

Radiographic examination of objects



Physics

Modern Physics

Production & use of X-rays



Difficulty level

hard



Group size

2



Preparation time

45+ minutes



Execution time

45+ minutes

This content can also be found online at:



<http://localhost:1337/c/5f60792d7e9d5b0003e1e627>

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General information



Application

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Setup

Most applications of X rays are based on their ability to pass through matter. Since this ability is dependent on the density of the matter, imaging of the interior of objects and even people becomes possible. This has wide usage in fields such as medicine or security.

Other information (1/2)

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Prior

knowledge



Main

principle

The prior knowledge required for this experiment is found in the Theory section.

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.

Other information (2/2)

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Learning objective



Tasks

The goal of this experiment is to get to know the characteristic of X-rays to penetrate soft matter.

- X-ray an object and observe the result on the fluorescent screen.
- Vary the anode current and voltage and observe the result on the fluorescent screen.

Theory (1/2)

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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.

Theory (2/2)

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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:

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

I : Intensity of the radiation behind the absorber; I_0 : initial intensity of the radiation

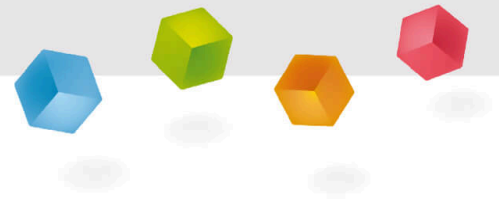
μ : linear absorption coefficient; d : thickness of the material

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 $\mu[\text{cm}^{-1}]$ 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.

Equipment

| Position | Material | Item No. | Quantity |
|----------|----------------------------------|----------|----------|
| 1 | XR 4.0 expert unit, 35 kV | 09057-99 | 1 |
| 2 | XR4 X-ray Plug-in Cu tube | 09057-51 | 1 |
| 3 | XR 4.0 X-ray imaging upgrade set | 09155-88 | 1 |

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Setup and procedure

Setup

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- 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 (1/3)

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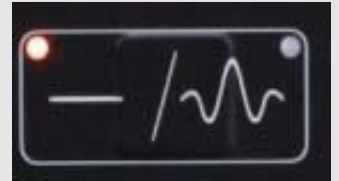
Position the object directly in front of the fluorescent screen, or at a distance from the screen, right in the beam path. If it is positioned at a distance from the screen, it will be magnified but at the same time it will also lose sharpness. You will obtain a high-contrast image with maximum anode 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 button 1.
- Activate the X-radiation with button 2.

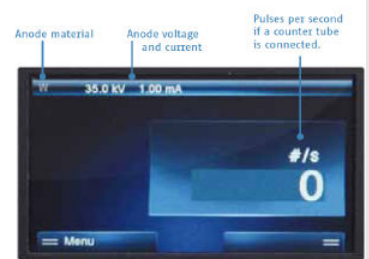


Button 1



Button 2

The display then shows:

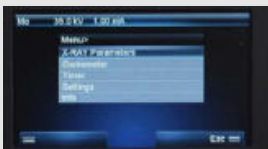


Procedure (2/3)

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Adjusting the anode voltage and current:

- 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.



Procedure (3/3)

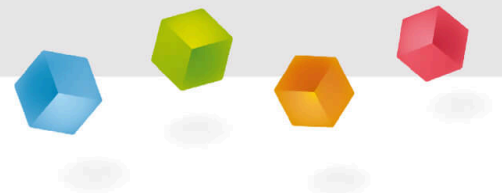
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Taking a picture with a digital camera:

- 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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Evaluation



Task 1

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

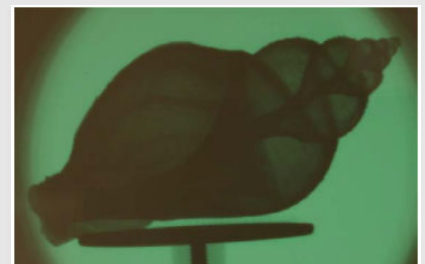
X-ray of a digital alarm clock: The relatively sharp image of the digital alarm clock can be seen on the fluorescent screen (Fig. 1). The parts that contain metals, in particular, are clearly visible. Inside the alarm clock, the wires can be seen very clearly because they consist of metal that has a considerably higher atomic number than the surrounding plastic. Plastic consists mainly of carbon, hydrogen, and oxygen.

X-ray of a snail shell: The inner spindle of the snail shell is clearly visible in Fig. 2. Figure 1 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.

Figure 1



Figure 2



Task 2

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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

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:

