Homework # 4_A

1. The diameter of the input screen of an image intensifier tube is 17cm, and the diameter of the output screen is 2.5 cm. Assume a 60KeV x-ray photon is absorbed by the input screen and some 20% of the absorbed photon energy is re-emitted from the input screen in the form of 3000 visible light photons. These together may cause the ejection of a total of about 400 electrons from the adjacent photocathode. Each such electron acquires enough kinetic energy on the way to the anode, and produces 1000 or so visible light photons at the output screen.

(a) What is the minification gain of the tube?

Solution:

$$\text{Minification gain} = \left(\frac{d_i}{d_0}\right)^2 = (17 / 2.5)^2 = 46.24$$

(b) What is the overall brightness gain of the tube?

Solution:
For each x-ray absorbed by the input screen,

# of light photons from input screen is: 3000 photons

# of light photons from output screen is: 400(electrons) × 1000 (photons/electron)
=400 × 1000= 400,000 photons

The electronic gain = (400 × 1000) / 3000 = 133.33

The overall brightness gain = (electronic gain) × (minification gain)
= 46.24 × 133.33 = 6165.33

2. Why is the surface of the vacuum window of the image intensifier designed with curvature?
Solution:
The vacuum window keeps the air out of the image intensifiers, and its curvature is designed to withstand the force of the air pressing against it.

3. (a) What is the cause of the pincushion distortion of image intensifiers?
Solution:
The pincushion distortion is the result of projecting the image with a curved input phosphor to the flat output phosphor.

(b) What is the cause of the S distortion of image intensifiers?
Solution:
The S distortion is caused by earth's magnetic field.

4. In fluoroscopy, switching image intensifiers from 9 inch to 6 inch field-of-view (FOV) results **_(A) an increase_**in the spatial resolution and **___(B) a decrease__**in the overall "brightness" gain of system.

A. an increase
B. a decrease
C. no change

5. A DSA procedure was performed for a patient in order to determine the thickness of his/her vessel at a specific location. The pixel value measured from the Mask image was 1000, and the pixel value measured from the Angio image was 900. Assume that the linear attenuation coefficient of the contrast agent used in the procedure was previously determined as 0.5 cm^{-1}. What is the vessel thickness?

Solution:

$$S_{\log} = \ln(N_{mask}) - \ln(N_{angio}) = \mu\, x$$

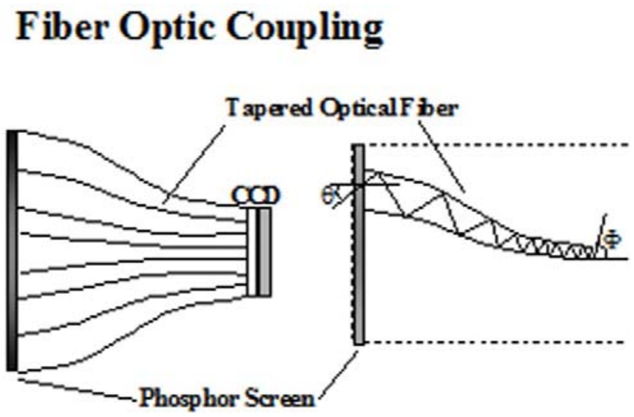
$$\ln(1000) - \ln(900) = \mu\, x$$

$$\Rightarrow 0.1 = \mu\, x$$

$$\Rightarrow x = \frac{0.1}{0.5\, cm^{-1}} = 0.2\ (cm)$$

Home Work #4_B

1. A fiber optically coupled CCD x-ray imaging system is schematically shown as follows. The CCD detector is a 1024 ×1024 pixel array, and each pixel is 0.025mm × 0.025mm in dimension. The fill factor of the CCD detector is assumed to be 100%. A 2:1 optical fiber taper is used to relay images from a scintillating screen to the CCD detector. Assuming the x-ray source used in this system is a "point" source (with very small focal spot) and the scintillating screen is very thin. Therefore these two components have no significant impact to the limiting spatial resolution of the overall x-ray imaging system.
   (1) Please determine the limiting spatial resolution of the overall x-ray imaging system.
   (2) Also determine the field of view (FOV) of the system.



