



KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

UNIA EUROPEJSKA
EUROPEJSKI
FUNDUSZ SPOŁECZNY



„Medical Imaging”

**Prezentacja multimedialna współfinansowana przez
Unię Europejską w ramach
Europejskiego Funduszu Społecznego w projekcie pt.
„Innowacyjna dydaktyka bez ograniczeń - zintegrowany
rozwój Politechniki Łódzkiej - zarządzanie Uczelnią,
nowoczesna oferta edukacyjna i wzmacniania zdolności
do zatrudniania osób niepełnosprawnych”**



Politechnika Łódzka

Politechnika Łódzka, ul. Żeromskiego 116, 90-924 Łódź, tel. (042) 631 28 83
www.kapitalludzki.p.lodz.pl



X – ray generation, X - ray equipment

Lecture overview:

- Conventional X-ray tube
- Electron source
- Electrical tube parameters
- Emission spectra
- Tube rating
- Film and screen characteristics





X-ray history

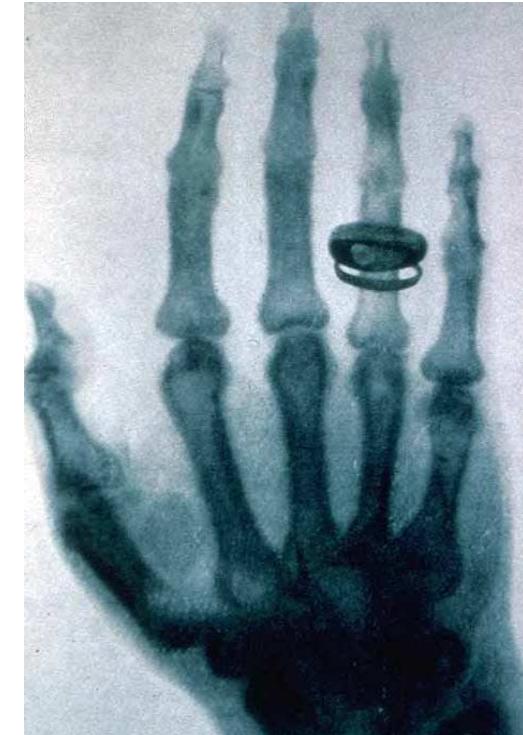
X-rays were discovered and described by Wilhelm Röntgen in 1895
(Nobel price in physics, 1901)

X-rays

$(10 \div 100) \times 10^{-12}$ m (hard)
 $(0.1 \div 10) \times 10^{-9}$ m (soft)

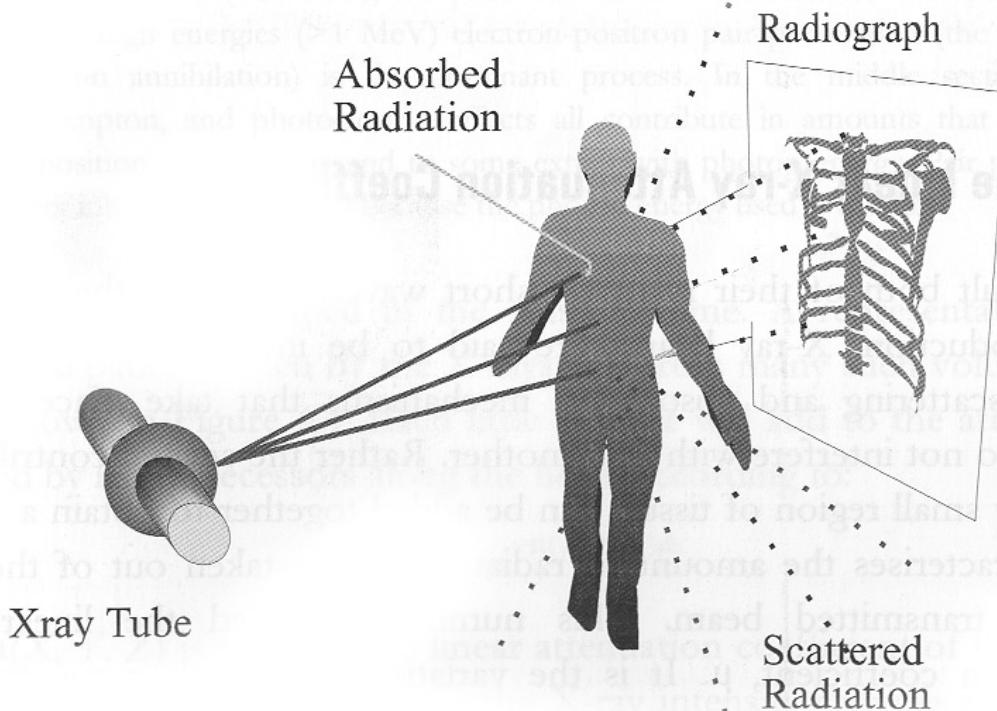


Frau Röntgen's hand, 1895





X-ray radiographic geometry



Two main problems: photon scattering and projection images



