Ignition and extinction of spontaneous gas discharge

Experiment objectives

- Record the voltage-current characteristic of a gas-filled triode valve with a non-heated cathode
- Determine ignition voltage U_Z and extinction U_L

Principles

Gas-filled triode valve tubes are used in two different formats, so-called thyratrons with heated cathodes, and cold-cathode thyratrons. The properties of hot-cathode triode valve tubes are explored in the experiment P3.9.1.1.

In cold-cathode thyratrons the gas discharge only occurs spontaneously (i.e. in the absence of external effects such as thermionic emission from the cathode) when a specific trigger voltage U_Z is exceeded. The magnitude of the trigger voltage depends on the type of gas with which the valve tube is filled and the type of material used for the electrode, as well as on other external effects capable of altering the number of free electrons, such as temperature, time since the last trigger, radiation, the charge on the valve tube walls, etc. After gas discharge is triggered, the gas-filled space becomes ionised. This is clear from the fact that the anode current I_A suddenly rises and a blue light becomes visible inside the tube. The extinction voltage U_L, at which the visible glow discharge is extinguished as the voltage drops, is lower than the trigger voltage due to the gas discharge itself. The differential U_Z - U_L depends on the gas pressure and the shape of the electrode.

Since cold-cathode thyratrons are not heated, they are immediately ready for use, consume no energy before triggering and have a long lifespan. They can also be constructed to a very compact design. When they are not activated they have a very high input resistance. The trigger voltage is typically ≥400 V, meaning that they can be operated directly from the mains. A visual indication of the operating status is provided by the glow discharge itself. Such valve tubes were once widely used in time relays and telephone exchanges.

This experiment investigates the spontaneous discharge of a helium gas triode. The voltage-current characteristic of an unheated tube is to be recorded. First the voltage between the anode and cathode is to be increased in steps up to a value of 500 V. Until the trigger voltage U_Z is reached, no current will flow between the cathode and anode. At the trigger voltage U_Z the gas discharge occurs. This is demonstrated by a sudden increase in current and the appearance of a blue light. Afterwards, the voltage should be reduced in steps once again. Even below the trigger voltage, the current initially keeps flowing and only stops when the extinguishing voltage U_L is reached.

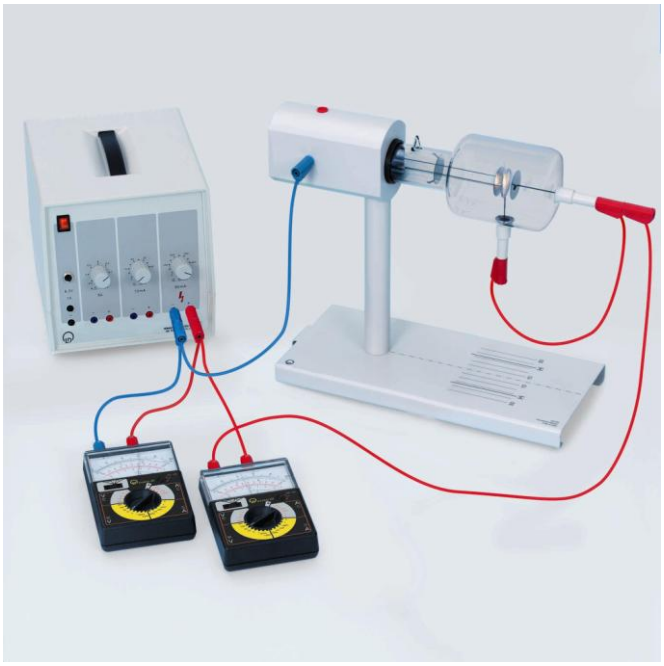


Fig. 1: Experiment set-up

Equipment

1 Gas triode	555 614
1 Tube stand	555 600
1 Tube power supply, 0...500 V	521 65
1 LDanalog 30 multimeter	531 130
1 LDanalog 20 multimeter	531 120
5 Safety leads, 100 cm, red	500 641
3 Safety leads, 100 cm, blue	500 642