Solution:

(1) CCD pixel size = 0.025mm, consider a 2:1 optical fiber taper,

Therefore, the overall pixel size of the system is 0.025mm × 2=0.05mm

The limiting spatial resolution = $\frac{1}{2\times 0.05mm} = 10(lp/mm)$

(2) 0.05mm×1024= 51.2mm; FOV of the system is 51.2mm X 51.2mm

2. A CCD detector system has a well depth of 100,000 electrons and a readout noise of 10 electrons. What is its dynamic range in dB?

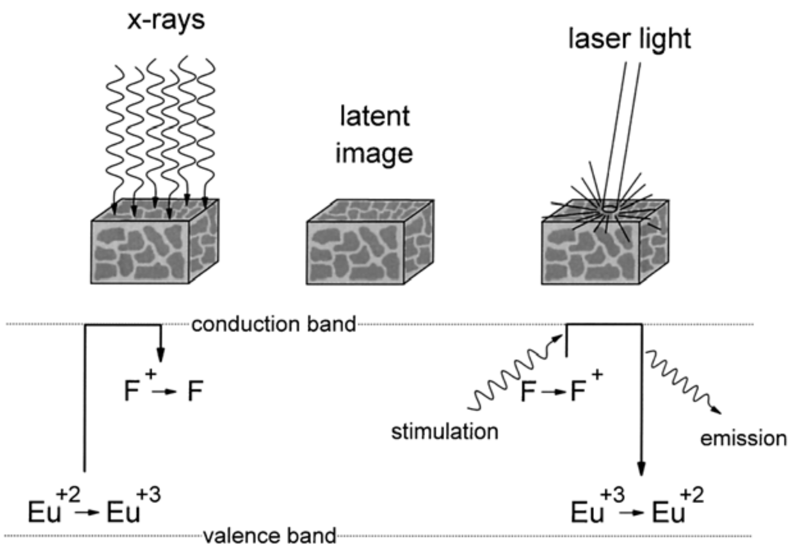
Solution:

Dynamic range = 20 × log (100,000/10) = 80 (dB)

3. Please describe, in your own words and/or schematics, the principle of a storage phosphor in recording x-ray images (how x-ray images is recorded by storage phosphor?)

Solution:

- Refer to the following figure. When the x-ray energy is absorbed by the BaFBr phosphor, the absorbed energy excites electrons associated with the europium atoms, causing divalent europium atoms (Eu^{+2}) to be oxidized and changed to the trivalent state (Eu^{+3}).
- The excited electrons become mobile, and some fraction of them interact with a so-called F-center. The F-center traps these electrons in a higher-energy, metastable state, where they can remain for days to weeks, with some fading over time.
- The latent image that exists on the imaging plate after x-ray exposure, but before readout, as billions of electrons trapped in F-centers.
- The number of trapped electrons per unit area of the imaging plate is proportional to the intensity of x-rays incident at each location during the exposure.



4. A direct flat panel detector system was built with 60% overall quantum efficiency for x-ray imaging in the diagnostic energy range. It has a 75% fill factor. The same type of the direct flat panel detector system was re-designed to offer higher spatial resolution. It now has a 50% fill factor. Please determine the overall quantum efficiency of the second system for x-ray imaging in the same diagnostic energy range.

Solution:

The quantum efficiency of the detector material:

= the overall quantum efficiency / detector fill factor

= (60%) / (75%)

= 80%

For the detector system with 50% fill factor,

The overall quantum efficiency = 80% × 50%

= 40%

5. What are the most important advantages of digital radiography as compared with the screen-film based radiography?

Solution:

Comparing with the screen-film based radiography, the most important advantages of digital radiography technique are:

Wider dynamic range

Immediate availability of digital data for image manipulation, transmission and archiving

Lower patient dose can potentially be enhanced through fewer repeat examinations

The digital radiography separates the detector and the display device.

6. Will less than perfect fill factor of electronic detectors affect the overall quantum efficiency of an X-ray imaging system, why?

Solution:

Yes, the less than perfect fill factor of electronic detector (fill factor < 100%) will lead to reduced overall quantum efficiency. If the fill factor is less than 100%, a fraction of the detector element's area is not sensitive to x-ray or light signal, the photons falling on these areas do not contribute to the formation of the final image.