Principles of beam intensity (Item No.: P2550300)

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:

Beam Intensity in relation to power and kV, inverse square law, beam hardening, filtration, spectrum, polychromaticity, detector dark current

Overview

Short description

Principle

Laboratory based X-ray sources are in most cases polychromatic, meaning that the spectrum of the source consists of an energy range instead of a single distinctive energy peak. This has a lot of influence on the X-ray measurements that are performed. Especially the relation of the pixel count on the digital detector versus the beam power is important for optimal image quality.

Fig. 1: Experimental set-up

Student's Sheet

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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. Determine the variation in beam intensity.
2. Investigate the inverse square law.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Set-up and Procedure

Set-up

Attach the XRIS to its stage.

Place the Digital X-ray detector XRIS on the rail at position $25\,\mathrm{cm}$. The back side of the XRIS stage cor-responds to its position on the rail. This position is called the 'source to detector distance' SDD (mm).

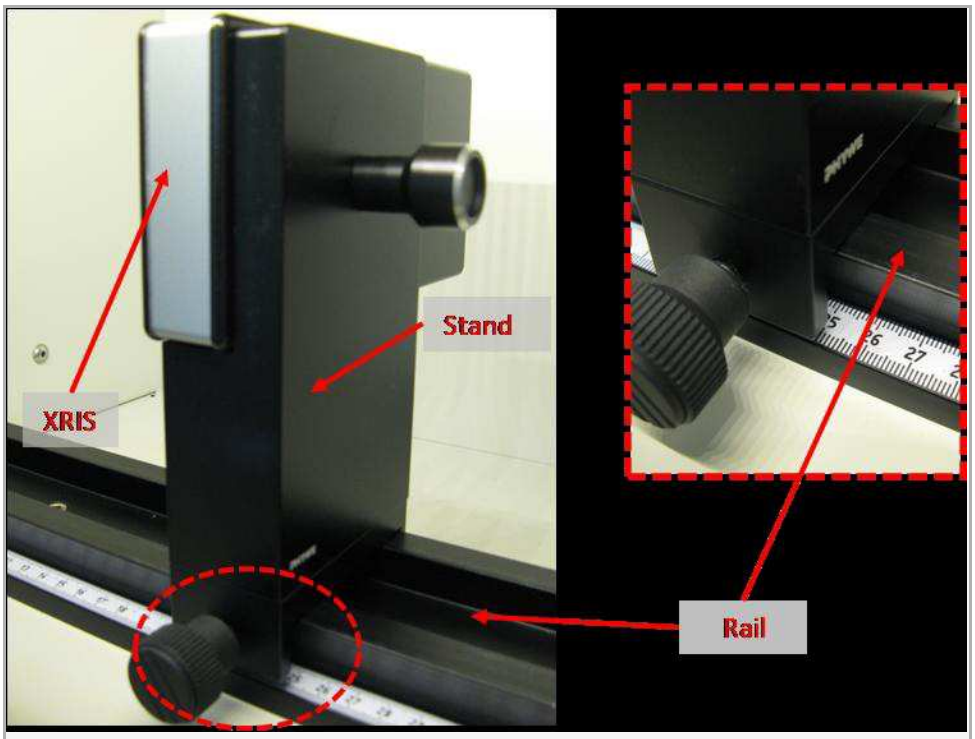

Fig. 2: Set-up of the XRIS

Note:
Details concerning the operation of the X-ray unit and Detector as well as information on how to handle the detector can be found in the respective operating instructions.

Procedure

- 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. 3).

Fig. 3: Connection of the computer

- Connect the usb cable of the detector to the computer.
- Start the “measureCT” program. A virtual X-ray unit , rotation stage and Detector will be dis-played on the screen. The green indication LED on the left of each components indicates that its presence has been detected (Fig. 4).
- You can change the High Voltage and current of the X-ray tube in the corresponding input windows or manually on the unit. (Fig. 4).
- When clicking on the unit pictogram additional information concerning the unit can be re-trieved(Fig. 4).
- 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. 4).

