IMAGING LAB
MPHY 487

Fluoroscopy Radiology Machines

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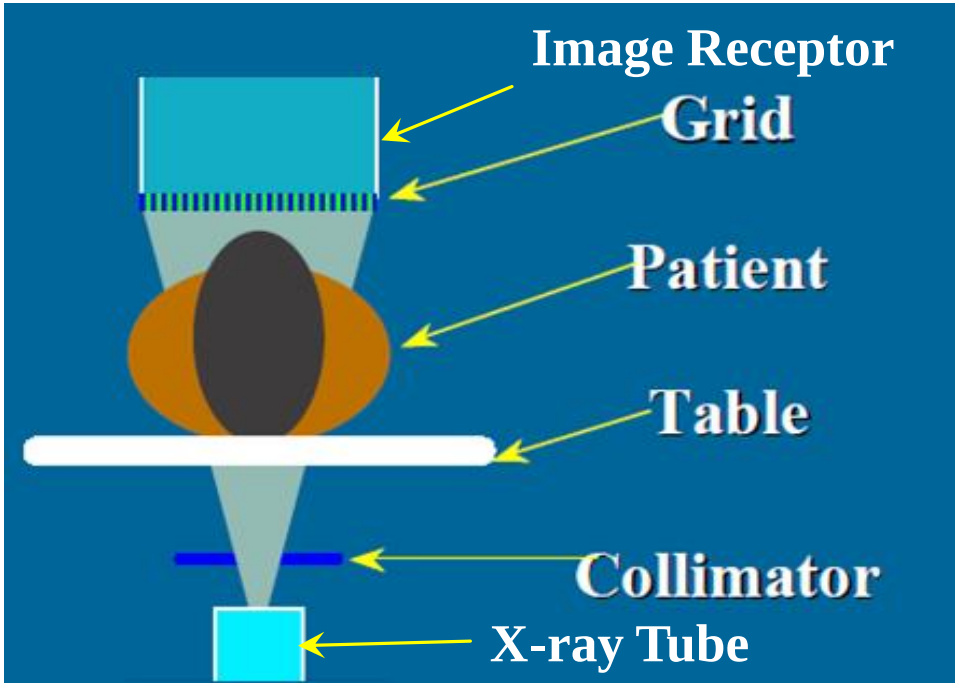
- http://pubs.rsna.org/doi/full/10.1148/radiographics.20.5.g00se181471
- http://www.upstate.edu/radiology/education/rsna/fluoro/artifact.php
- Fluoroscopy & Interventional Imaging ByAdnan Z. Alwatban, Ph.D., FIPEM Consultant Medical Physicist, King Faisal Specialist Hospital & Research Centre

Contents

Fluoroscopy Radiology Machines

- Fluoroscopy provides a dynamic view of the anatomy, in real time within high temporal resolution and keeping total patient dose low.
- Real time always consider 30 frame/Sec
- Newer Fluoroscopy allow the acquisition of real time digital sequence of images (Digital Video), that can be played back.



Mode of Fluoroscopy Operations

- Continuous Fluoroscopy
- High Dose Rate Fluoroscopy
- Variable Frame Rate Pulsed Fluoroscopy

Continuous Fluoroscopy

- Continuously on x-ray beam, 0.5 – 4 mA or higher
- Display at 30 frames/sec, acquisition time = 33 msec/frame
- Blurring present due to patient motion
- 10 R/min is the maximum legal limit

High Dose Rate Fluoroscopy

- Specially activated fluoroscopy
- 20 R/min is the maximum legal limit
- Audible signal required to sound
- Used for obese patients

Variable Frame Rate Pulsed Fluoroscopy

- Series of short x-ray pulses, 30 pulses at ~10 msec per pulse.
- Exposure time is shorter, reduces blurring from patient motion.
- Can be used where object motion is high, e.g., positioning catheters in highly pulsatile vessels.
- 15 frames/sec, 7.5 frames/sec
- Variable frame pulsed fluoroscopy is instrumental in reducing dose.
- 7.5 frames/sec instead of 30 frames/sec, dose savings of (7.5/30) = 25%.

Automatic Brightness Control

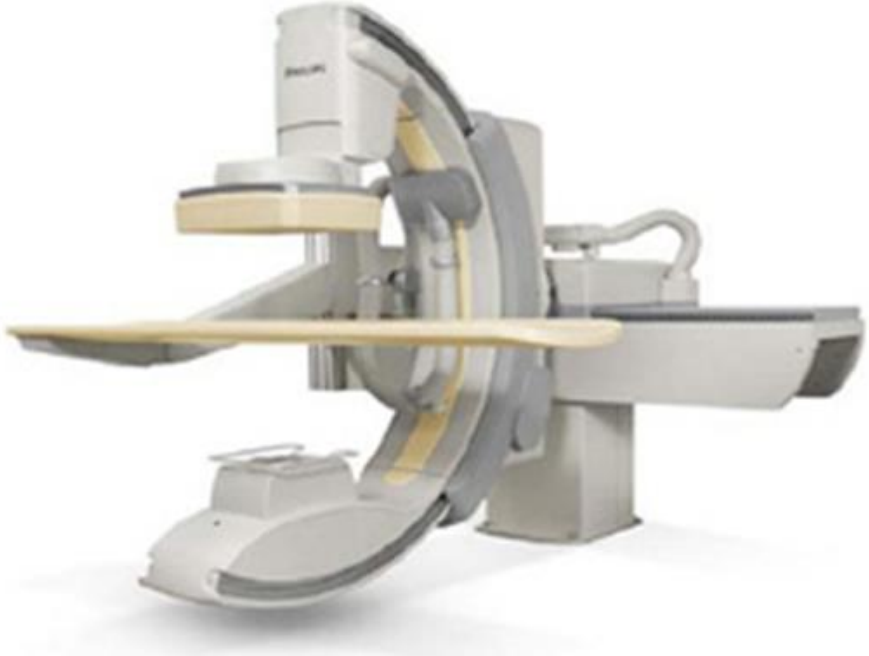
- The purpose of the automatic brightness control (ABC) is to keep the brightness of the image constant at monitor
- It does this by regulating the x-ray exposure rate (control kVp, mA or both)
- Automatic brightness control triggers with changing patient size and field modes

Type of Medical Fluoroscopy

There are two type of fluoroscopy:

- X-ray image intensifiers

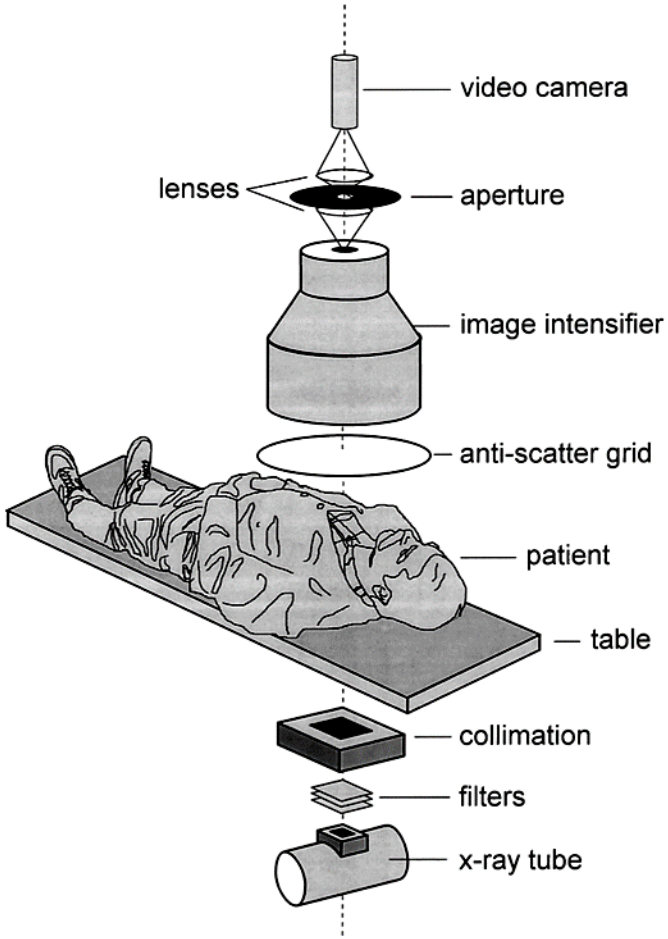
- Flat-panel detectors

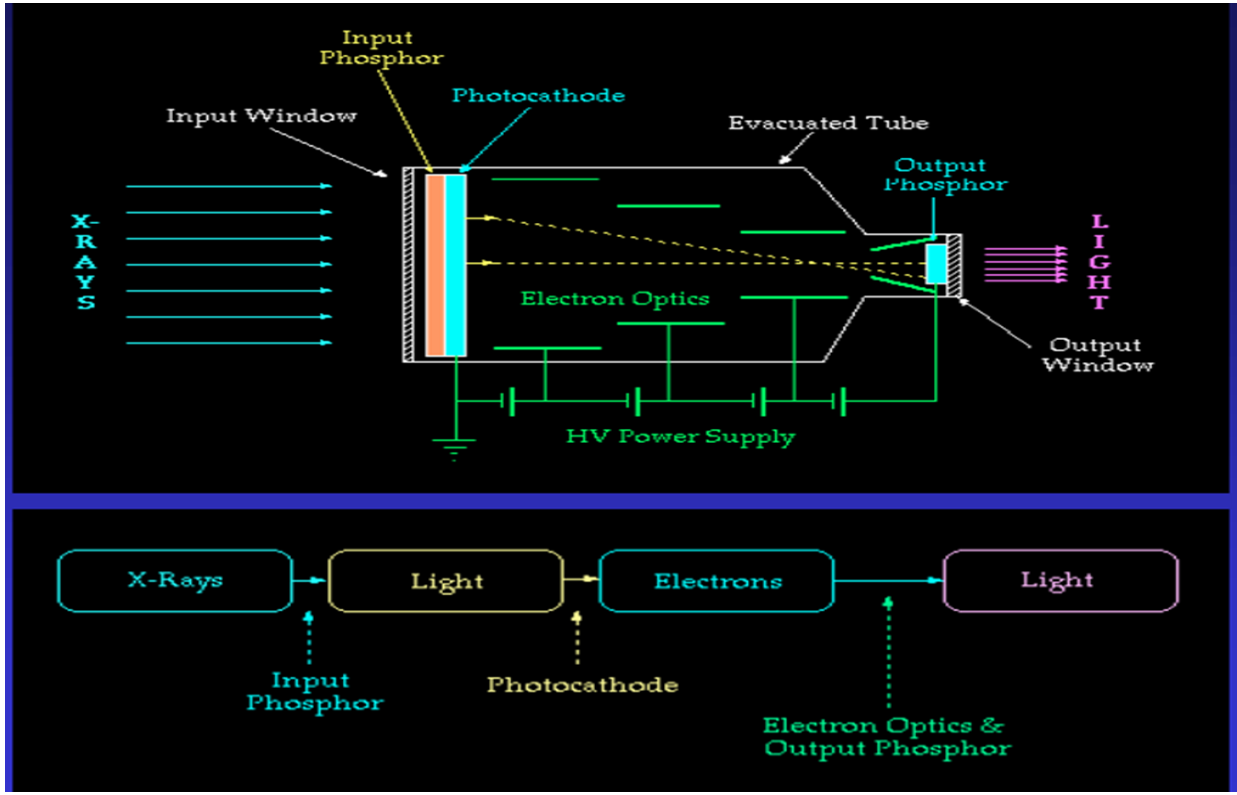


X-ray Image Intensifiers

- Invention in 1950 allowed the image on the screen to be visible under normal lighting conditions, as well as providing the option of recording the images with a conventional camera.
- Improvements included the coupling of, at first, video cameras and, later, digital cameras.
- Available with input diameters of up to 45 cm, and a resolution of approximately 2-3 line pairs mm^{-1}.
- The function of the x-ray image intensifier in the fluoroscopic imaging system is to convert the x-ray spectrum transmitted through the patient into a highly visible image.

The operational principles





The operational principles

X-ray photons penetrate the input window of the vacuum case.

The input phosphor absorbs the x-ray photons and converts them into optical photons (a phenomenon called luminescence).

The optical photons are converted to photoelectrons at the photocathode.

The photoelectrons are accelerated by the electric field produced by the strong electric potential difference of the image intensifier and are collected at the output phosphor.

Each accelerated electron produces many optical photons at the output phosphor

The intensity of the final image is several thousand times brighter than the initial image created at the input phosphor.

