Hounsfield units (Item No.: P2550900)

Curricular Relevance

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

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

Additional Requirements:

- PC
- Sample for CT

Experiment Variations:

Keywords:

Attenuation coefficient, Hounsfield units

Overview

Short description

Principle

Depending on the type of CT scanner and the settings, the result of a CT scan of the same material can be different attenuation coefficient (grey-values). In order to make it easier to compare CT data, espe-cially in medicine, the grey-values of a CT scan are often rescaled to a standard scale. Hounsfield units is such a scaling that uses air and water as a calibration material which is regularly used in medicine.

Fig. 1: Experimenta set-up

Equipment

Position No.	Material	Order No.	Quantity
1	XRE 4.0 X-ray expert set, with tungsten tube	09110-88	1
2	XRCT 4.0 X-ray Computed Tomography upgrade set	09180-88	1

Tasks

1. Perform a CT scan of the calibration material.
2. Recalculate the results to Hounsfield units.

Set-up and procedure

Set-up

Attach the XRIS to its stage.

Place the Digital X-ray detector XRIS on the rail at position $30\,\mathrm{cm}$. The back side of the XRIS stage corresponds to its position on the rail. This position is called the 'source to detector distance' SDD (mm).

Connect the usb cable between the detector and the computer.

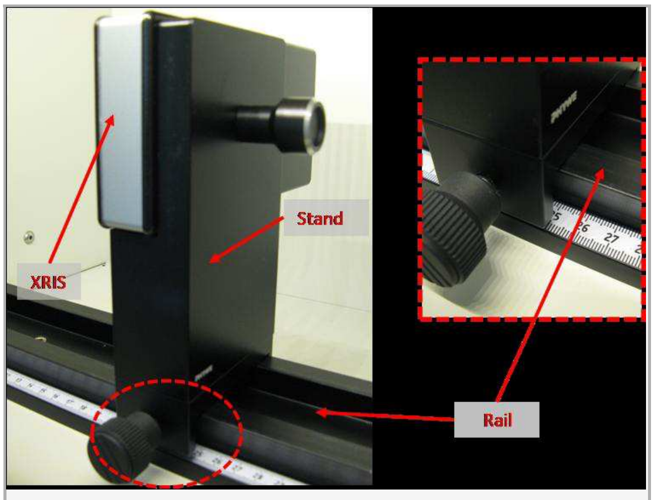

Fig. 2: Set-up of the XRIS

Place the rotation stage XRstage on the rail at position $25\,\mathrm{cm}$. The back side of the XRstage corresponds to its position on the rail. This position is called the 'source to object distance' SOD (mm). Connect the XRstage cable with the 'Motor' connection block in the experiment chamber. Attach the sample table to the XRstage with the fastening screw.

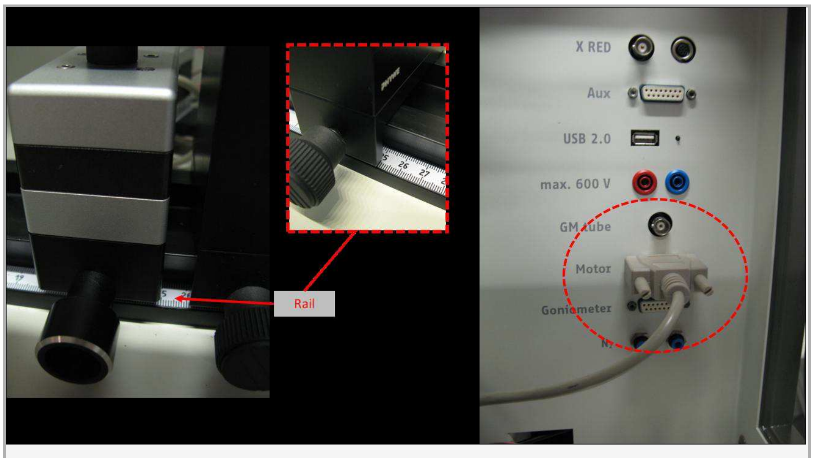

Fig. 3: Set-up of the XRstage

Connect the X-ray unit via USB cable to the USB port of your computer (the correct port of the X-ray unit is marked in Fig. 4).

