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Principles of resolution and detail detectability

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

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

This content can also be found online at:

http://localhost:1337/c/5fa1c5bdd6b04000035a718e

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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.

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Other information (1/2)

Prior knowledge

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

Main principle

In X-ray imaging, resolution is an important factor. It determines the sharpness of the images and the de-tails of a sample that can be observed. In this experiment, the different factors that determine the resolu-tion are investigated.

Other information (2/2)

Learning objective

The goal of this experiment is to get to know the principles of resolution and detail detectability.

Tasks

1. Investigate the resolution in function of detector binning.
2. Investigate the detail detectability.
3. Investigate the resolution in function of SOD.

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Theory (1/7)

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Detector binning

The Xris is a digital sensor composed of 1000×1000pixels (picture elements). Each X-ray pho-ton that interacts with the detector generates a signal under the form of a charge that is collected by the pixel corresponding to the location of the interaction. During read-out, the total charge that was collected by each pixel during the exposure time is converted to a digital signal by a digital-to-analogue converter (DAC). This signal is displayed as a grey-value in a 1000×1000array to form a 1 Mpix image.

When detector binning is used, the charge corresponding to several pixels is averaged to represent one new pixel. In the 1000×1000mode, no binning is applied while for the 500×500mode 4 pixels are grouped together to generate a 500^2 pixels image, and for the 250×250mode, 16 pixels are grouped to-gether.

Theory (2/7)

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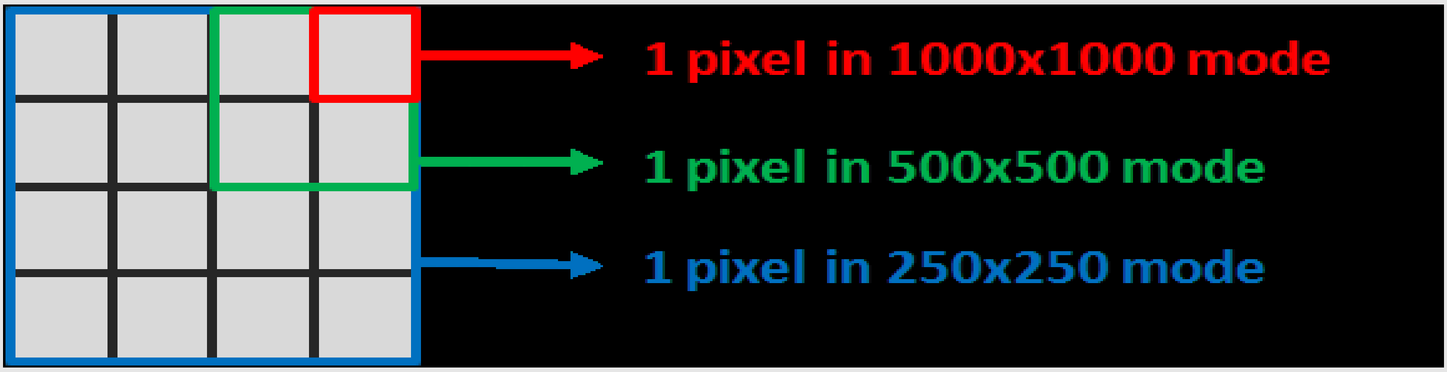
Binning has the advantage that the size of the images becomes much smaller, which is very intersting for CT as a large number of images are recorded and reconstructed.



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Theory (3/7)

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Definition of contrast

Contrast is the difference in luminance that makes an object distinguishable. There are many possible definitions and ways of calculating contrast that are used in different situations. Also in X-ray imaging contrast can have different meanings and be measured in a different ways.

Overall, the most representative way of expressing contrast (C)between two objects in an X-ray radio-graph is as their absolute difference in transmission: $\mathrm{C} = \mathrm{T}_{\mathrm{obj1}} - \mathrm{T}_{\mathrm{obj2}}$ with $\mathrm{T}_{\mathrm{obj1}}$ the transmission of object 1 and $\mathrm{T}_{\mathrm{obj2}}$ the transmission of object 2.

The best possible contrast exists when one objects has no absorption (T = 1 - A = 1) while the other object has no transmission (T = 1 - A = 0). The C-value can either be expressed as a value between 0 and 1 or as a percentage (0 - 100). In these experiments the absorption of air is taken into consideration when calibrating the detector, therefore the air has no absorption ($\mathrm{T}_{\mathrm{air}=1-\mathrm{A}_{\mathrm{air}}} = 1$).

