Determination of length and position of an object which cannot be seen

Physics | Modern Physics | Production & use of X-rays

Difficulty level	Group size	Preparation time	Execution time
hard	2	45+ minutes	45+ minutes

General information

Application

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 peaple becomes possible. This has wide usage in fields such as medicine or security.

PHYWE excellence in science
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other information (1/2)

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Prior knowledge

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

Main principle

This experiment provides training in determining the length and position of an object based on an X-ray image. A metal pin that is embedded in a wooden block is used as the model. This experiment is also an excellent preparatory exercise for demonstrating the principle of computed tomography.

Other information (2/2)

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Learning objective

The goal of this experiment is to get familiar with the methods of radiospectroscopy

Tasks

1. X-ray the implant model in two planes that are shifted by 90° with regard to each other. Take a picture of the image on the fluorescent screen.
2. Calculate the true length of the embedded metal pin by taking into account the magnification factor that needs to be determined.
3. Determine the spatial position of the metal pin.

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Theory (1/3)

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Figure 1 shows example photos of the implant model.
Figure 2 shows a random oblique position of the metal pin of the length l in a three-dimensional space.

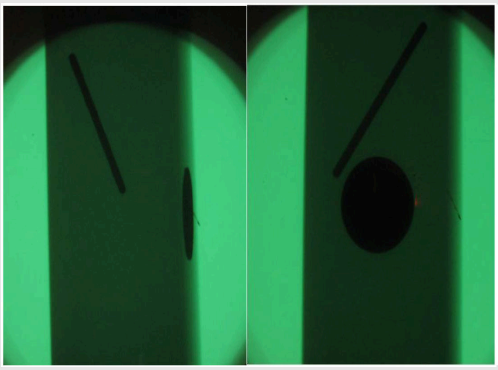
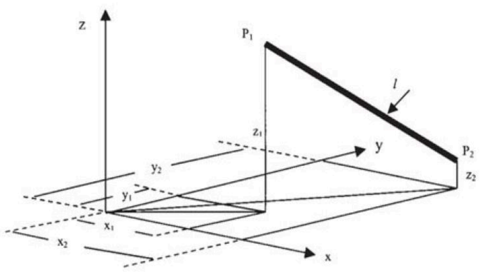


Fig. 1: Pictures of the implant model; projection in the x,z-plane (left) and in the y,z-plane (right)

Fig. 2: Random oblique position of the metal pin



Theory (2/3)

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The length l of the pin with its ends $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ is:

$$l = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} = \sqrt{l_x^2 + l_y^2 + l_z^2} \qquad (1)$$

Since the metal pin is irradiated by a conical bundle of X-rays and since it has a certain distance towards the film plane, it is projected on the film plane in a magnified form. In order to be able to determine the degree of magnification, the implant model is equipped with a metallic reference disk with a diameter of d = 30 mm. If the diameter of the disk projection on the film is d*, then the magnification is V = d*/d. As a consequence, the true length of the metal pin is $l_V = l/V$.

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Theory (3/3)

Figure 3 shows the projections of the metal pin for two planes of the implant model that are shifted by 90° with regard to each other. For the evaluation in accordance with figure 5, we recommend printing the photo as large as possible and determining the corresponding lengths with the aid of a Vernier calliper.

As an alternative, a graphics program can be used.

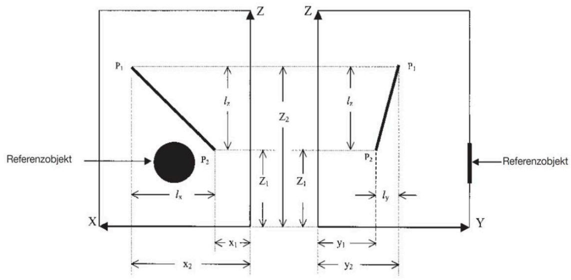

Fig. 3: Schematic representation of the projection of the metal pin in the x,z-plane (left) and in the y,z-plane (right)

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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

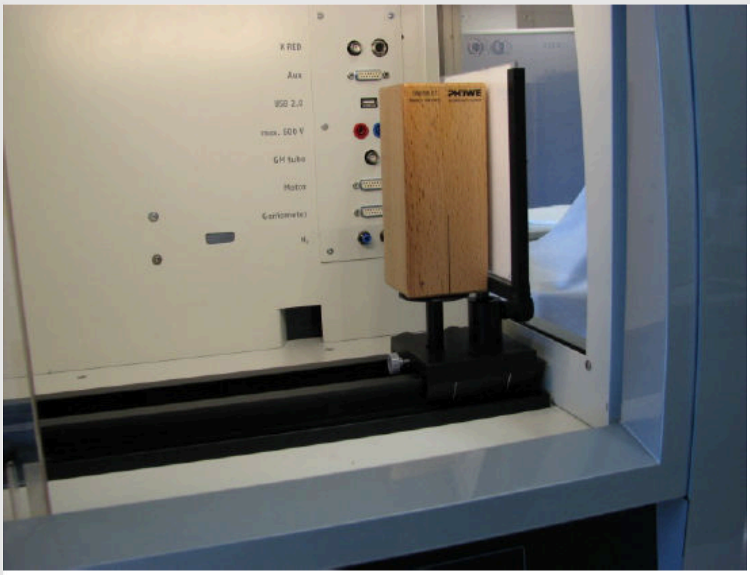

Fig. 4: Setup

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Procedure

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Place the implant model directly in front of the fluorescent screen with both of them as far to the right as possible on the optical bench. The distance between the front of the model and the outlet tube of the X-ray plug-in unit is then approximately 30 cm. Do not use a diaphragm tube for the irradiation.

- Adjust an acceleration voltage $U_A = 35\,\mathrm{kV}$ and an anode current $I_A = 1\,\mathrm{mA}$.
- Fasten the camera to the slide mount on the optical bench, then.select the night mode and deactivate the flash.
- Either darken the room completely or cover the device with the protective cover.
- We recommend taking the picture with the automatic camera release (self-timer) in order to prevent the camera from shaking.
- Then, turn the implant model by 90° around its longitudinal axis and repeat the procedure.

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Evaluation

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Example results

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The evaluation of the experiment example provided the following results:

$l_x = 52.0\,\text{mm}$, $l_y = 35.0\,\text{mm}$, $l_z = 71.0\,\text{mm}$ and V = 46.0/30.0 mm = 1.533.

Thus $l_x^* = 33.9\,\text{mm}$, $l_y^* = 22.8\,\text{mm}$, $l_z^* = 46.3\,\text{mm}$

These value lead to: l = 61.74 mm and $l_V = 60.06\,\text{mm}$ (the actual length of the metal pin (as manufactured) is 60.0 mm).

Based on the projection lengths l_x, l_y, l_z of l on the respective axes, the corresponding angles are calculated as follows:

$$\cos(\alpha) = \frac{l_x}{l};\ \cos(\beta) = \frac{l_y}{l};\ \cos(\gamma) = \frac{l_z}{l} \qquad \Rightarrow \qquad \alpha = 53.6^\circ;\ \beta = 67.7^\circ;\ \gamma = 39.6^\circ$$

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