Fig. 4: Connection of the computer

Procedure

- Start the “measureCT” program. A virtual X-ray unit , rotation stage and Detector will be displayed on the screen. The green indication LED on the left of each components indicates that its presence has been detected (Fig. 5)
- You can change the High Voltage and current of the X-ray tube in the corresponding input windows or manually on the unit. (Fig. 5).
- When clicking on the unit pictogram additional information concerning the unit can be retrieved (Fig. 5).
- The status pictogram indicate the status of the unit and can also be used to control the unit such as switching on and off the light or the X-rays (Fig. 5).
- The position of the XRIS and XRstage can be adjusted to its real position either by moving the XRIS pictogram or by filling in the correct value in the input window. (Fig. 5).
- The settings of the XRIS can be adjusted using the input windows. The exposure time controls the time between two frames are retrieved from the detector, the number of frames defines how many frames are averaged and with the binning mode the charge of neighbouring pixels is averaged to reduce the total amount of pixels in one frame.

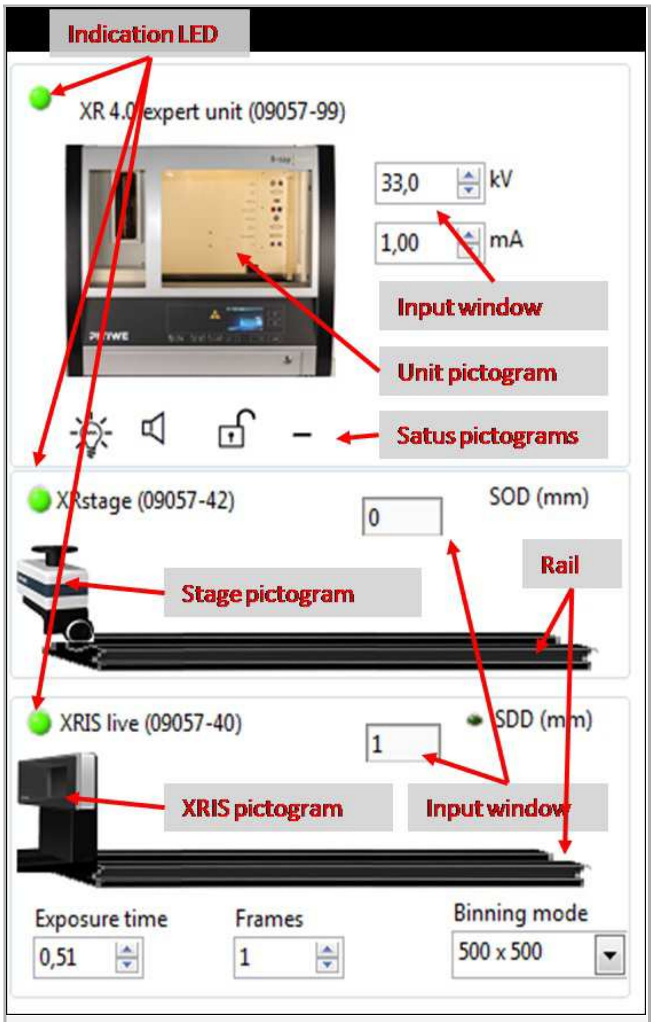

Fig. 5: Part of the user interface of the software

Experiment exection

1. CT scan of the calibration material

- Adjust the XRIS settings and X-ray unit settings according to Fig. 6 or load the configuration from the predefined CTO file 'Experiment 9' (see Fig. 6).

