Atomic and nuclear physics

X-ray physics
Detection of x-rays

LEYBOLD Physics Leaflets

P6.3.1.1

Fluorescence of a luminous screen due to x-rays

Objects of the experiment

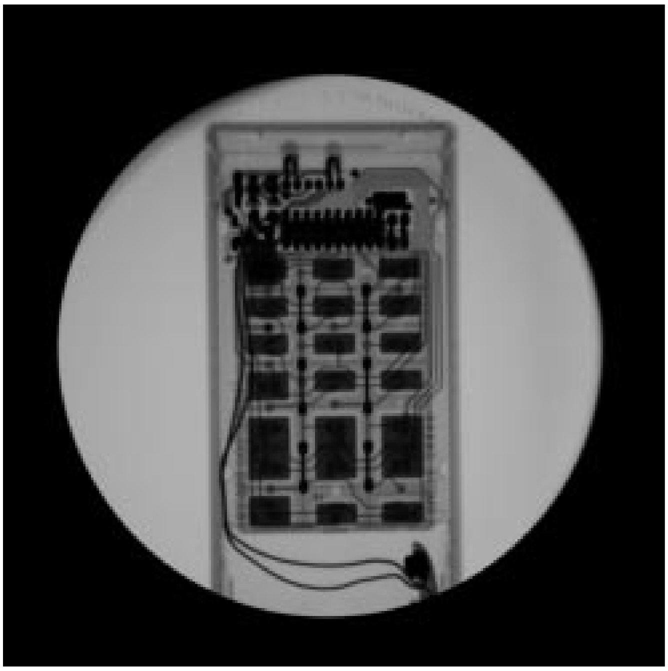
- Detecting x-rays by observing the fluorescence of a luminous screen.
- Transillumination of objects with different absorption characteristics.
- Investigating the dependence of brightness and contrast of the luminous screen on the emission current and tube high voltage.

Principles

Very soon after *W. C. Röntgen*'s discovery of x-rays in 1895, researchers were quick to apply the fact that x-rays can be “observed” on a luminous screen in medical examinations. At that time, the most common type of luminous screen was barium-platinum-cyanide, which fluoresces bright green; today, yellow-green zinc-cadmium-sulfide is used almost exclusively. The fluorescent substance is applied to lead glass, which protects the observer from the harmful effects of x-rays.

Fluorescence is a luminous phenomenon that occurs in certain materials when these are exposed to light, x-ray or particle radiation. The energy of the incident radiation is used to excite or ionize the atoms and molecules; when these return to the ground state, a portion of this energy is released in the form of visible light. The transitions are extremely rapid ($< 10^{-5}$ s), so that fluorescence can only be observed during irradiation (in contrast to phosphorescence).

The ability of x-rays to pass through opaque materials and bodies make them particularly useful in diagnostic applications. Depending on the composition of the irradiated object, the radiation is attenuated to a greater or lesser extent. That is why the images on the luminous screen reveal details of the internal structure of objects. In this experiment, this fact is demonstrated using a simple object, e. g. a pocket calculator, which has parts made of materials with different absorption properties. This experiment investigates the effect of the emission current *I* of the x-ray tube on the brightness and the effect of the tube high voltage *U* on the contrast of the luminous screen.



Luminous-screen image of a pocket calculator

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Apparatus

1 X-ray apparatus 554 811
or
1 X-ray apparatus 554 812

Additionally required:

1 Object for transillumination, e.g. pocket calculator with plastic housing

Any flat, opaque object with an internal structure and made primarily of plastic and metal parts is suitable.

Safety notes

The x-ray apparatus fulfills all regulations governing an x-ray apparatus and fully protected device for instructional use and is type approved for school use in Germany (NW 807/97 Rö).

The built-in protection and screening measures reduce the local dose rate outside of the x-ray apparatus to less than 1 µSv/h, a value which is on the order of magnitude of the natural background radiation.

- Before putting the x-ray apparatus into operation inspect it for damage and to make sure that the high voltage is shut off when the sliding doors are opened (see Instruction Sheet for x-ray apparatus).
- Keep the x-ray apparatus secure from access by unauthorized persons.