Theory (4/7)

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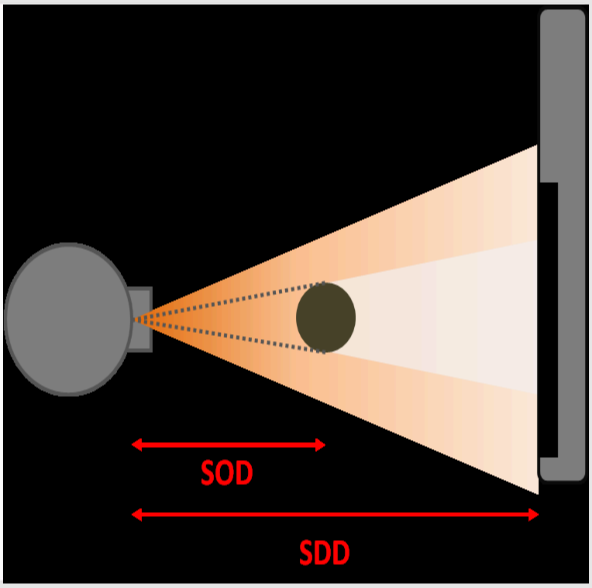
Principle of X-ray imaging resolution

In an X-ray source, all the X-ray photons originate from one location on the target of the source, this lo-cation is called the focal spot of the source. The generated X-rays leave the focal spot in all possible di-rections and a part of the beam illuminates the detector, this part of the beam is called the field of view. As the origin of the X-rays is a point and the field of view beam conical, each object placed between the source and detector is magnified upon the detector. The level of magnification (M) is the relation be-tween the distance of the object to the source (SOD) and the detector to the source (SDD).

$$\mathrm{M} = \frac{\mathrm{SDD}}{\mathrm{SOD}}$$



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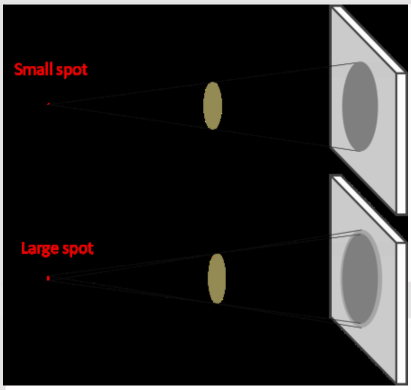
Theory (5/7)

The resolution of an X-ray system is mainly determined by the detector resolution and the focal spot size resolution.

- Detector resolution: The maximal obtainable resolution of a detector is its pixel size. The XRIS has a pixels size of 48 μm in the 1000×1000 binning mode. When the detector is used in 500×500binning mode, four pixels are grouped together as one and the resolution becomes two times lower with 96 μm. In reality, the resolution is slightly inferior to this because the interaction of one single X-ray photon can cause a signal in more than one pixel.
- Focal spot size: The smaller the size of the focal spot, the sharper the radiography. When the focal spot has a certain size, the X-ray projection of the object in the field of view is slightly blurred. this blurring is proportional to the size of the spot and the magnification.



Theory (6/7)

The relation between the detector pixels size (d), the focal spot size (s) and the system resolution (R) can be simplified with this formula:

$$\mathrm{R} = \frac{\mathrm{d}}{\mathrm{M}} + \mathrm{s}(1 - \frac{1}{\mathrm{M}})$$

If the object is placed very close to the detector (M = 1), the resolution equals the pixel size. The closer the object is brought to the source, the more important the spot size becomes. If the spot size is larger than the pixel size, bringing the object closer to the source will magnify it but will worsen the sharpness of the image.

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Theory (7/7)

Resolution versus detail detectability

Resolution on itself is a relatively vague term as it can be defined in many ways. But it is important to discriminate resolution from detail detectability. Detail detectability refers to the ability to identify one detail. Even if the detail is smaller than one pixel, it can often be identifies if its signal is sufficiently different from the surroundings. resolution on itself is the ability to disciminate two small features that are placed very close to each others.

The easiest way to verify the resolution of a system is by using a resolution pattern.

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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 Computed Tomography upgrade set	09185-88	1

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Setup and Procedure

Setup

Attach the XRIS to its stage.
Place the Digital X-ray detector XRIS on the rail at position 25 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).