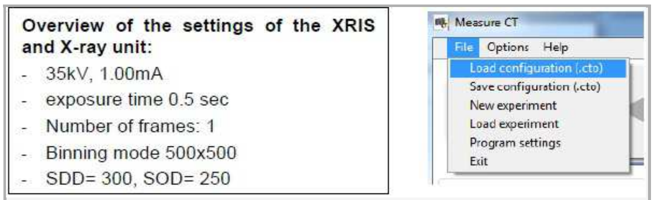

Fig. 6: The settings for this experiment (left panel) and the method load and adjust the settings (right panel)

- Start a new experiment, give it a unique name and fill in your details (Fig. 7). Alternatively it is also possible to load this experiment with pre-recorded images and open this manual. The correct configuration will be loaded automatically as well but the functionalities of the software will be limited to avoid overwriting the existing data.

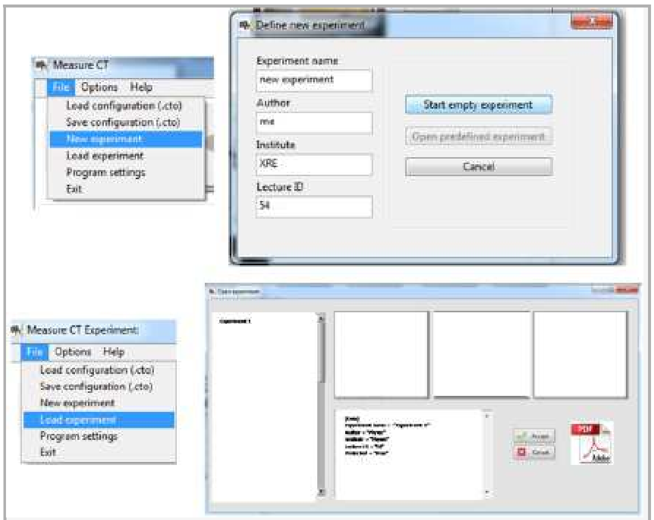

Fig. 7: How to create a new or open an existing experiment

- Switch on the X-rays (Fig. 8.1) and activate the 'Live view' (Fig. 8.2). When the Live view is activated, every new image that is retrieved from the X-ray detector is displayed. The Detector exposure load bar (Fig. 8.3) indicates the average degree of fill for each pixel. **It is very important to remain below the maximal fill degree of the detector**. Otherwise the detector will be saturated and won't work properly. If the saturation level is reached, the 'detector exposure' load bar will turn red. (see experiment 1 for more details)
- Calibrate the detector by clicking on "Calibrate'(Fig. 8.4). When the calibration is successfully performed, the indication LED (Fig. 8.5) will turn green. The Load bar (Fig. 8.3) will disappear and the Contrast/intensity cursor (Fig. 8.6) will become available. (see experiment 1 for more information).
- Place object XXXX in the centre of the sample stage and close the door.
- Adjust SOD (Fig. 8.7) and SDD (Fig. 8.8) in the software according to the actual position.