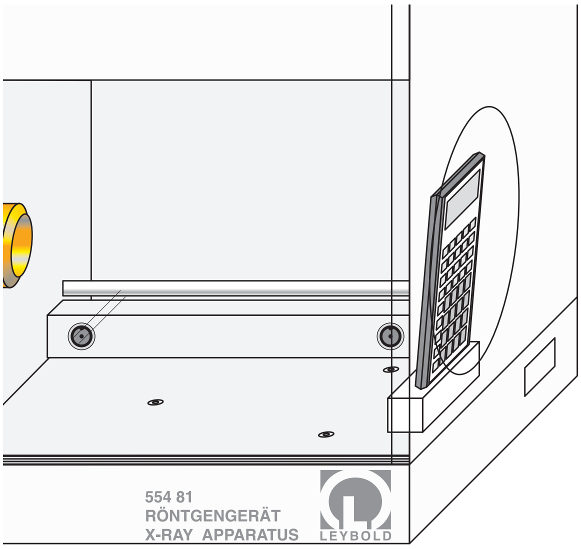
Do not allow the anode of the x-ray tube Mo to overheat.

- When switching on the x-ray apparatus, check to make sure that the ventilator in the tube chamber is turning.

Setup

– Remove the collimator from the experiment chamber, as well as the goniometer or any other assemblies.
– Remove the protective cover of the luminous screen.

Fig. 1 Experiment setup for demonstrating fluorescence of a luminous screen due to x-ray radiation



Carrying out the experiment

Note:
Carry out the experiments in a darkened room.

a) Brightness of the luminous screen:

– Close the lead glass sliding door, set the tube high voltage U = 35 kV and switch on the apparatus with the hv on/off key.
– Increase the emission current I continuously from 0 to 1.00 mA and observe the brightness of the luminous screen.

b) Varying the emission current *I*:

– Place the transillumination object, e.g. pocket calculator, in the experiment chamber as close as possible in front of the luminous screen.
– Set the emission current I = 1.00 mA, the tube high voltage U = 35 kV and switch on the unit with the hv on/off key.
– Reduce the emission current I in steps and observe the change on the luminous screen.

c) Varying the tube high voltage *U*:

– Set the emission current I = 1.00 mA.
– Reduce the tube high voltage in steps and observe the change on the luminous screen.