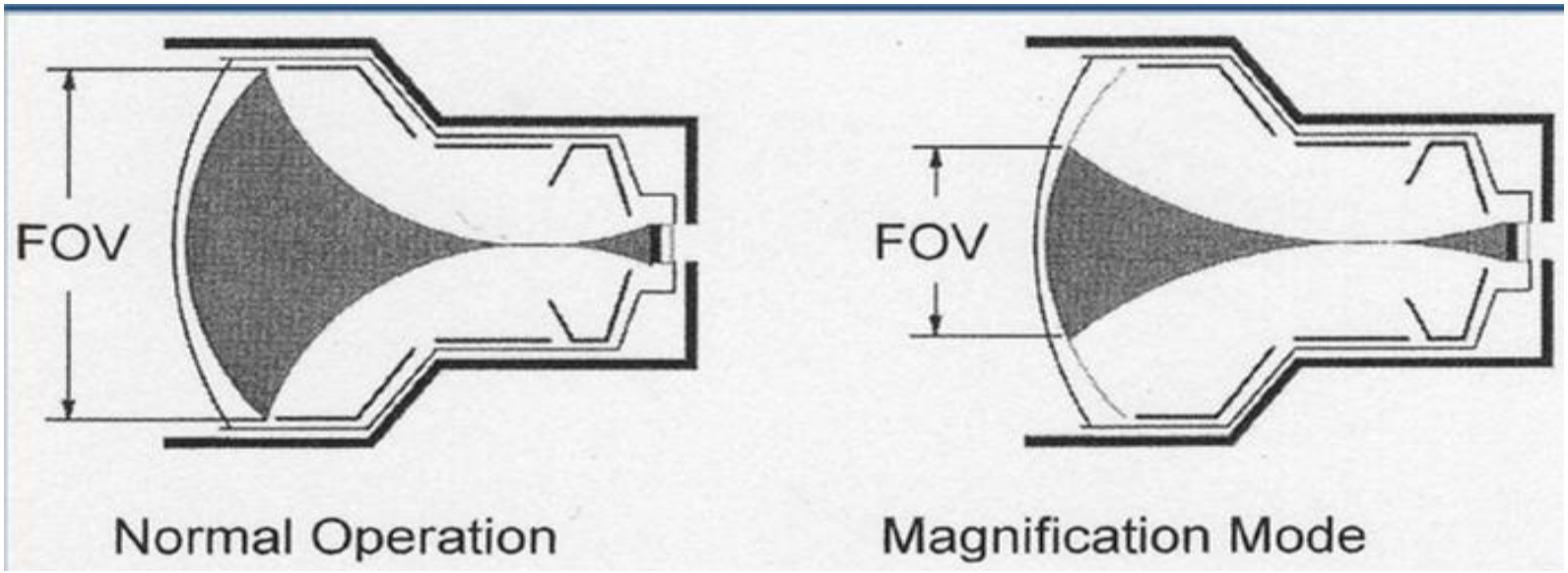
The output screen compared with that at the input screen. The output screen image can be viewed with closed-circuit television or recorded with film

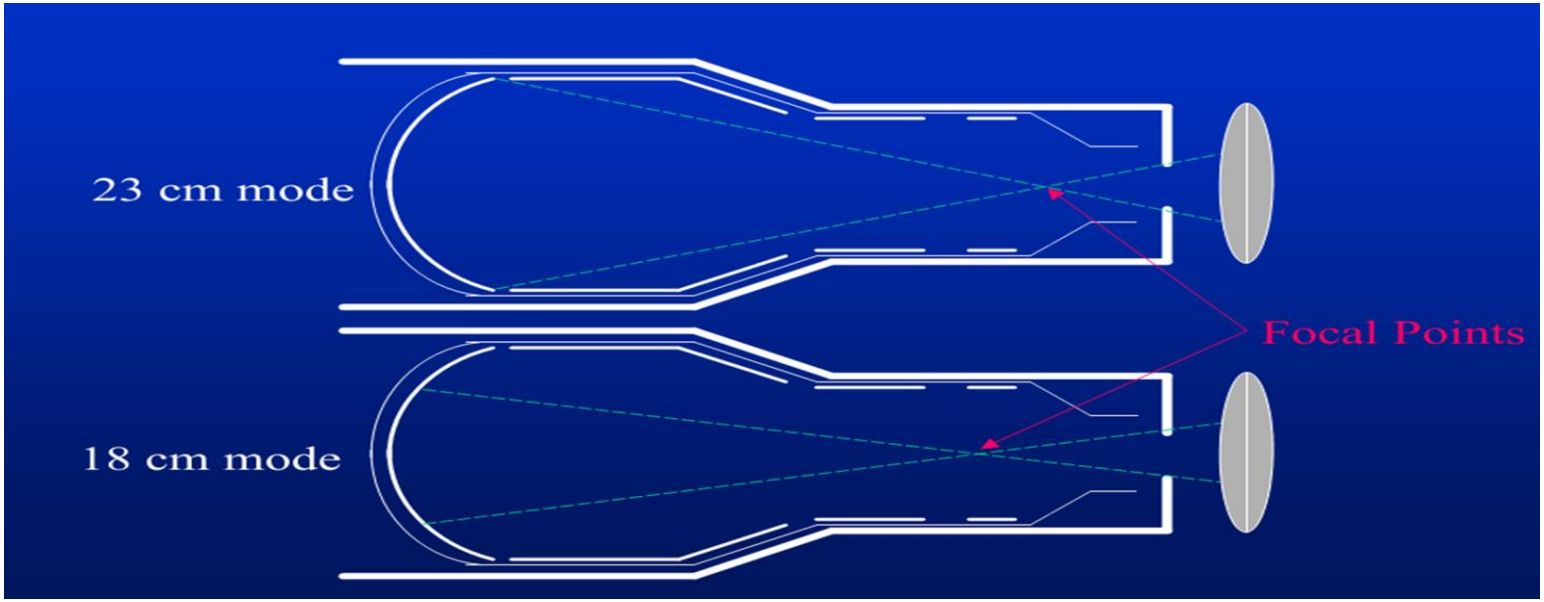
Image intensifier tubes come in many sizes, and most have multiple magnification modes associated with them.

Magnification Modes and Spatial Resolution

- Changing the voltage applied to the electronic lenses inside an image intensifier will change the magnification mode of the image intensifier.
- In a magnification mode, a smaller area of the input phosphor is used, giving the effect of zooming in on the image.
- Because the **input field size is reduced**, **the exposure** to the input phosphor must be **increased** to maintain a constant brightness level at the output phosphor.
- Each magnification mode yields a different dose rate to the patient.
- **In general, the smaller the field size, the larger the magnification, and the higher the patient dose.**
- The image intensifier exposure rate is typically set to 30 μR/sec for the 25-cm mode, 60 μR/sec for the 17-cm mode, and 120 μR/sec for the 12-cm mode

Magnification Modes and Spatial Resolution

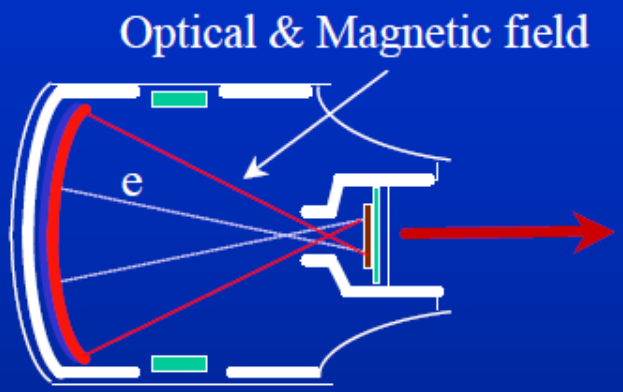




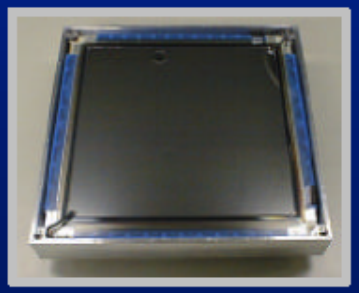
Flat-panel detectors

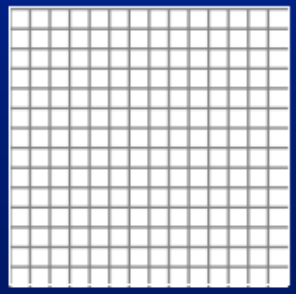
- The introduction of flat-panel detectors allows for the replacement of the image intensifier in fluoroscope design.
- Flat panel detectors offer increased sensitivity to X-rays, and therefore have the potential to reduce patient radiation dose.
- Temporal resolution is also improved over image intensifiers, reducing motion blurring.
- Image intensifier operating in 'magnification' mode may be slightly better than a flat panel.
- Flat panel detectors are considerably more expensive to purchase and repair than image intensifiers, so their uptake is primarily in specialties that require high-speed imaging, e.g., vascular imaging and cardiac catheterization.

