Radiographic examination of objects (Item No.: P2540020)

Curricular Relevance

| Area of Expertise: ILIAS | Education Level: Physik | Topic: Hochschule | Subtopic: Moderne Physik | Experiment: Röntgenphysik |

Difficulty	**Preparation Time**	**Execution Time**	**Recommended Group Size**
Difficult	1 Hour	2 Hours	2 Students

Additional Requirements:	**Experiment Variations:**
• Irradiation objects	

Keywords:

X-ray tube, absorption of X-rays, radiography, fluorescence

Overview

Short description

Principle

An X-ray tube produces X-rays that cause a fluorescent screen to emit light. Objects that are located between the X-ray source and the fluorescent screen will be irradiated so that their inner structure becomes visible. If one varies the anode current and voltage, the change in intensity can be observed in a qualitative manner on the fluorescent screen.

Fig. 1: P2540020

Equipment

Position No.	Material	Order No.	Quantity
1	XR 4.0 expert unit, X-ray unit, 35 kV	09057-99	1
2	XR 4.0 X-ray plug-in unit W tube	09057-81	1
3	XR 4.0 X-ray fluorescent screen	09057-26	1
4	Slide mount for optical bench expert, h = 30 mm	08286-01	2
5	Table with stem	09824-01	1
6	XR 4.0 X-ray optical bench	09057-18	1

Tasks

1. X-ray an object and observe the result on the fluorescent screen.

2. Vary the anode current and voltage and observe the result on the fluorescent screen.

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Set-up and procedure

Set-up

If a goniometer is installed in the experiment chamber, it should be removed if possible.

Install the optical bench and position the fluorescent screen in its holder on the optical bench as far to the right as possible. In order to position the various objects in front of the fluorescent screen in a stable manner, we recommend using the object stages.

Procedure

Position the object directly in front of the fluorescent screen, or at a distance from the screen, right in the beam path. If it is positioned at a distance from the screen, it will be magnified but at the same time it will also lose sharpness. You will obtain a high-contrast image with maximum anode voltage ($35\,kV$) and maximum anode current ($1.0\,mA$).

Now, close the door and proceed as follows:

- Lock the door with the aid of this button:

- Activate the X-radiation with this button:

- The display shows:

Adjusting the anode voltage and current:

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- Press the button under "Menu" (display).

- In the following window, select the option "Xray parameters" (use the arrow keys for the selection).

- Select the parameter that you would like to change.

- Confirm your selection with "Enter".

- Change the current value that is displayed with the aid of the arrow keys.

- Confirm with "Enter".

The new parameters will now be displayed.

Taking a picture with a digital camera:

- Fasten the camera to a slide mount on the optical bench.

- Switch it to night mode and deactivate the flash.

- Either darken the room completely or cover the unit with its cover.

- We recommend starting the camera with the self-timer so that the picture does not blur during the handling of the camera.

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Theory and evaluation

Theory

X-rays are invisible to the human eye. In order to be able to perceive them nonetheless, they are "converted" into visible light by fluorescence and with the aid of certain materials. These substances absorb the X-radiation and enter into an excited state. When they fall back into the ground state, they partly emit this energy. The loss in energy results in a changed wavelength of the emitted light: The wavelength is longer and now in the visible range. Nowadays, mostly zinc sulphide is used as the luminescent agent on the screen.

X-rays penetrate objects that are impenetrable for visible light. Visible light is absorbed to a far lower extent. The absorption depends on the thickness and type of the material. While in the past X-rays were even used to check whether a shoe fits well, we now know about the harmful effects of the radiation. At airports, it is used in order to inspect luggage.

When X-rays with the intensity I_0 hit matter of the thickness d, the intensity I of the transmitted radiation is as follows in accordance with the law of absorption (see experiment P2541101):

$$I = I_0 \, e^{-\mu(\lambda, Z) \cdot d} \qquad\qquad (1)$$

I : intensity of the radiation behind the absorber

I_0 : initial intensity of the radiation

μ : linear absorption coefficient

d : thickness of the material

Equation (1) directly shows that the intensity of the radiation behind the absorber also depends on the thickness of the absorber.

