3B SCIENTIFIC® PHYSICS

Complete Fine Beam Tube System…1013843

Instruction sheet

10/15 SD/ALF

1. Safety instructions

The operating unit for fine-beam tube conforms to the safety requirements for electrical equipment for measurement, control and laboratory use of DIN EN 61010 part 1 and is classified as belonging to protection class I. It is in-tended for operation in dry rooms that are suitable for electrical equipment or installations.

Safe operation of the apparatus is guaranteed with correct handling. However, safety is not guaranteed if the apparatus is handled improperly or carelessly.

If it is to be expected that safe operation is impossible (e.g., in case of visible damage), the apparatus is to be rendered inoperative immediately and to be safe-guarded from unintentional use.

In schools and training institutions, operation of the apparatus is to be responsibly supervised by trained personnel.

While the equipment is in operation, voltages may be present at the tube socket which are unsafe to touch.

- Never operate the device without a tube inserted.
- Never remove or insert tubes while the equipment is turned on.
- The instrument may only be connected to the mains via a socket that has an earth connection.
- Replace a faulty fuse only with one matching the specifications stated at the rear of the housing.
- Disconnect the equipment from the mains before replacing a fuse.
- Never short the fuse or the fuse holder.
- Never cover the air vents in the housing. This is necessary in order to ensure sufficient circula-tion of air required for cooling the internal com-ponents of the equipment.

Hot cathode tubes are thin-walled, highly evacuated glass tubes. Treat them carefully as there is a risk of implosion.

- Do not subject the tube to mechanical stresses.
- Before switching on the anode voltage wait about 1 minute for the heater temperature to stabilise.

When the tube is in operation, the stock of the tube may get hot.

- Allow the tube to cool before putting away the apparatus.

2. Description

Operating Unit for Fine-Beam Tube

The operating unit for the fine beam tube is to be used with the fine beam tube T (1008505) in order to determine the specific charge of an electron and for investigating the deflection of electron beams in a uniform magnetic field.

The Helmholtz coils are permanently attached to the apparatus while the removable fine beam tube is placed on a socket that can be rotated by up to 270°. The tube and coil pair are both connected internally to the operating unit without a need for external wiring. All supply voltages for the tube and the current through the Helmholtz coils are adjustable. The anode voltage and coil current are displayed digitally and can be tapped additionally as equivalent voltage values.

Fine-Beam Tube T

Inside the fine beam tube, a sharply delimited electron beam is generated by a system comprising an indirectly heated oxide cathode, perforated anode and Wehnelt cylinder in a residual helium atmosphere with accurately known gas pressure. Impact ionisation of helium atoms creates a very bright, also sharply delimited trace of the electron path in the tube. If the tube is aligned optimally and an appropriate current flows through the Helmholtz coils, the electrons are deflected into a circular orbit, whose diameter can be easily determined when the electrons strike one of the equidistant measurement marks, causing its end to light up.

The operating unit for the fine beam tube is designed for operating the fine beam tube (1009948).

3. Contents

a) Operating Unit for Fine-Beam Tube

1 Operating unit

1 Set of power supply cables EU, UK, US

1 Instruction sheet

b) Fine-Beam Tube T

1 Fine-beam tube

1 Instruction sheet

4. Technical data

a) Operating Unit for Fine-Beam Tube

Helmholtz coil pair:

Coil diameter:	approx. 300 mm
Winding count:	124
Magnetic field:	0 – 3.4 mT (0.75 mT/A)

Operating unit:

Coil current:	0 – 4.5 A
Measurement output:	$U_{\mathrm{OUT}} = I_{\mathrm{H}} \cdot \frac{1\mathrm{V}}{1\mathrm{A}}$
Anode voltage:	15 – 300 V, 10 mA max.
Measurement output:	$U_{\mathrm{OUT}} = \frac{U_{\mathrm{A}}}{100}$
Heating voltage:	5 – 7 V DC, 1 A max.
Wehnelt voltage:	0 – -50 V
Display:	3-digit digital LED display for coil current and anode voltage
Precision	
Display:	1% + 2 digits
Measurement outputs:	1%
Output connections:	4 mm safety sockets

General data:

Tube's rotary angle:	-10° – 270°
Supply voltage:	100 – 240 V, 50/60 Hz
Power supply cable:	EU, UK and US
Dimensions:	approx.310x275x410 mm³
Weight:	approx.7.5 kg

b) Fine-Beam Tube T

Gas filling:	Helium
Gas pressure:	0.13 hPa
Bulb diameter:	165 mm
Orbit diameter:	20 – 120 mm
Measurement mark spacing:	20 mm

5. Basic principles

An electron moving with velocity v in a direction perpendicular to a uniform magnetic field B experiences a Lorentz force in a direction perpendicular to both the velocity and the magnetic field

$$F = e \cdot v \cdot B \qquad (1)$$

e: elementary charge

This gives rise to a centripetal force on the electron in a circular path with radius r, where

$$F = \frac{m \cdot v^2}{r} \qquad (2)$$

and m is the mass of an electron.