Distortion-free Images



Pin Cushion Distortion





No Distortion

Image Quality

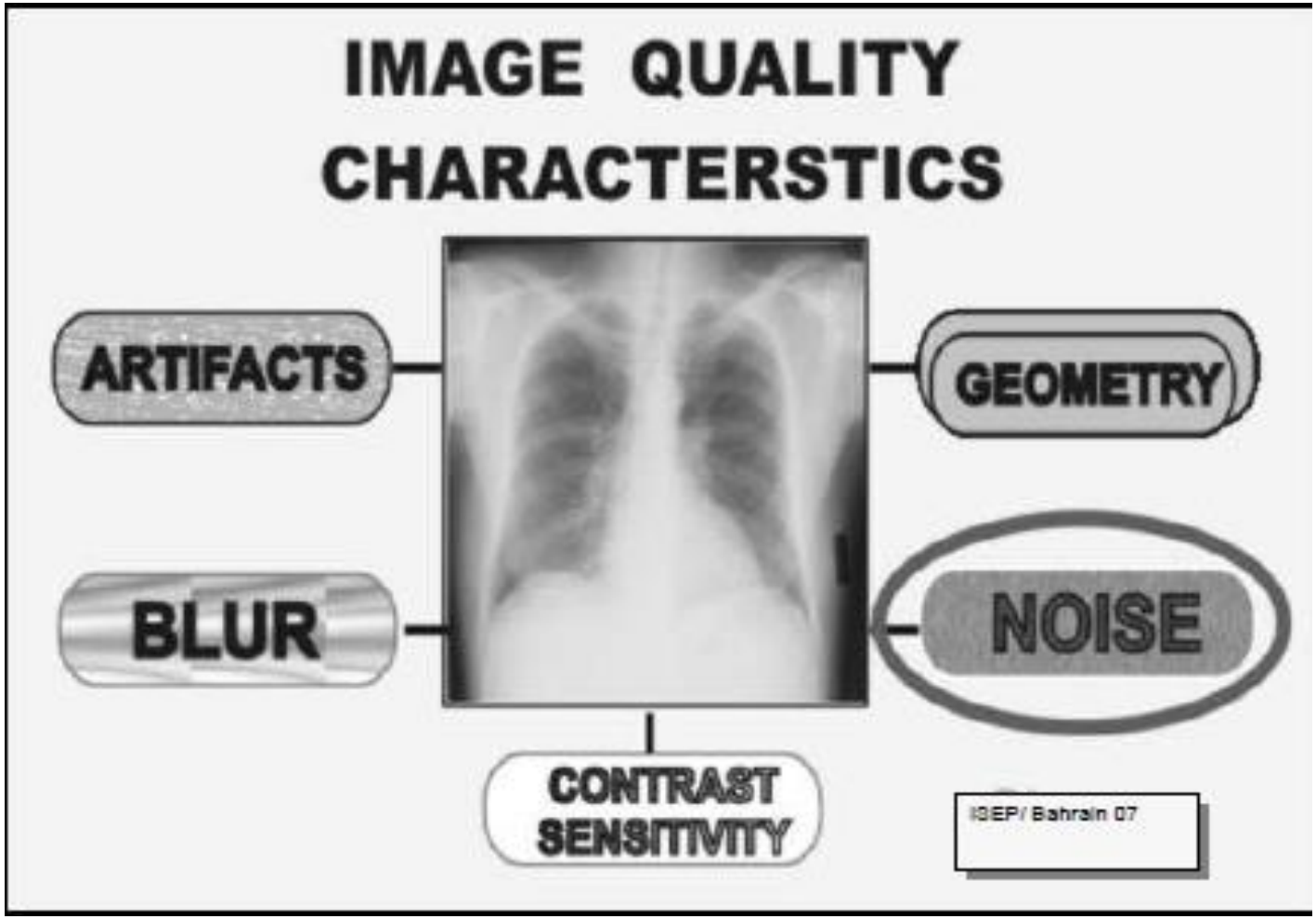
Fluoroscopy image
nominal image intensifier diameter of 38 cm
75 kV and 2.4 mAS
Entrance skin air kerma rate = 35 mGy/minute/ 4 R/minute

digital image
65 kV, and 9 mAS.
Entrance skin air kerma = 1.4 mGy

- Fluoroscopy is performed by generating 30 frames every second, so that in one minute there will be a total of 60 seconds x 30 frames/second image, or 1800 images
- 1800 images generated every minute and the patient entrance dose is thus ~(35 mGy entrance air kerma)/(1800 acquired images), or ~0.019mGy entrance air kerma per frame.