- The position of the digital detector can be ad-justed to its real position either by moving the XRIS pictogram or by filling in the correct value in the input window (Fig. 4).
- 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 aver-aged to reduce the total amount of pixels in one frame.

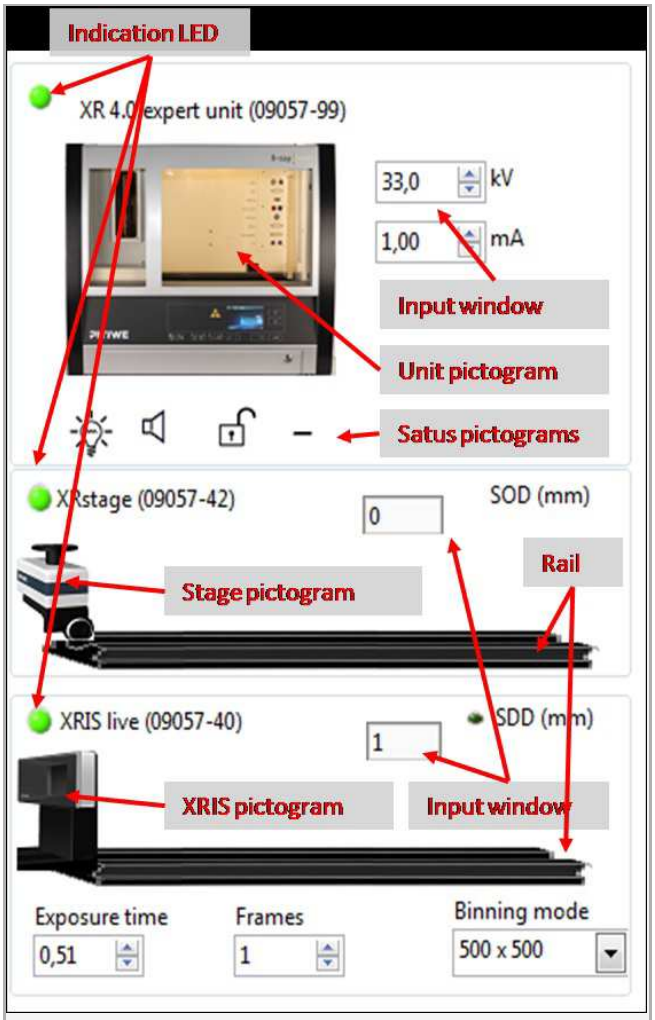

Fig. 4: Part of the user interface of the software

Experiment execution

1. Determine the variation in beam intensity

- Adjust the XRIS settings and X-ray unit settings according to Fig. 5 or load the configuration from the predefined CTO file 'Experiment 3' (see Fig. 5).

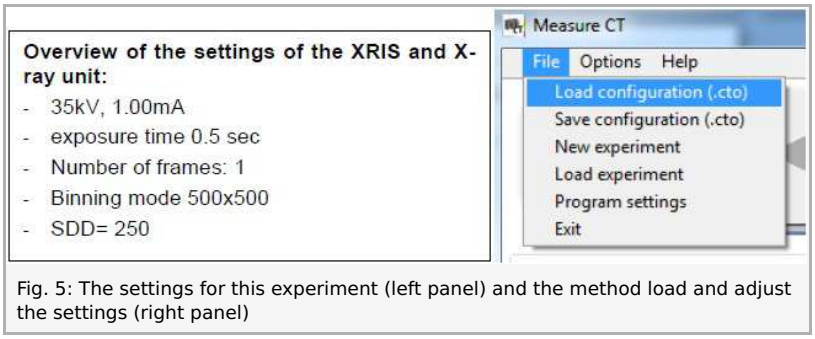

Fig. 5: The settings for this experiment (left panel) and the method load and adjust the settings (right panel)

- Start a new experiment, give it a unique name and fill in your details (Fig. 6). Alternatively it is also possible to load this experiment with pre-recorded images and open this manual. The correct con-figuration will be loaded automatically as well

but the functionalities of the software will be limited to avoid overwriting the existing data.