Thus,

$$e \cdot B = \frac{m \cdot v}{r} \qquad (3)$$

The velocity *v* depends on the accelerating voltage of the electron gun:

$$v = \sqrt{2 \cdot \frac{e}{m} \cdot U} \qquad (4)$$

Therefore, the specific charge of an electron is given by:

$$\frac{e}{m} = \frac{2 \cdot U}{(r \cdot B)^2} \qquad (5)$$

If we measure the radius of the circular orbit in each case for different accelerating voltages *U* and different magnetic fields *B*, then, according to equation 5, the measured values can be plotted in a graph of r^2B^2 against *2U* as a straight line through the origin with slope *e*/*m*.

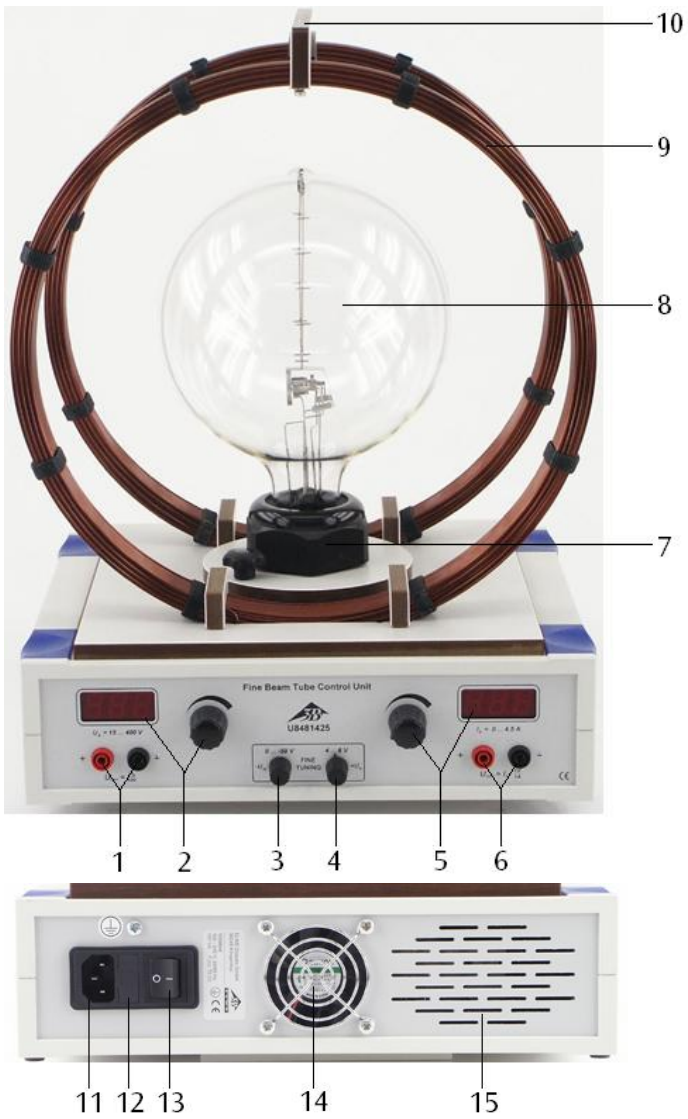
The magnetic field *B* generated in a pair of Helmholtz coils is proportional to the current I_H passing through a single coil. The constant of proportionality *k* can be determined from the coil radius $R = 147.5$ mm and the number of turns $N = 124$ per coil:

$$B = k \cdot I_H \text{ where} \qquad (6)$$

$$k = \left(\frac{4}{5}\right)^{\frac{3}{2}} \cdot 4\pi \cdot 10^{-7} \frac{\text{Vs}}{\text{Am}} \cdot \frac{N}{R} = 0{,}756 \frac{\text{mT}}{\text{A}}$$

Thus, all parameters for the specific charge are known.

6. Operating unit controls



1 Measurement output for accelerating voltage
2 Adjustment knob and display for accelerating voltage
3 Adjustment knob for Wehnelt-voltage
4 Adjustment knob for heater voltage
5 Adjustment knob and display for coil current
6 Measurement output for coil current
7 Rotating socket
8 T-model fine beam tube (1008505)
9 Helmholtz coils
10 Carrying handle

11 Mains socket
12 Fuse holder
13 Mains switch
14 Fan
15 Ventilation slits

7. Operation

7.1 Installation of fine beam tube

- Screw on the cap nut by turning it anti-clockwise.
- Check the fine beam tube to ensure that none of its contacts are bent.
- Insert the tube vertically downward, making sure that the contact pins and the coding pin are correctly aligned (see Fig 1).

Fig. 1: Insertion of tube

- Press the tube down with gentle pressure until it sits firmly on the socket.
- **Note:** Measure the height of the socket up to the top of the cap nut and compare this with the height of the tube. This will enable you to see whether the tube is sitting correctly in the socket.
- Tighten the cap nut manually by turning it to the right, making sure that the tube remains vertical.