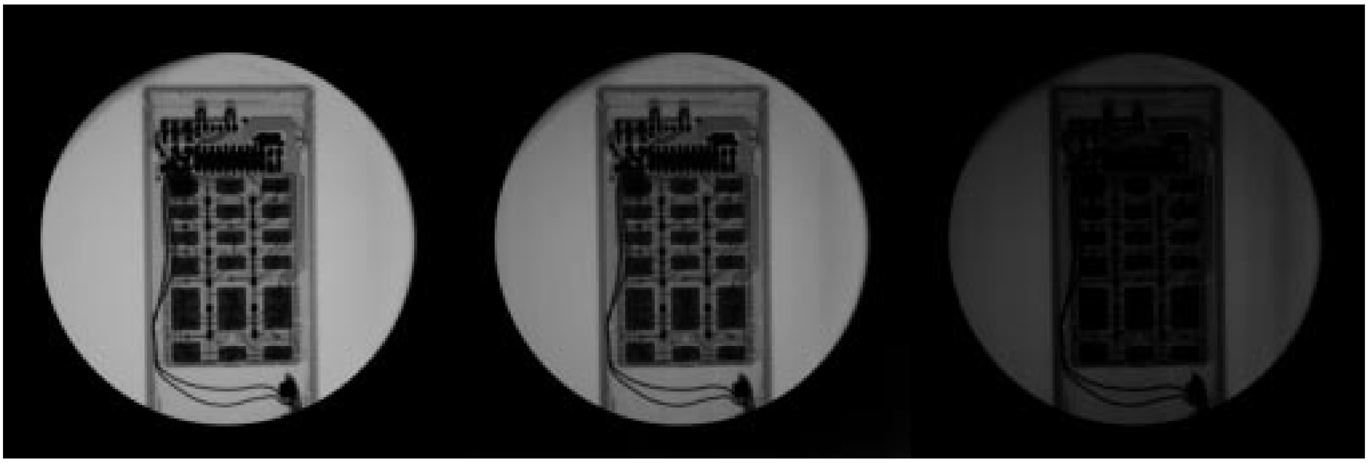


Fig. 2 Luminous-screen image of a pocket calculator (photographed using a digital camera) at maximum tube high voltages and different emission currents.
I = 1.0 mA, *I* = 0.7 mA and *I* = 0.4 mA

Measuring example

a) Brightness of the luminous screen:

The luminous screen becomes brighter as the emission current rises.

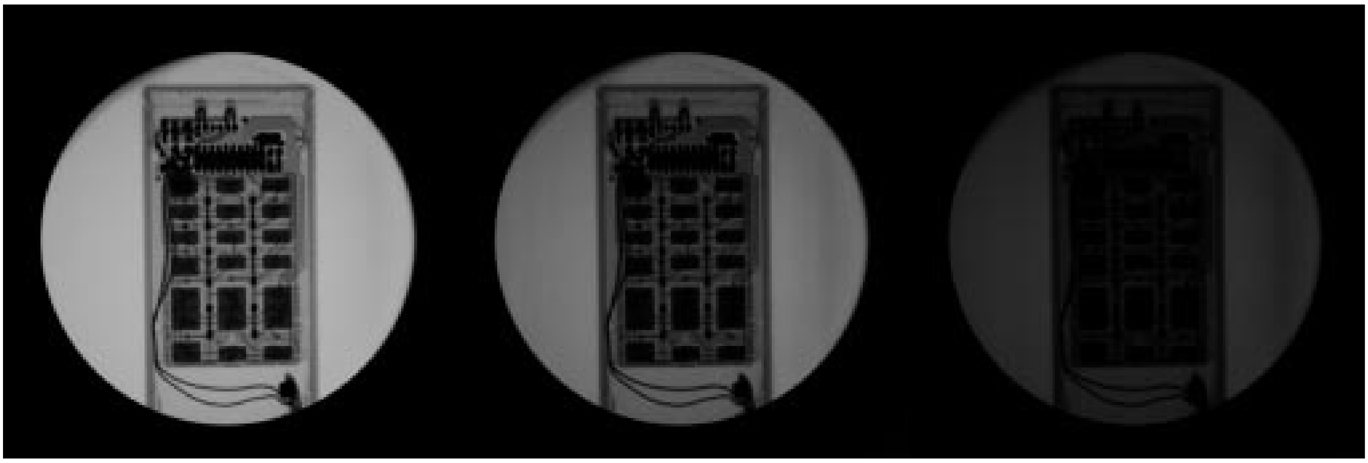
b) Varying the emission current *I*:

Fig. 2 shows the relationship between the luminous screen and the emission current *I*.

c) Varying the tube high voltage *U*:

Fig. 3 shows the relationship between the luminous screen and the tube high voltage *U*.

Fig. 3 Luminous-screen image of a pocket calculator (photographed using a digital camera) at maximum emission currents and different tube high voltages.
U = 35 kV, *U* = 31 kV and *U* = 27 kV



Evaluation

When no object is in the beam path, the luminous screen fluoresces more brightly as the emission current rises, because the intensity of the x-radiation increases.

The brightness of the luminous screen is reduced behind the transilluminated object, because the object attenuates the x-rays. Objects that are thicker or have greater attenuation characteristics show up on the luminous screen as darker features. However, the brightness of the image as a whole increases with the emission current.

An increase in the tube high voltage generally results in greater image contrast, as the x-rays are harder (a greater proportion of high-energy x-rays). At the same time, the brightness increases, because the intensity of the x-rays also increases (see P6.3.3.2).

Results

The luminous screen shows a relatively sharp image of the internal structure of the transilluminated object. This explains the great importance of x-rays in diagnostic medicine and non-destructive materials testing.