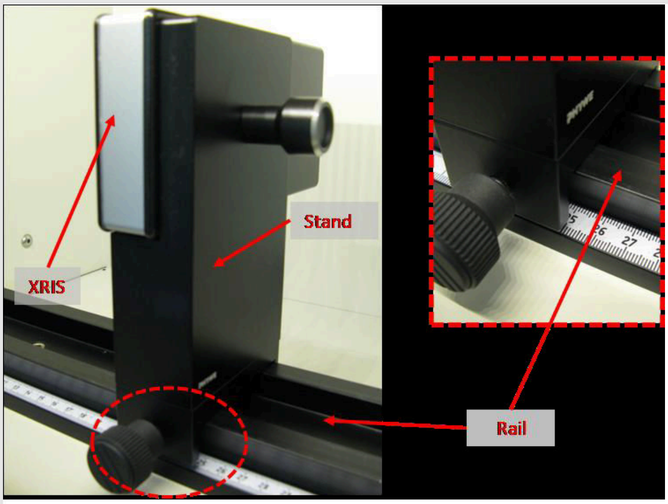

Fig. 1: Set-up of the XRIS

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Procedure (1/2)

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- 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. 2).
- 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. 3)
- You can change the High Voltage and current of the X-ray tube in the corresponding input windows or manually on the unit. (Fig. 3)
- When clicking on the unit pictogram additional information concerning the unit can be re-trieved(Fig. 3).

Fig. 2: Connection of the computer

Procedure (2/2)

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- 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. 3).
- 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. 3).
- 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.

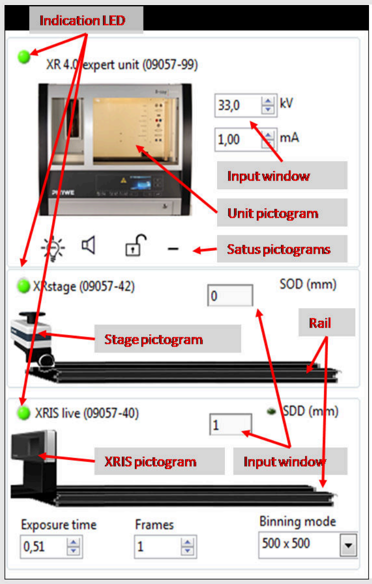

Fig. 3: Part of the user interface of the software

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Experiment execution

Determine the resolution in function of binning

- Adjust the XRIS settings and X-ray unit settings according to Fig. 4 or load the configuration from the predefined CTO file 'Experiment 4' (see Fig. 5).
- Start a new experiment, give it a unique name and fill in your details (Fig. 5). 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.

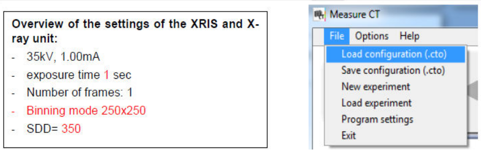

Fig. 4: The settings for this experiment (left panel)and the method load and adjust the settings (right panel)

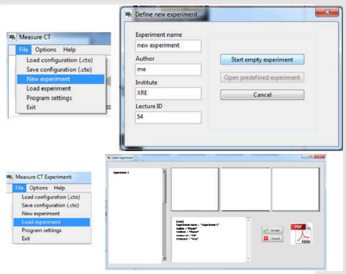

Fig. 5: How to create a new or open an existing experiment

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Determine the resolution in function of binning (part 2)

- Check whether the detector is not saturated (see experiment 1)
- Calibrate the detector (see experiment 1)
- Place the object xx in the detector with its coloured side towards the source. This object contains a resolution pattern in the centre.
- Take a radiography of the object and save it as 'binning250_350' under the tif format.
- Remove the object

Adjust the detector binning (see Fig. 6) from 250x250 to 500x500 (from 500x500 to 1000x1000) and repeat the previous steps while saving the image as 'binning500_350' ('binning1000_350').

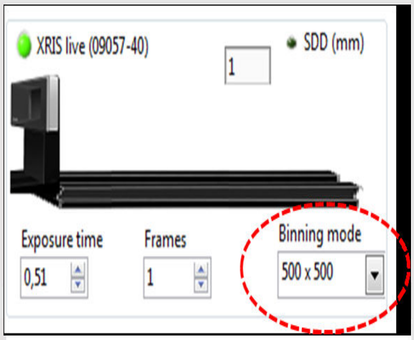

Fig. 6: How to change the binning

Determine the resolution in function of binning (part 3)

- Open the viewer (see experiment 1) and select the directory with the images you just saved.
- Start with the 'binning250_350' image. Play with the upper and lower levels of the histogram to clearly see all markings and change the middle colour to white.
- Start with the 1000 μm region (see Fig. 7), these are holes in the resolution pattern with a diameter of 1000 μm and the same distance between the edges of the holes. Adjust the cursors and look at the line profile (zoom in on the region if necessary). Move the image towards the 500 μm region and re-peat this for all the regions. Determine for which region the circular holes are still separately visible, this is the resolution of this configuration.
- Determine what the contrast between the centre of the hole and the metallic plate of the resolution pattern itself is for all the visible hole-series using the line profile.
- Repeat this operation for the two other images and compare the results.