Caution: as long as the knurled screw is not tightened, the tube is not secured and could fall out when being transported.

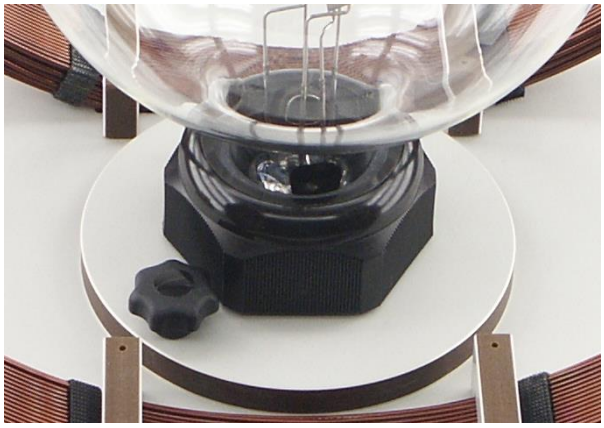


Fig. 2: Inserted tube

7.2 Adjusting the electron beam

- Set up the fine beam apparatus in a darkened room.
- Align the tube as illustrated above (with the cathode ray gun perpendicular to the magnetic field of the Helmholtz coils). For instructions on how to rotate the tube, see section 7.3.
- Set the adjustment knob for the heater voltage to a position in the middle (6 V approx.).
- Turn the knob for the coil current all the way to the left, i.e. 0 A.
- Wait about 1 minute for the heater temperature to stabilise.
- Slowly increase the anode voltage to 300 V (the electron beam is initially horizontal and is visible as a weak, bluish ray).
- Select the Wehnelt voltage so that a very clear and narrow electron beam is visible.
- Optimise the focus and brightness of the electron beam by varying the heater voltage.
- Increase the current I_H passing through the Helmholtz coils and check that the electron beam curves upwards.
- If the beam is deflected downwards, the tube should be rotated by 180°.
- Turn the coil current back up and check whether the electron beam follows a closed circular path. You may need to rotate the tube slightly.
- Carry out the experiment as described below.

7.3 Rotating the tube

The tube is mounted on a socket which can rotate from -10° to 270°.

- In order to rotate the tube, you must loosen the knurled screw, **but do not screw it all the way out**
- Do **not** turn the tube itself, instead rotate the turntable or the cap nut.
- Tighten up the knurled screw again.

Caution: if the knurled screw is screwed out all the way, the tube is not secured and could fall out when being transported.

7.4 Changing the fuse

- Turn off the power switch and unplug the mains plug.
- Pull out the fuse holder using a flat end screwdriver (see Fig. 3).
- Use the screwdriver as a lever from the side of the mains socket.

- Replace the fuse and reinsert the holder in its socket.

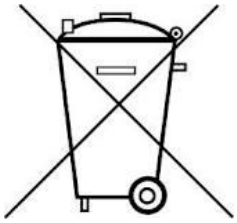
Fig. 3: Changing the fuse

8. Care and maintenance

- Before cleaning the equipment, disconnect it from its power supply.
- Use a soft, damp cloth to clean it.

9. Disposal

- The packaging should be disposed of at local recycling points.
- Should you need to dispose of the equipment itself, never throw it away in normal domestic waste. Local regulations for the disposal of electrical equipment will apply.



10. Sample experiment

Determination of the specific charge of an electron *e/m*

- Select the current passing through the coils so that the radius of the circular path is for example 5 cm. Note the set current value.
- Decrease the anode voltage in steps of 20 V to 200 V. In each case, set the coil current I_H so that the radius remains constant. Take down these values.
- Record other series of measured values for radii of 4 cm and 3 cm.
- For further evaluation, plot the measured values in a graph of r^2B^2 against $2U$.

The slope of the line through the origin corresponds to e/m.

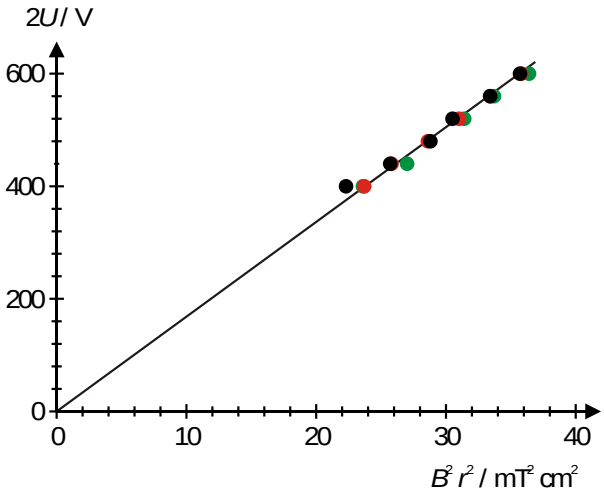


Fig. 4 Graph of r^2B^2 against $2U$ for values as measured (black: r = 5 cm, red: r = 4 cm, green: r = 3 cm)