The linear absorption coefficient $\mu \left[cm^{-1} \right]$ depends on the wavelength λ of the radiation as well as on the atomic number Z of the absorbing matter. The absorption capacity of a material increases drastically when the wavelength or atomic number of the absorber increases.

Evaluation and results

Task 1: X-ray an object and observe the result on the fluorescent screen.

X-ray of a digital alarm clock:

The relatively sharp image of the digital alarm clock can be seen on the fluorescent screen (Fig. 2). The parts that contain metals, in particular, are clearly visible.

Inside the alarm clock, the wires can be seen very clearly because they consist of metal that has a considerably higher atomic number than the surrounding plastic. Plastic consists mainly of carbon, hydrogen, and oxygen.

Note: If you would like to take a picture of an object that "floats in space": Place it on a kitchen sponge. The sponge transmits nearly the entire X-radiation.

Fig. 2: Radiography of a digital alarm clock.

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X-ray of a snail shell:

The inner spindle of the snail shell is clearly visible in Fig. 3.

Figure 2 shows that the transmission depends on the thickness of the absorber. The snail shell consists completely of the same material, but in the area of the spindle there is more "mass" between the X-ray source and the screen. This is why this area is more clearly visible due to its higher absorption level.

Fig. 3: Radiography of the shell of a common whelk

Task 2: Vary the anode current and voltage and observe the result on the fluorescent screen.

When the anode current is reduced, the image gets darker. The same happens when the anode voltage is reduced (Fig. 4).
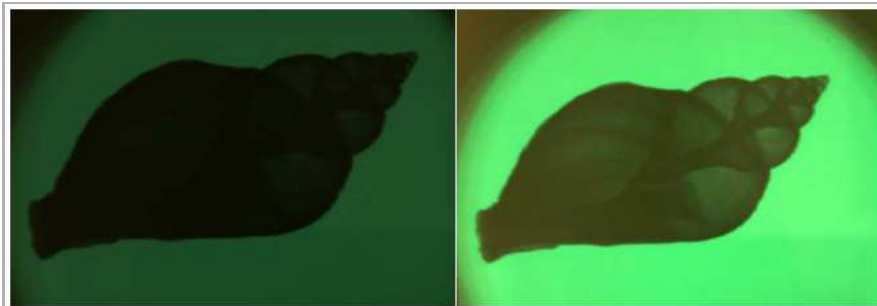

Fig 4: The shell of a common whelk with different anode voltages

Note:

A wide range of different objects can be used to demonstrate the effect of X-rays. Particularly impressive results can be achieved either with objects that consist of several different materials of different absorption capacities or with objects with a varying material thickness. Examples:
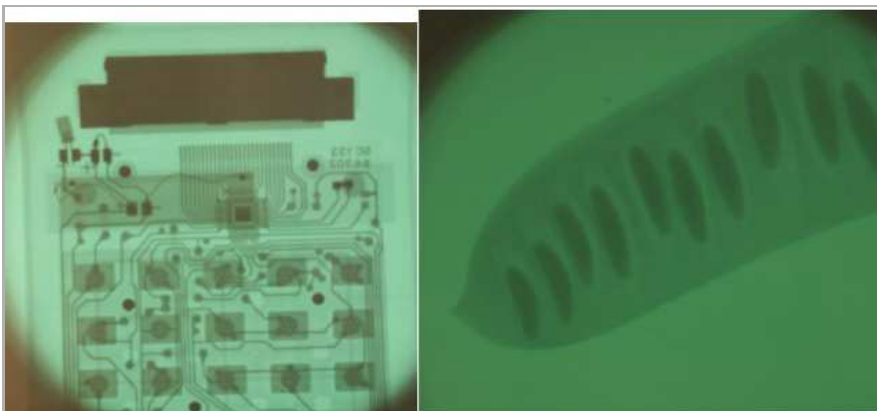

Fig. 5: Radiography of a pocket calculator and of a gleditsia pod.