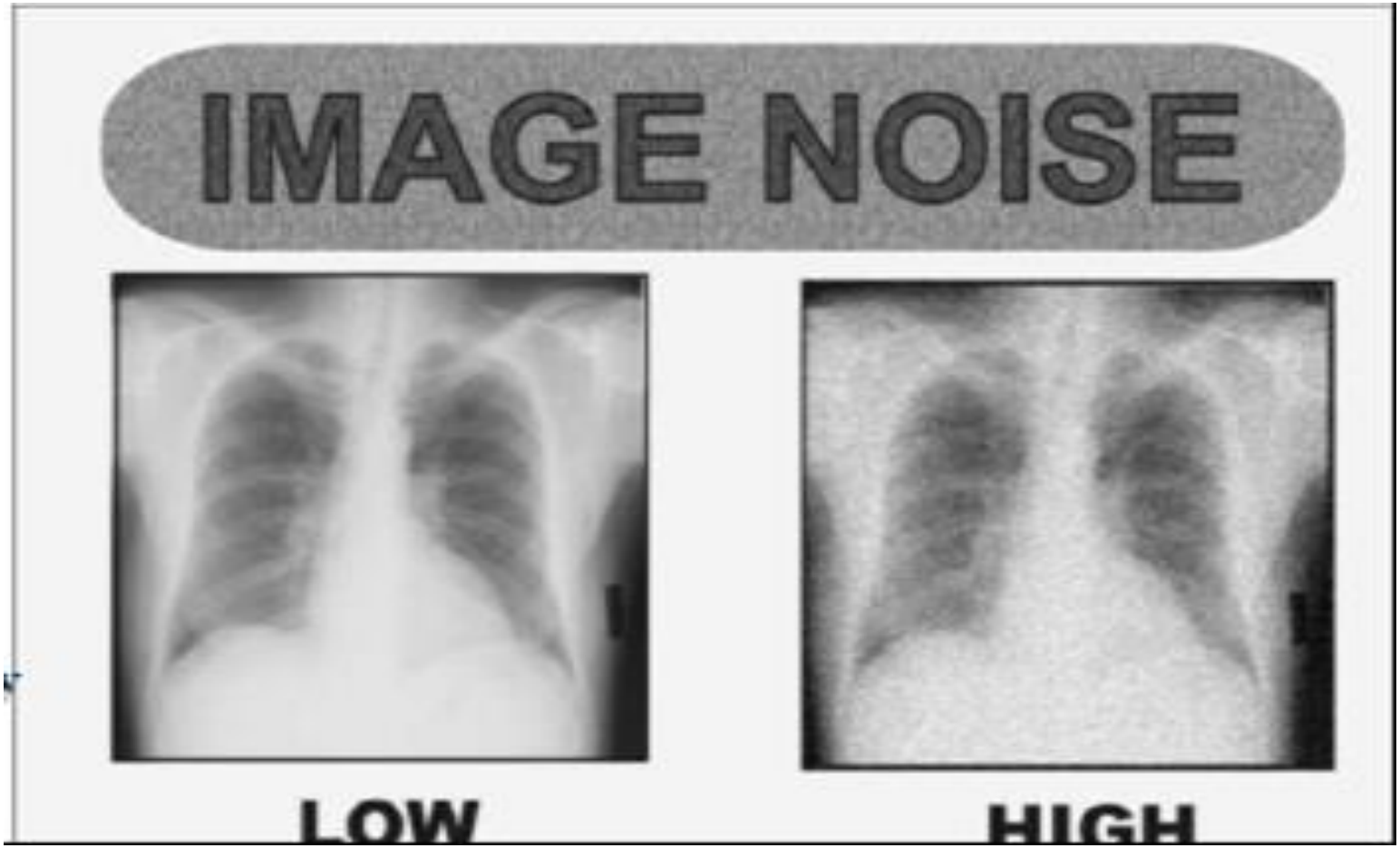
- Fluoroscopy images are generally very low quality, and are used to identify the location of a catheter rather than for diagnostic interpretation.
- Digital images are acquired using radiation intensities that use ~100 or so times more photons, and are considered to be diagnostic

Image Quality



Noise

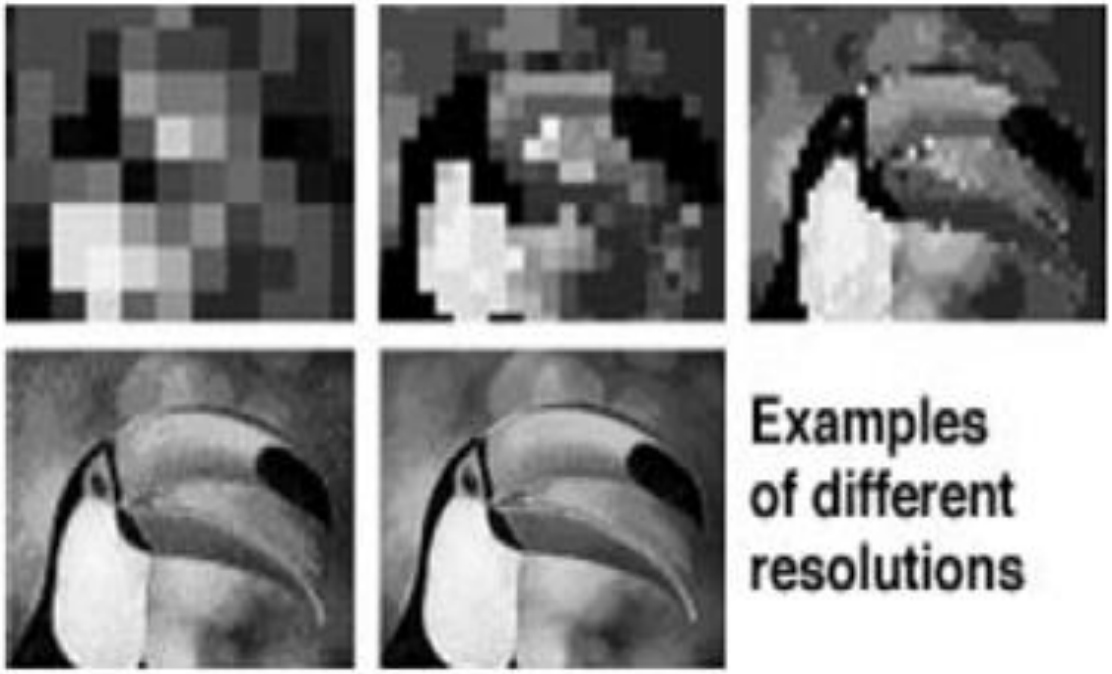
How well can an object be seen ?



