of the power supply.

##### Applying the collector voltage $U_E$ :

- The collector bias voltage is generated internally in the 'Franck-Hertz' power supply; thus, all operating voltages ( $U_A$ ,  $U_G$  und  $U_F$ ) are shifted by the value  $U_E$  against ground potential. Connecting the collector to input E of the measuring amplifier closes the circuit.
- Connect the BNC plug of the tube to socket E of the power supply.

##### Electrical screening of the tube:

- Slide the screening frame over the tube and the folded edge into the T-slot of the tube holder so that the tube is completely inside the screening.
- Connect the plug of the screening frame to the ground socket (located between the measurement outputs  $U_X$  und  $U_Y$ ) of the power supply.

##### Before switching on the power supply:

- Set all potentiometers of the voltage sources  $U_F$ ,  $U_G$ ,  $U_A$  and  $U_E$  to the left stop, while amplification V is set to the right stop.

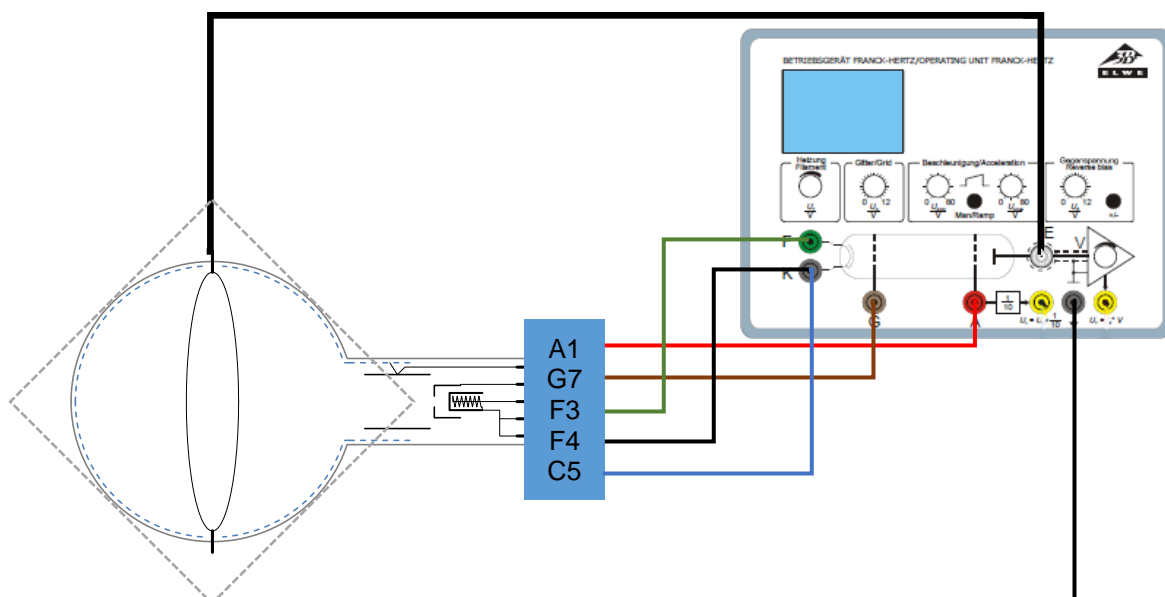


Fig. 2: Schematic layout of the experiment set-up by using the Franck-Hertz-power supply

### 7.3 Experiment execution with an oscilloscope

- Connect output  $U_X$  of the Franck-Hertz power supply to input CH 1 of the oscilloscope (deflection in X) and output  $U_Y$  to input CH 2 (deflection in Y) (see Fig. 3).
- Select the ramp mode and a "negative" reverse voltage  $U_E$  on the power supply.
- Slowly increase the heat voltage  $U_F$  to the value recommended in the test report. Reaching thermal equilibrium with stable electron emission can take several minutes.
- Set Grid voltage  $U_G$  and collector voltage  $U_E$  to the values recommended in the test report.
- Select accelerating voltage  $U_{Amin}$  and  $U_{Amax}$  according to the desired section of the spectrum. Settings of 18 V for  $U_{Amin}$  and 26 V for  $U_{Amax}$  are good starting parameters for helium, since the entire range of excitation by simple inelastic collisions, including ionization, can thus be observed.
- To record the ion current curve, change the polarity of the collector voltage by pressing the „+/-“ on the "Counter voltage" control panel of the power supply. Readjust the value of the collector voltage so that an optimum display is obtained.
- Adjust the gain  $V$  of the power supply in such a way that, depending on the sensitivity selected at the oscilloscope (50...500mV/DIV.), an optimum display for CH 2 (Y-deflection) is obtained.
- Since the repetition rate of the ramp provided by the power supply is  $20\text{ s}^{-1}$ , the selection of a time base of 2...5ms/DIV. is advantageous for a 2-channel display. (depending on the image format on the oscilloscope)
- To obtain a detailed measurement curve that fills the display format of the oscilloscope, vary  $V$ ,  $U_F$ ,  $U_G$ ,  $U_E$ ,  $U_{Amin}$  and  $U_{Amax}$  as well as the settings of the oscilloscope.