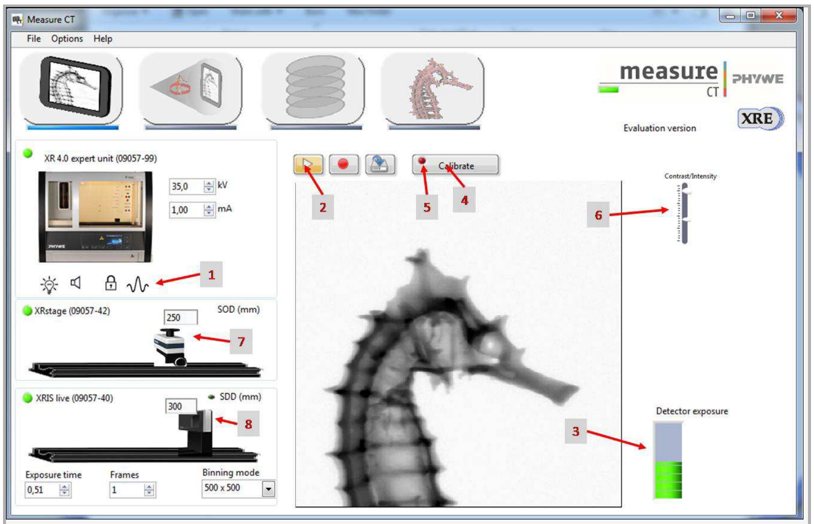

Fig. 8: Settings to set before start of a CT-scan, part 1

- Go from the "Live view page" to the "CT scanning page". The indication pictogram will turn blue when the page is activated.

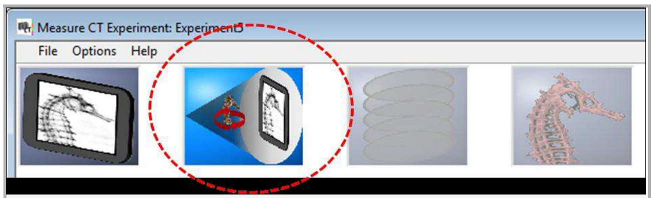

Fig. 9: CT scanning page

- In the CT scan page, change the number of projections to 400 (Fig10.8).
- Start a CT scan (Fig. 10.1). More info in experiment 5.

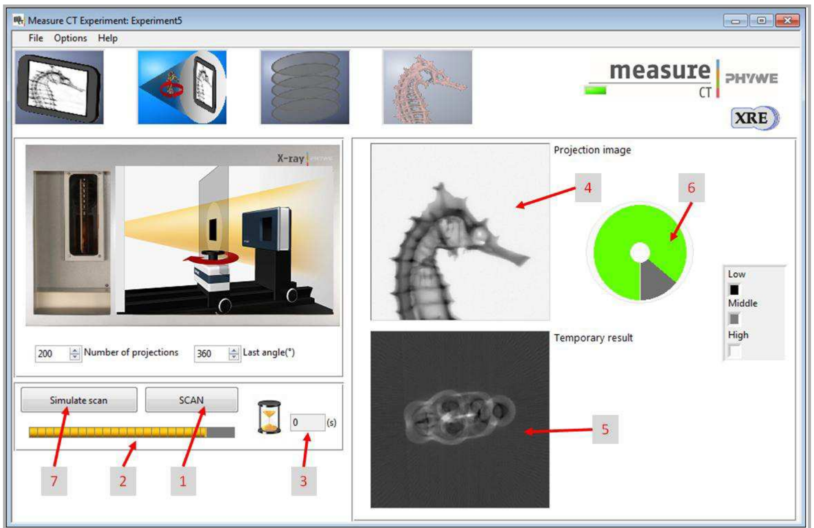

Fig. 10: Start a CT-scan

- When the CT scan is finished it is possible to proceed to the reconstruction. Go from the "CT scanning page" to the "Data reconstruction page". The indication pictogram will turn blue when the page is activated.

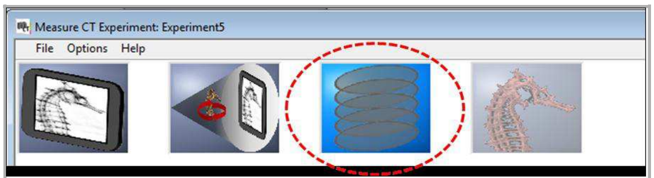

Fig. 11: Data reconstruction page

- Find the slice at the top of the object that looks like Fig 12.I.