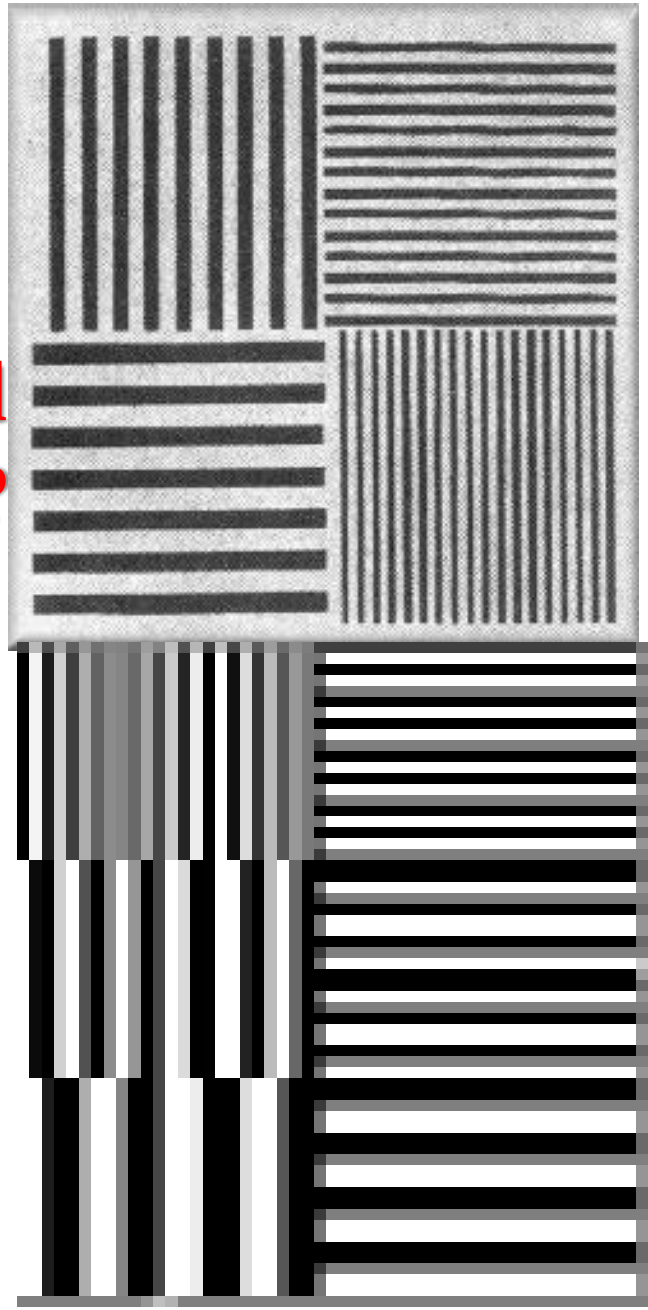
Resolution

How small an object be seen ?

How close can two objects get and still be recognized as two objects ?



