Maltese Cross tube

DEMONSTRATE THE STRAIGHT-LINE PROPAGATION OF ELECTRONS IN THE ABSENCE OF ANY FIELD

- Demonstrate the straight-line propagation of electrons in the absence of a field
- Demonstrate the deflection of electrons by a magnetic field
- Introduction to electron optics

UE307030

06/06 JS

BASIC PRINCIPLES

In a Maltese cross tube, a divergent electron beam from a cathode ray gun can be seen on a fluorescent screen by observing the shadow on the screen of an object (a Maltese cross) that is opaque to cathode rays. The position of the shadow changes when the straight-line propagation of the electrons towards the screen is disturbed.

If the anode A and the Maltese cross M are at the same potential, there will be no field within the tube and electrons will propagate in a straight line (see Fig. 1). The electron shadow of the cross will then be coincident with its shadow in the light that is emitted from the glowing cathode.

How this straight-line propagation is disturbed when a field is present within the tube can be seen easily by disconnecting the lead between the anode and the cross. The cross then becomes statically charged and the electron shadow on the screen becomes blurred.

If the electrons are deflected by a magnetic field on their way to the screen, the electron shadow can be seen to shift or rotate.

The deflecting force ***F*** depends on the velocity ***v*** of the electrons, on the magnetic field ***B*** and is a result of the Lorentz-force:

$$\boldsymbol{F} = -e \cdot \boldsymbol{v} \times \boldsymbol{B} \quad (1)$$

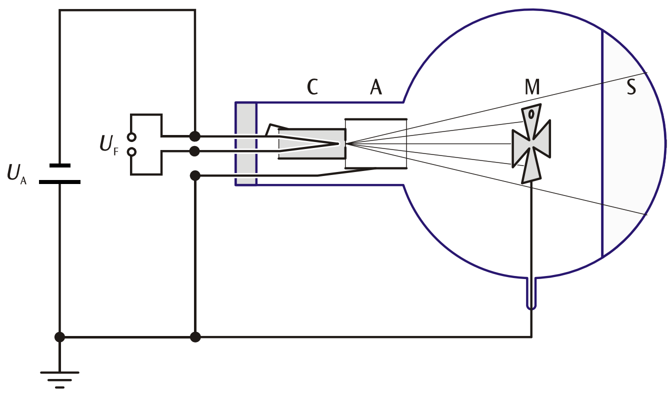

Fig. 1: Schematic diagram of the straight-line propagation of electrons in a Maltese Cross tube

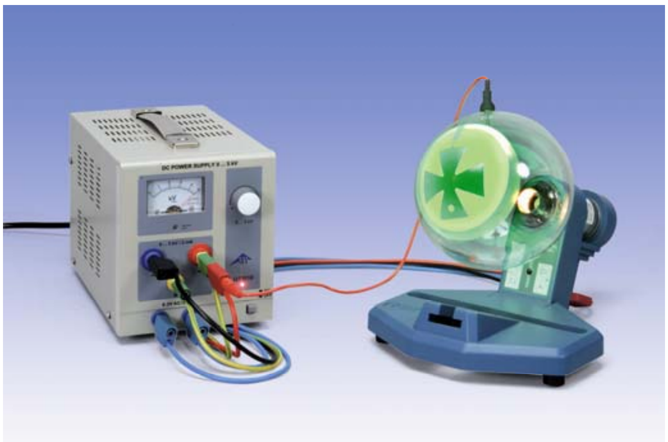

Fig. 2 Experiment set-up to demonstrate the straight-line propagation of electrons using a Maltese Cross tube

LIST OF APPARATUS

1	Maltese Cross tube S	U18553
1	Tube holder S	U185001
1	High-voltage power supply unit, 5 kV	U33010
1	Set of 15 safety experiment leads	U138021

Additionally required:

1	Helmholtz coil pair S	U185051
1	DC power supply unit, 16 V, 5 A, e.g.	U33020

SAFETY INSTRUCTIONS

Thermionic cathode tubes are thin-walled, evacuated glass bulbs. Handle with care: danger of implosion!

- Do not expose the Maltese Cross tube to any mechanical stress or strain.
- Do not expose the connecting lead of the Maltese Cross tube to any tensile stress.
- Only use safety experiment leads for connections.
- Make the connections only when the power supply unit is switched off.
- Set up and disconnect the Maltese Cross tube only when the power supply unit is switched off.