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Determine the resolution in function of binning (part 4)

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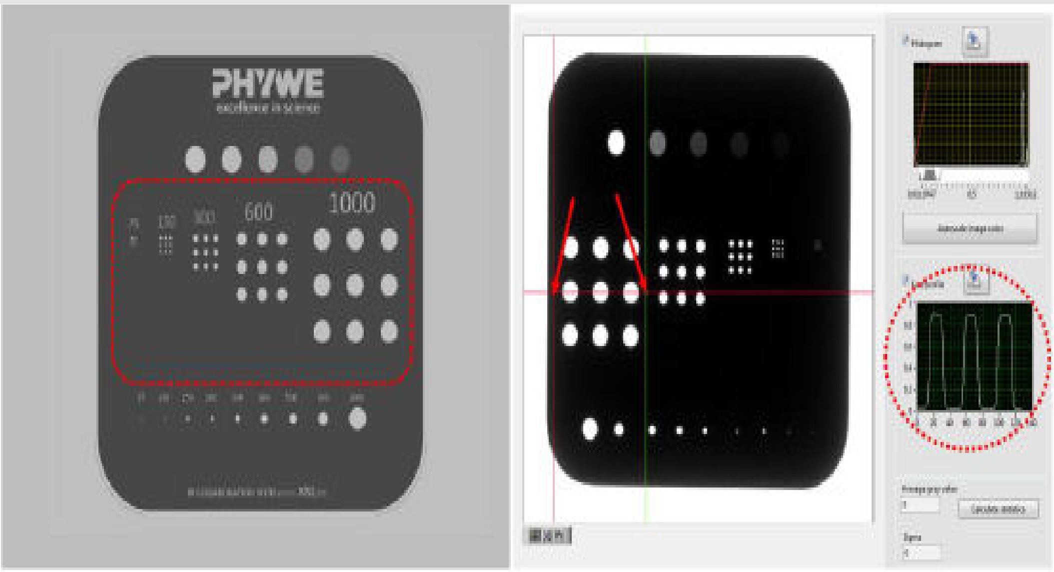

Fig. 7: The resolution pattern and the line profile through the 1000 μm holes series

Investigate detail detectability

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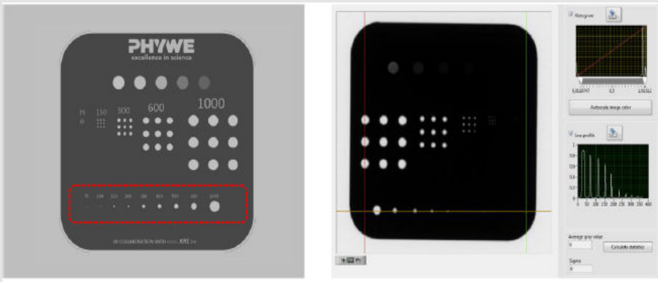
- Using the images previously saved images.
- Zoom in on the region with the single holes, start with the 1000 μm hole. Adjust the cur-sors and look at the line profile. Move the image towards the μmhole and repeat this for all the holes. Determine which hole is still visible, this is the detail detectability for this configuration.
- Determine what the contrast between the centre of the hole and the metallic plate of the resolution pattern itself is for each hole.
- Repeat this operation for the two other images



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Investigate resolution in function of the SOD

Keep the detector in binning 1000x1000 and calibrated. Place the object XX on a stand and take some images with the stand on different positions 250 mm, 200 mm, 100 mm. Save the images as 'binning1000_XXX' with XXX the position of the stand.

Compare the resulting images with 'binning1000_350' recorded before. Determine the resolution and detail detectability of these images.

Note: By placing the object closer to the X-ray source, the projection of the object will be magnified upon the detector. At that point the resolution is not only determined by the resolution of the detector alone but also by the resolution of the X-ray source. As the resolution of this source is inferior to the detector resolution, the image will be blurred and the resolution will be less good.

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