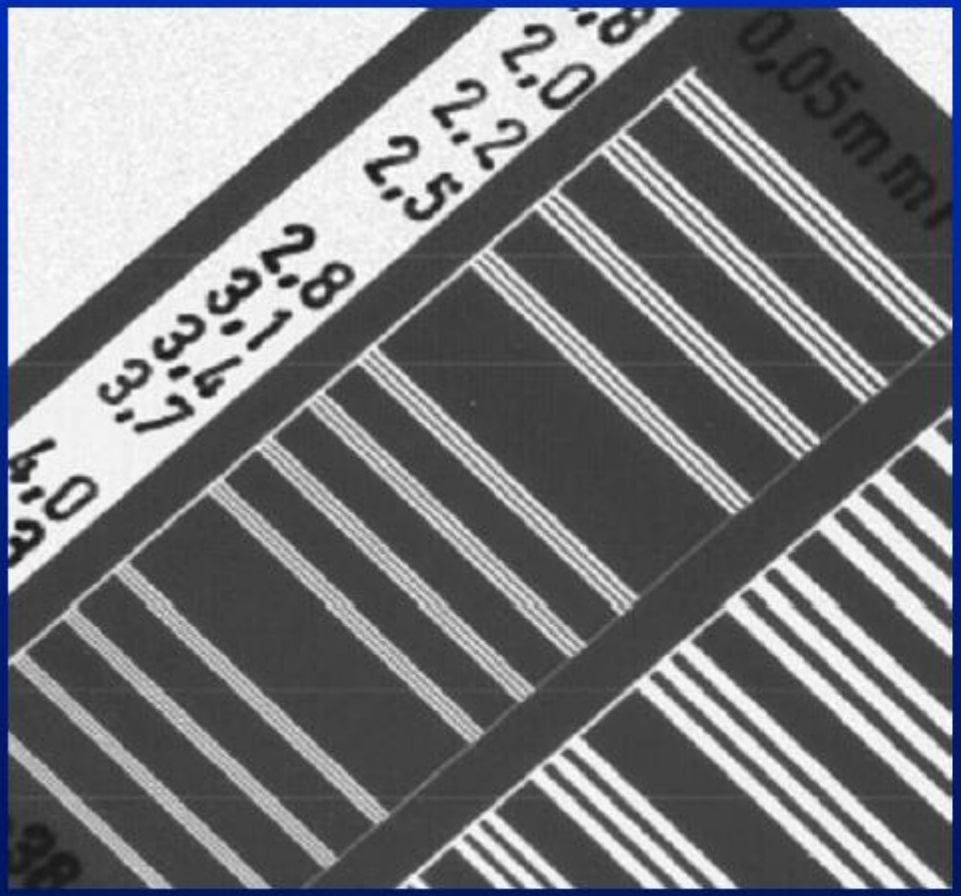
Examples of different resolutions



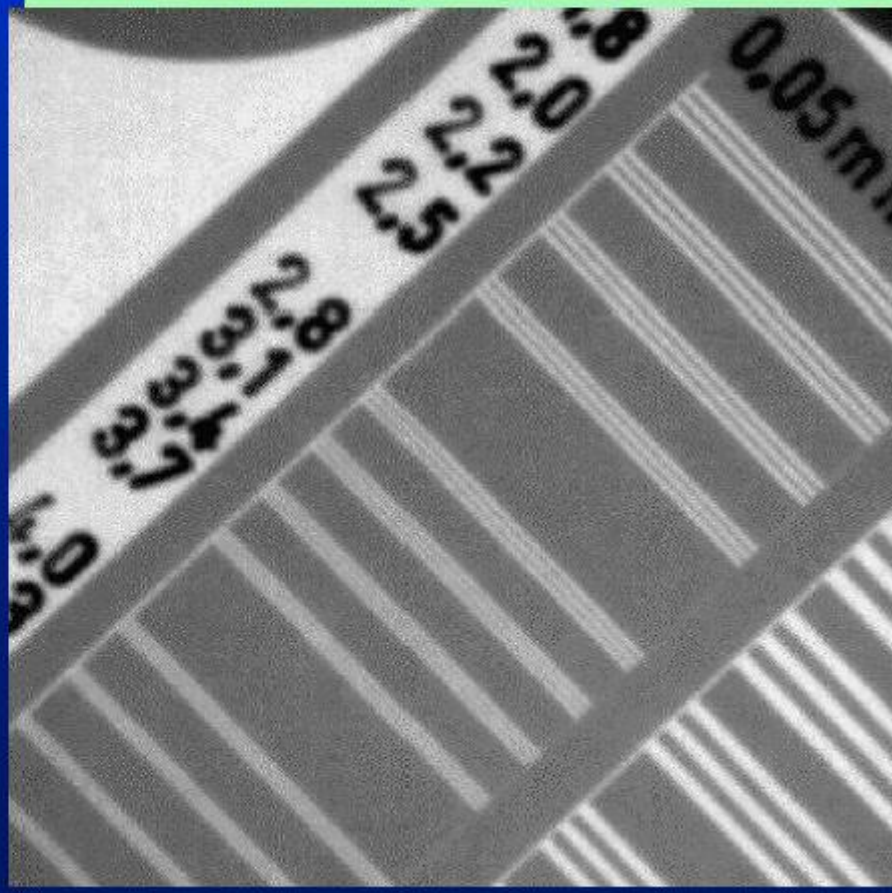
Spatial Resolution Comparison

FPD Vs I.I./TV

Direct conversion type FPD

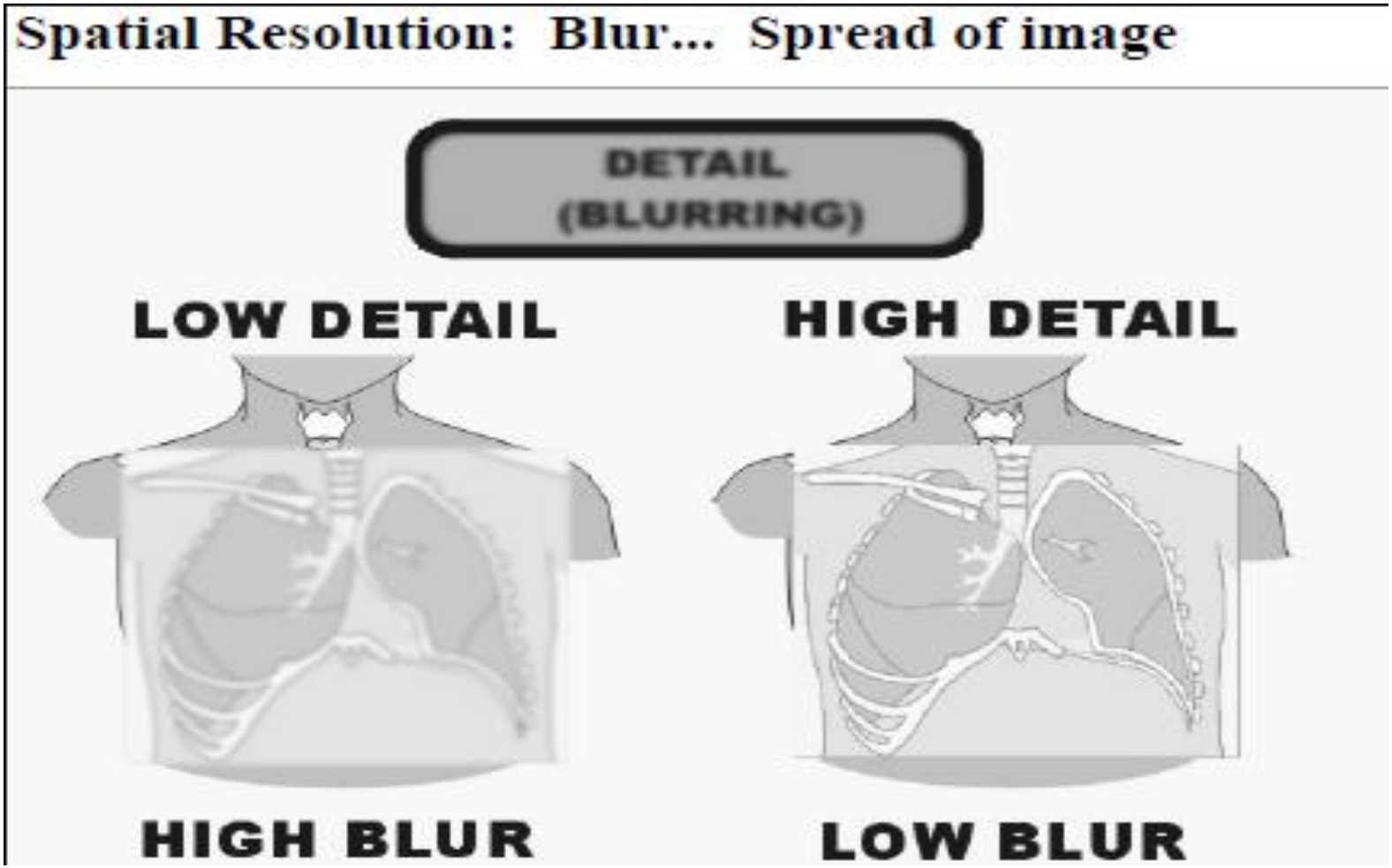


I.I./TV system
(9" I.I. 4.5"mode + 1M pixels CCD)

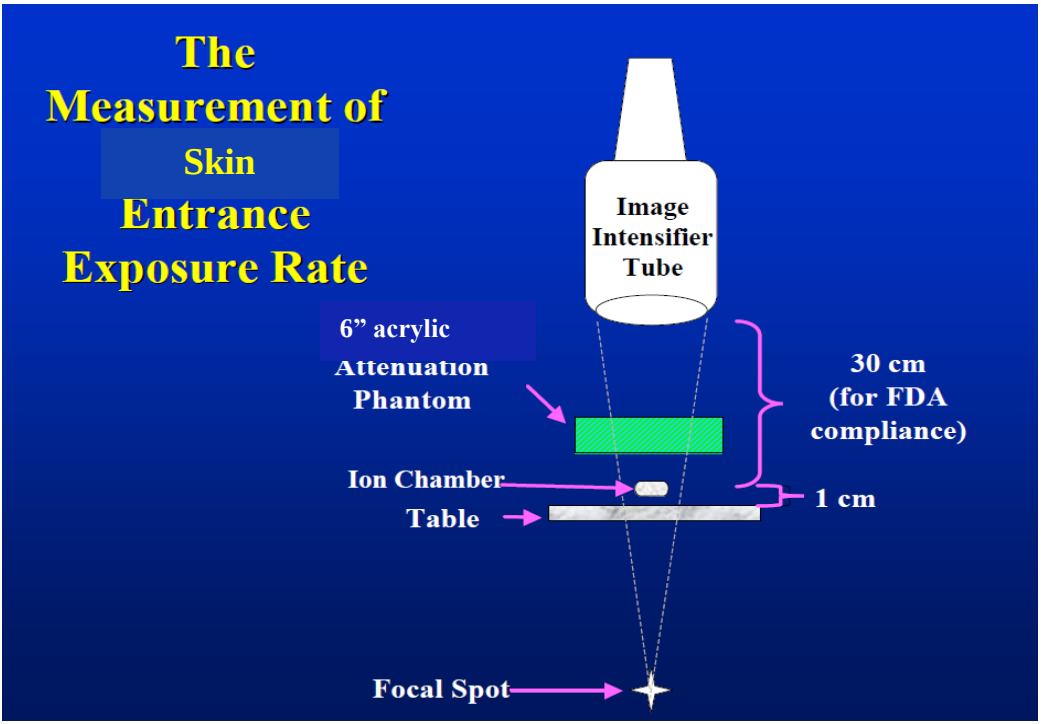


1.6 MAS, 60 kVp for Both Images

Blurring


Spatial Resolution: Blur... Spread of image
DETAIL
(BLURRING)
LOW DETAIL
HIGH DETAIL
HIGH BLUR
LOW BLUR