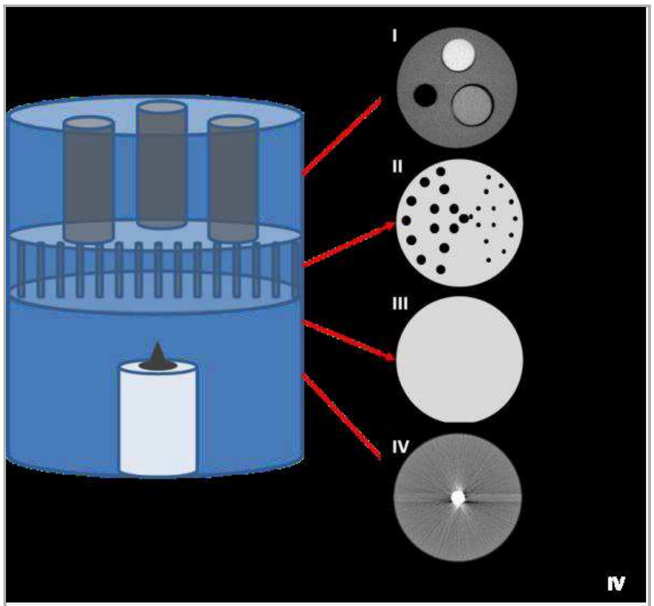

Fig. 12: CT experiment sample

Note: The upper part of the object consist of a plastic cylinder with three holes. One hole is left empty, one hole is filled with plastic that has an attenuation coefficient very close to water (transparent with largest diameter) and one hole is filled with plastic that has to mimic bone (white plastic).

- Optimise the centre of rotation (see experiment 5 and 6 for more information).
- Open the image viewer, the corresponding slice will be visible.

2. Determine the Hounsfield unit of the 'bone'plastic.

- In the image viewer, select a region inside each of the holes by adjusting the position of the cursors (Fig. 13.1) and click on calculate (Fig. 13.2) o calculate the average attenuation coefficient.

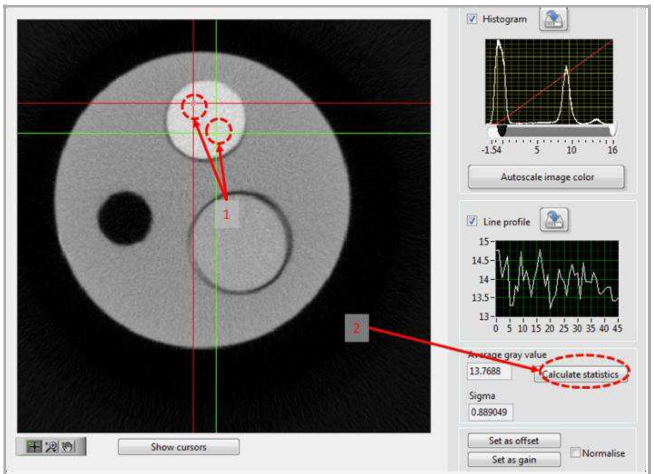

Fig. 13: calculate the average grey value in each of the holes

- Use the attenuation coefficient of the air and the water to calculate the Hounsfield units of the 'bone'-plastic.
- Repeat this but with different kV settings. report and explain the differences.

Theory

Depending on the type of CT scanner and the settings, the result of a CT scan of the same material can be different attenuation coefficient (grey-values). In order to make it easier to compare CT data, especially in medicine, the grey-values of a CT scan are often rescaled to a standard scale. Hounsfield units (HU) is such a scaling that uses air and water as a calibration material which is regularly used in medicine.

To calculate the HU:

$$HU = 1000 \times \frac{\mu_x - \mu_{water}}{\mu_{water} - \mu_{air}}$$

With μ_{water} and μ_{air}, the linear attenuation coefficients of water and air respectively and μ_x the linear attenuation coefficient of the components that needs to be defined. With this formula, the HU of watter is 0 and the HU of air is -1000.

Although HU are very practical, they can cause wrongful interpretation of the data. CT artefacts such as beam hardening and metal artefacts (see experiment 8) generate errors in this principle. Also, the linear attenuation coefficient of different materials is energy dependant in a non-linear way. Using different Xray photon spectra will cause variations in the HU conversions that is not consistent to compare data across different scans.