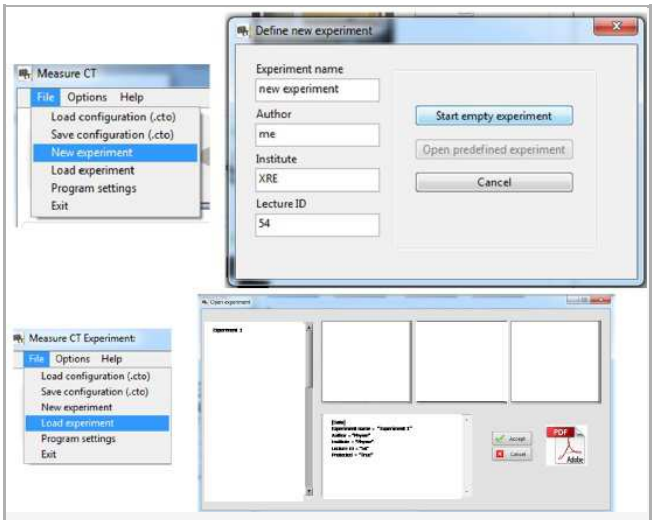

Fig. 6: How to create a new or open an existing experiment

- Check whether the detector is not saturated for the highest power ($35\,\mathrm{kV}$, $1\,\mathrm{mA}$) (see experiment 1).
- Switch of the X-ray source and wait a couple of seconds. Activate the 'live view'. Wait long enough between the image to allow the source and detector to adjust to the new settings ($3 - 5\,\mathrm{sec}$). Deacti-vate the 'live view'.
- Take on image with the X-rays of and save it as DI_500ms in the tiff format.
- Switch on the X-rays.
- Take un-calibrated images at $35\,\mathrm{kV}$ but change the current in steps of 0.1 from 0 to $1\,\mathrm{mA}$, save the images accordingly. Wait long enough between the image to allow the source and detector to adjust to the new settings.
- Take un-calibrated images for 20kV but change the current in steps of 0.1 from 0 to $1\,\mathrm{mA}$, save the images accordingly.
- Open the viewer.
- Double click on the DI_500ms image, 'Set as offset image' (see Fig. 7.1) and normalise (see Fig. 7.2). This way the detector dark current is subtracted from the images.
- Double click on one of the other images. Select a large, central region of image 'see Fig. 7.3), calcula-te the average pixel count (average grey value), (see Fig. 7.4 and 7.5) in that region and write it down.
- Repeat this for all the images that were saved.

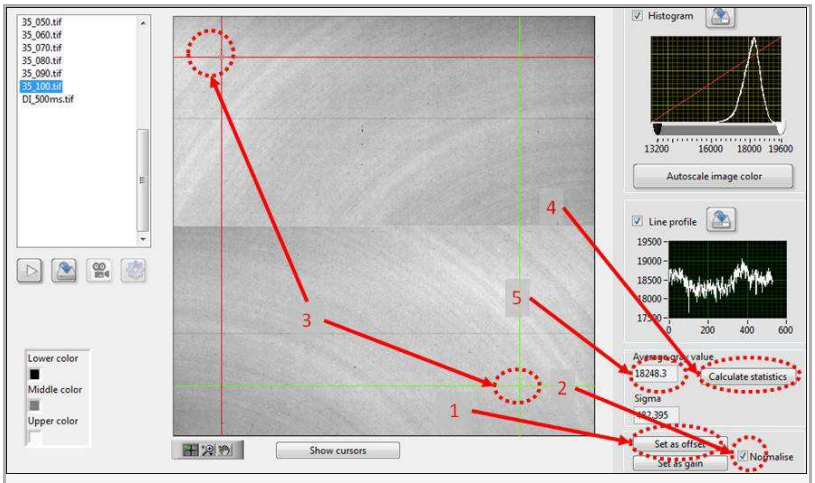

Fig. 7: How to normalise for dark current and calculate the pixel count

- Put the results in a table and calculate the power for every setting (see Fig. 8).