CS 2013-08

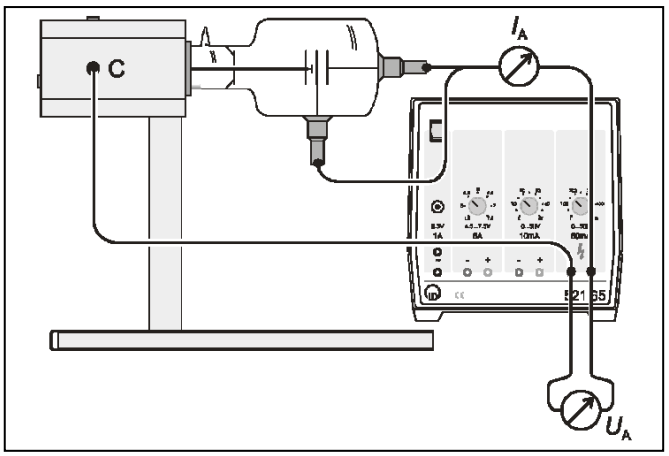


Fig. 2: Circuit sketch for experiment parts a and b

Safety instructions

A gas triode is a thin-walled, evacuated glass tube. There is a risk of implosion.

- Do not put the tubes under mechanical stress.

When a gas triode is in operation, there may be situations when voltages are present with which it is dangerous to come into physical contact:

- Only use safety leads for connecting the tubes.
- Connect leads only if the power supply is switched off.

Please observe the instructions for the gas triode (555 614) and the tube stand (555 600).

Set-up

A sketch of the experiment set-up is shown in Fig. 2. In order to set up the experiment, the following steps need to be taken:

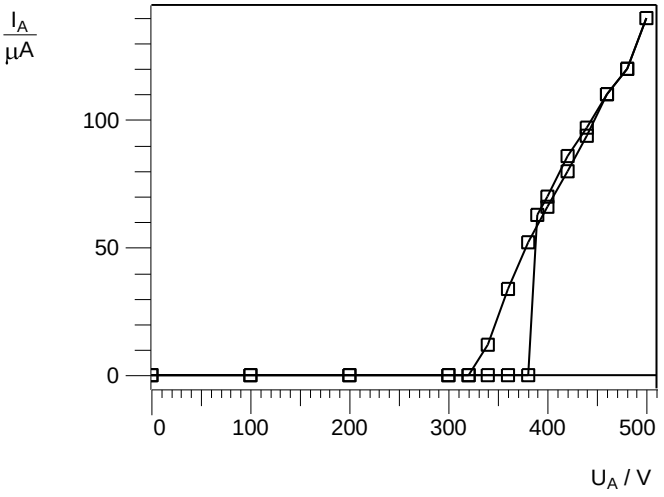
- Carefully insert the gas triode into the tube stand.
- Connect the tube power supply to the mains.
- Connect up the anode and grid terminals.
- In order to measure anode current I_A, connect the anode terminal of the gas triode to the negative socket of the ammeter (531 120), with the positive ammeter socket being connected to positive of the 500-V output.
- The negative pole of the 500-V output should be connected to the cathode terminal C on the tube stand.
- To measure the anode voltage U_A, connect a voltmeter (531 130) across the 500-V output.
- Select suitable measuring ranges for the voltmeter and ammeter.
- Turn on the tube power supply.

Procedure

- Use the potentiometer knob for the 500-V output to increase the anode voltage in steps (go up to approximately 300 V in steps of 100 V, but use smaller steps after that) and read the anode current from the ammeter. Enter the results of the measurements into a table.
- After reaching 500 V, you should decrease the voltage in steps. Read off the anode current from the ammeter and enter the results into a table.

Conclusions and example measurements

	Measurements with increasing voltage	Measurements with decreasing voltage
$\frac{U_A}{V}$	$\frac{I_A}{\mu A}$	$\frac{I_A}{\mu A}$
0	0.0	0.0
100	0.0	0.0
200	0.0	0.0
300	0.0	0.0
320	0.0	0.0
340	0.0	12
360	0.0	34
380	0.0	52
390	63	—
400	70	66
420	86	80
440	97	94
460	110	110
480	120	120
500	140	140



While the voltage is being increased, no anode current flows until the trigger voltage U_Z = 390 V is reached. When U_Z is reached, the current rises suddenly to more than 60 µA. When the voltage is increased further, the anode current continues to rise. No saturation occurs in the voltage range used for this experiment. When the anode voltage is being decreased, the current continuously decreases until the extinguishing voltage U_L = 320 V is reached. The difference between the two values, U_Z - U_L, is therefore 70 V.

Note

Below the trigger voltage U_Z discharge triggering can still occur by mechanisms other than self-discharge. For example, this can occur at voltages as low as 30 V if cathode heating is applied. Ultra-violet light (e.g. from high-pressure mercury lamp 451 15) can cause triggering at voltages above the self-extinguishing level U_L.