Patient entrance skin exposure rate



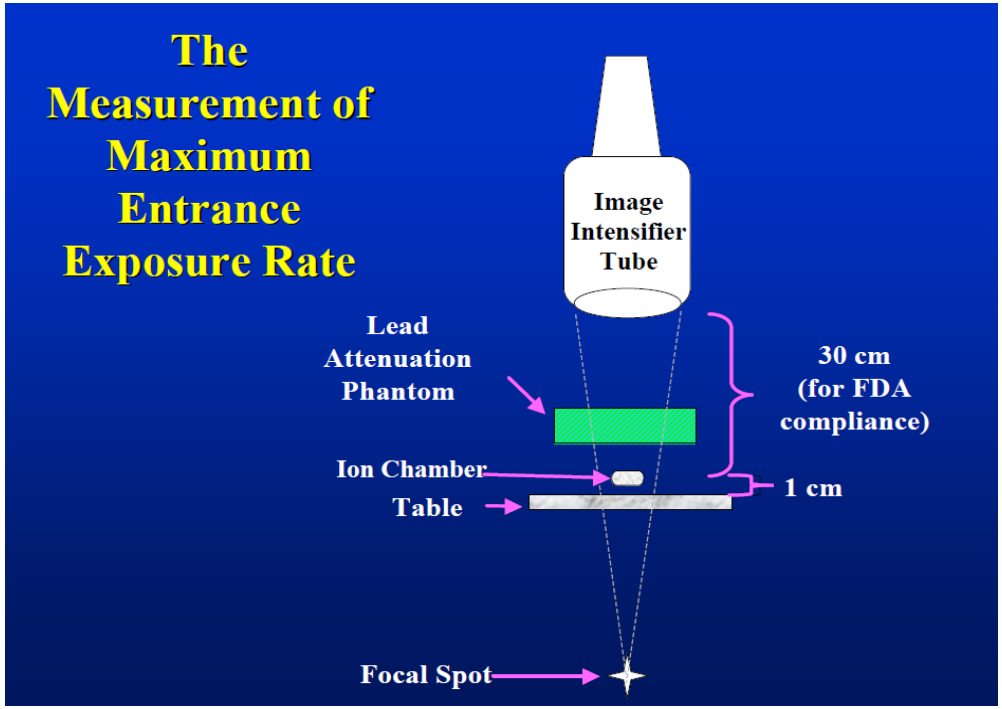
Typical Skin Entrance Exposure Rates

Normal fluoro	1 to 5 rads/min (10 - 50 mGy/min)
High dose fluoro	10 to 20 rads/min (100 - 200 mGy/min)

One hour of exposure can yield 60 - 300 rads with normal fluoro; 600-1200 rads with Hi-dose fluoro

For diagnostic energies, 1 R ≅ 1 rad ≅ 1 rem

Patient entrance skin exposure rate



Skin Entrance Exposure Limitations*

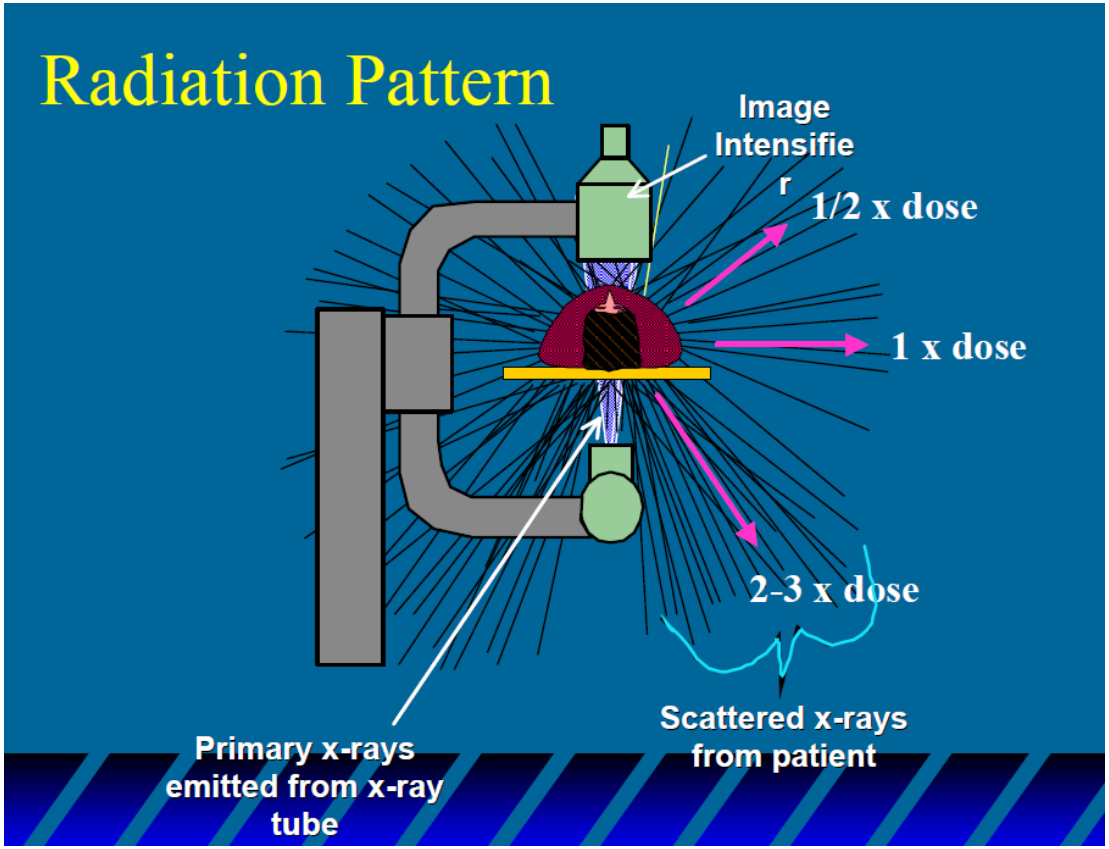
For Normal Fluoro = 10 R/min

For High Dose Fluoro = 20 R/min

Note: No limits for Cine, Digital

* Set by Regulatory Bodies in US

Patient entrance skin exposure rate



Fluoro dose levels at 1 m without shield are expected as followed;

1- at eye level, around 5 mR/hr

2- at chest level, around 5 mR/hr

3- at abdomen level, around 7 mR

4- at knee level, around 3 mR/hr

5- at ankle level, 20-30 mR/hr

Type of QC in Fluoroscopy Machines

MP1	Collimation	Annually	Physicist
MP2	kV Accuracy	Annually	Physicist
MP3	kV Consistency	Annually	Physicist
MP4	Timer Consistency	Annually	Physicist
MP5	Output Consistency	Annually	Physicist
MP6	Output Linearity	Annually	Physicist
MP7	Beam Quality	Annually	Physicist
MP8	High Contrast Resolution	Annually	Physicist
MP9	Entrance Skin Dose	Annually	Physicist
MP10	Pediatric	Annually	Physicist
MP11	Adult	Annually	Physicist
MP12	X-Y Measurement Accuracy	Annually	Physicist
MP13	Image Artifacts	Annually	Physicist
Systems with Flat Panel Detectors			
MP14	Detector AEC Reproducibility	Annually	Physicist
MP15	Detector Uniformity	Annually	Physicist
MP16	Detector Image Lag	Annually	Physicist
Systems with Image Intensifiers			
MP17	Image intensifier input exposure rates	Annually	Physicist