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35 kV		
current(mA)	power (W)	Intensity(counts)
1	35.0	18250
0.9	31.5	16404
0.8	28.0	14530
0.7	24.5	12613
0.6	21.0	10697
0.5	17.5	8756
0.4	14.0	6827
0.3	10.5	4930
0.2	7.0	3100
0.1	3.5	1430
0	0.0	0

20 kV		
current(mA)	power (W)	Intensity(counts)
1	20	2531
0.9	18	2254
0.8	16	1981
0.7	14	1711
0.6	12	1447
0.5	10	1187
0.4	8	934
0.3	6	688
0.2	4	448
0.1	2	219
0	0	0

Fig. 8: Pixels counts in function of current and power for different kV settings

- Make a plot of the resulting pixel counts in function of the current (see Fig. 9).

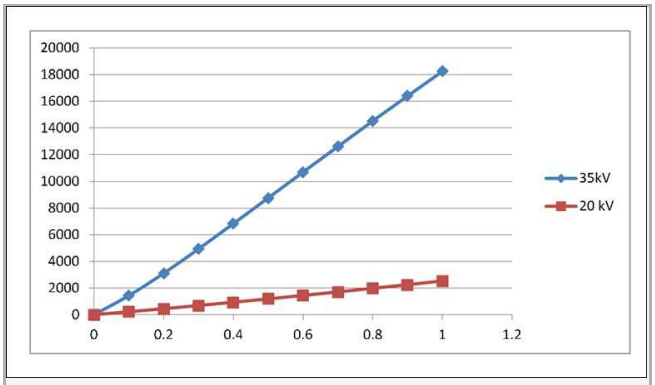

Fig. 9: Pixels counts in function of current for different kV set-tings

Note: For the same current settings but different kV settings, the pixel count is much lower. There are two several reasons for this, the first reason that the beam intensity is correlated to the beam power and not to the current alone.

- Make a plot of the resulting pixel counts in function of the power (see Fig.10).

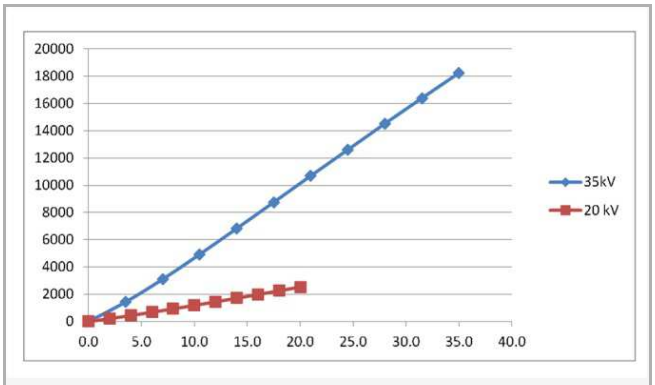

Fig. 10: Pixels counts in function of the power for different kV settings

Note: Even when the beam power is correlated to the pixel count, the pixel count at lower kV is much lower. This is caused by the inherent filtration of the X-ray source and the sensitivity of the detector (see theory for more information).

2. Investigate the inverse square law

- Move the detector to position SDD= 200.
- Take and save an image.
- Repeat this for SDD= 250, 300, 350, 400.
- Open the image viewer, correct for dark current and calculate the average pixel count in a relatively large area (see Fig. 7).
- Make a table and plot the results (see Fig. 11).

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SDD	counts
200	25927
250	17700
300	12750
350	9188
400	7056

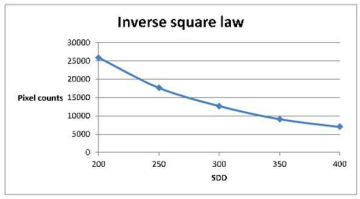

Fig. 11: Pixels counts in function of the SDD for same power and kV settings.

Note: The pixel count for SDD= 200 is approximately four times higher than at position SDD=400. This effect is called the inverse square law. (see theory for more information).

Theory

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