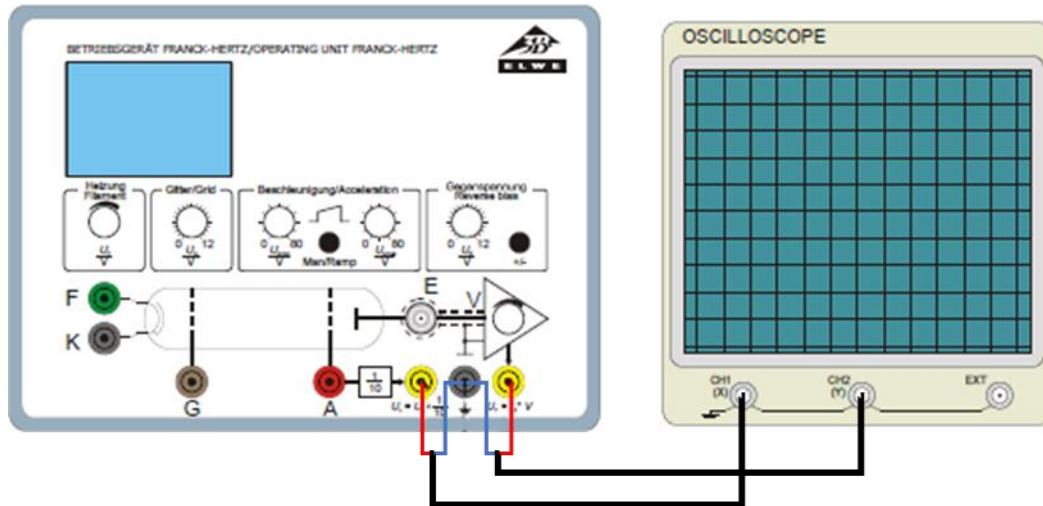


Fig. 3: Electrical connection of an oscilloscope to the Franck-Hertz power supply

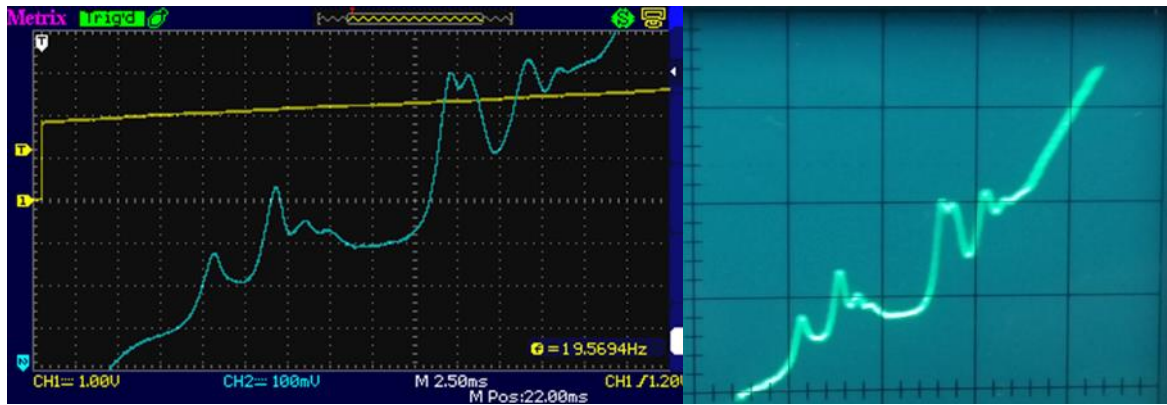


Abb. 4: Measurement example with left: a digital oscilloscope in 2-channel setting mode, right: analog oscilloscope in X-Y-mode