SET-UP

- While keeping the high-voltage power supply unit switched off, turn the voltage regulator fully to the left.
- Insert the Maltese Cross tube into the tube holder. While doing so, make sure that the contact pins of the tube snap tight into the contact openings of the tube holder which are provided for this purpose. The central guiding pin of the tube should slightly jut out of the holder at the rear.
- Using safety experiment leads, connect sockets F3 and F4 of the tube holder to the high-voltage output (blue sockets) of the high-voltage power supply unit.
- Using safety experiment leads, connect socket C5 of the tube holder to the negative terminal (black socket) of the high-voltage power supply unit. (Connections C5 and F4 are internally connected within the tube.)
- Connect socket A1 to the positive pole (red socket) and also insert the connecting lead of the Maltese Cross tube at this connection.

EXPERIMENT PROCEDURE

Observe the light shadow:

- Switch on the high-voltage power supply unit so that the filament begins to glow.
- Observe the shadow cast by the Maltese Cross cast in the light on the fluorescent screen.

Observe the shadow caused by the electron beam:

- Gradually increase the high voltage supply from 0 V to a maximum of 5 kV and observe the shadow caused by the electron beam in the increasingly bright green on the fluorescent screen.
- Compare the position of the shadow projected by the electron beam with that of the light shadow.

Disturb the propagation by applying a field:

- Pull out the connecting lead to the Maltese Cross tube from the positive terminal of the power supply unit and set it aside.
- Observe the distortion of the shadow projected by the electron beam.

- Re-connect the lead and bring a permanent magnet close to the Maltese Cross tube.
- Observe the displacement of the shadow projected by the electron beam.

In case a Helmholtz pair and a DC power supply unit are available:

- Insert one coil from the front into the tube holder and connect it to the DC power supply unit (see Fig. 3).
- Starting with 0 V, gradually increase the DC voltage and observe how the shadow projected by the electron beam rotates.
- In addition, vary the high voltage and observe its influence on the shadow projected by the electron beam.

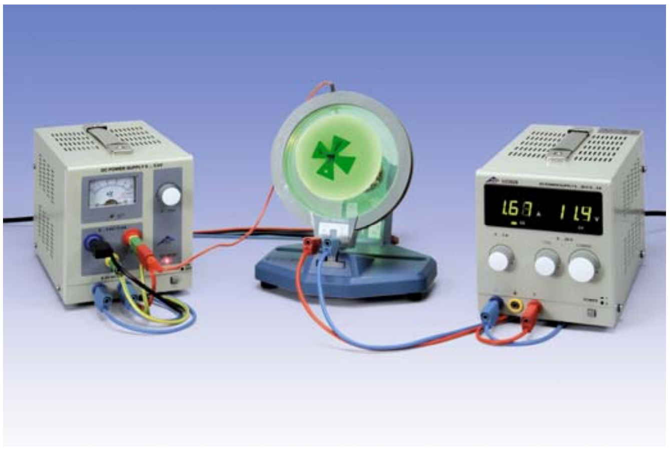

Fig. 3: Modified experiment set-up with an additional axial magnetic field

EVALUATION

If the anode and the Maltese Cross have the same potential, and if there is no additional influence from a magnetic field, then there is no field present and the electrons propagate in a straight line. The shadow of the electron beam projected by the Maltese Cross is then identical to the shadow cast in the light of the glowing cathode.

If the conducting link between the anode and the Maltese Cross is disconnected and the Maltese Cross is isolated from the environment, then the Maltese Cross becomes electrostatically charged by the incident electrons. This charge causes the electron beam to project a blurred shadow on the fluorescent screen.

In a magnetic field, the electrons are deflected and the shadow projected by the electron beam is displaced with respect to the shadow cast in the light. The deflecting force is perpendicular to the direction of flow of the electrons and to the magnetic field.

If a magnetic field runs along the axis, the electrons are deflected along a spiral path and the shadow projected by the electron beam is rotated and, in certain situations, its size also diminishes. The deflecting Lorentz force depends, firstly, on the magnetic field B and thus on the current passing through the coil, and, secondly, on the speed of the electrons and thus on the high-voltage U_A present at the anode.

Upon suitably selecting the parameters U_A and B, the shadow is almost reduced to a point. As a result, the divergent electron beam is focused at one “point”.