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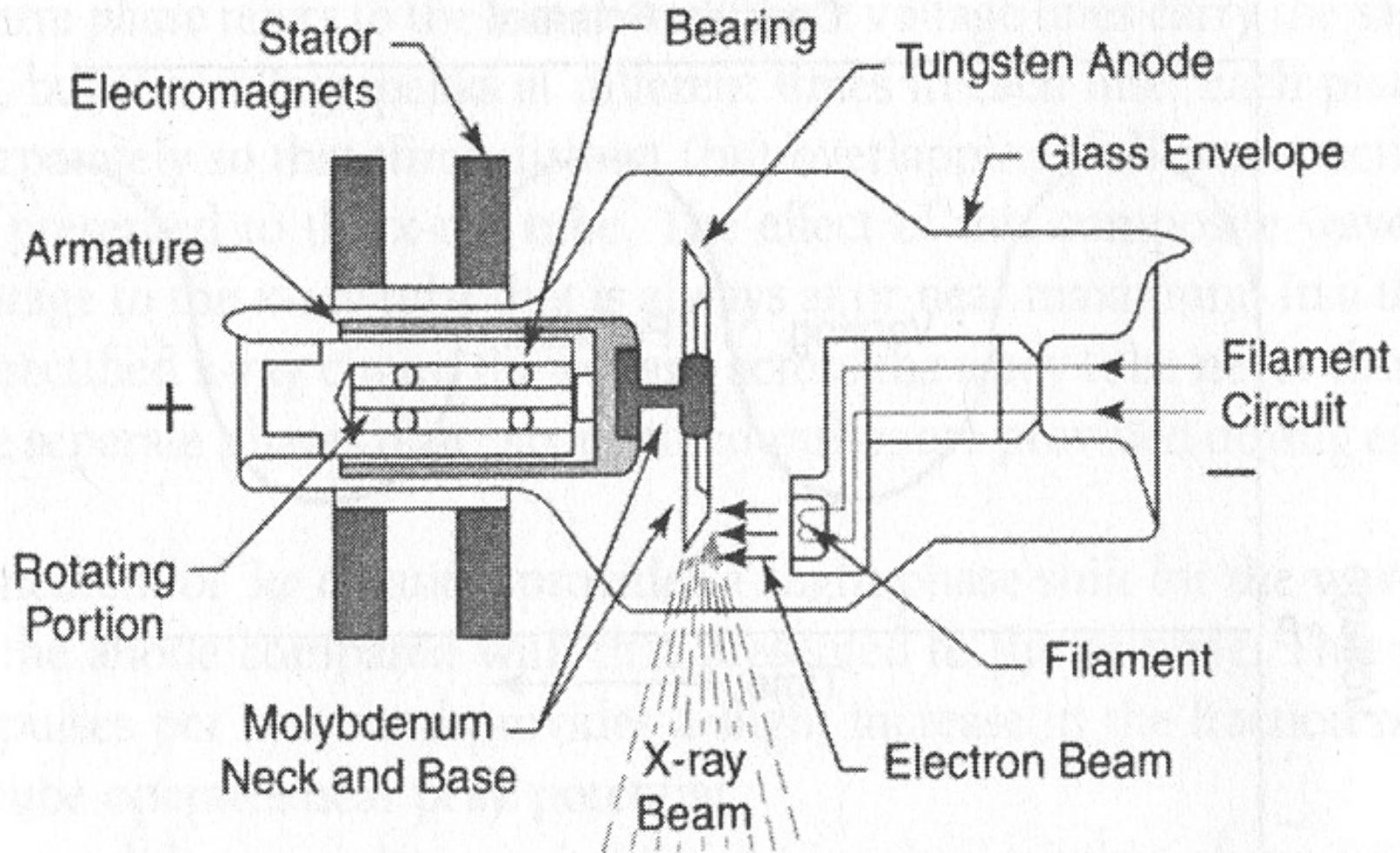
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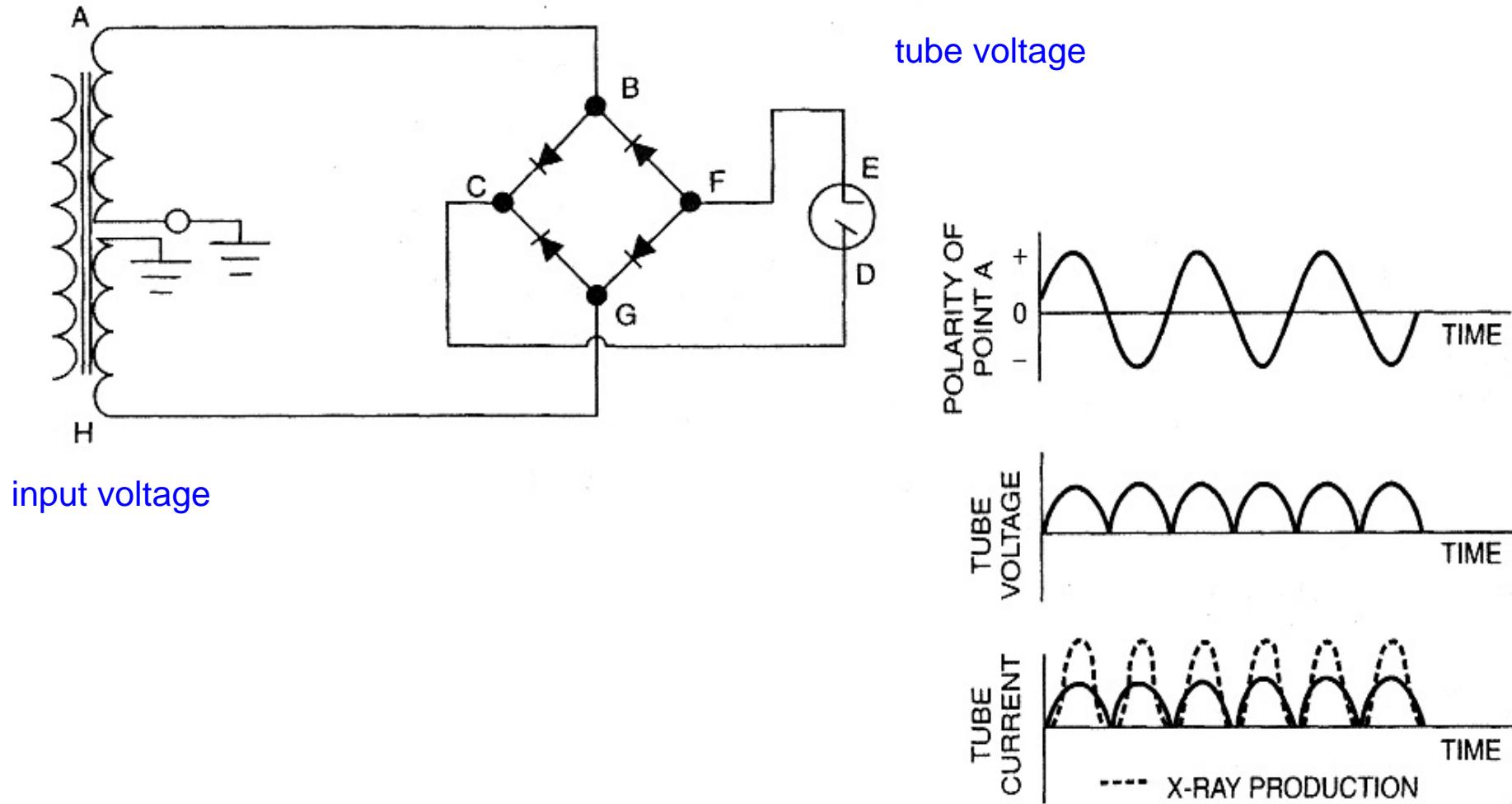


X-ray tube architecture



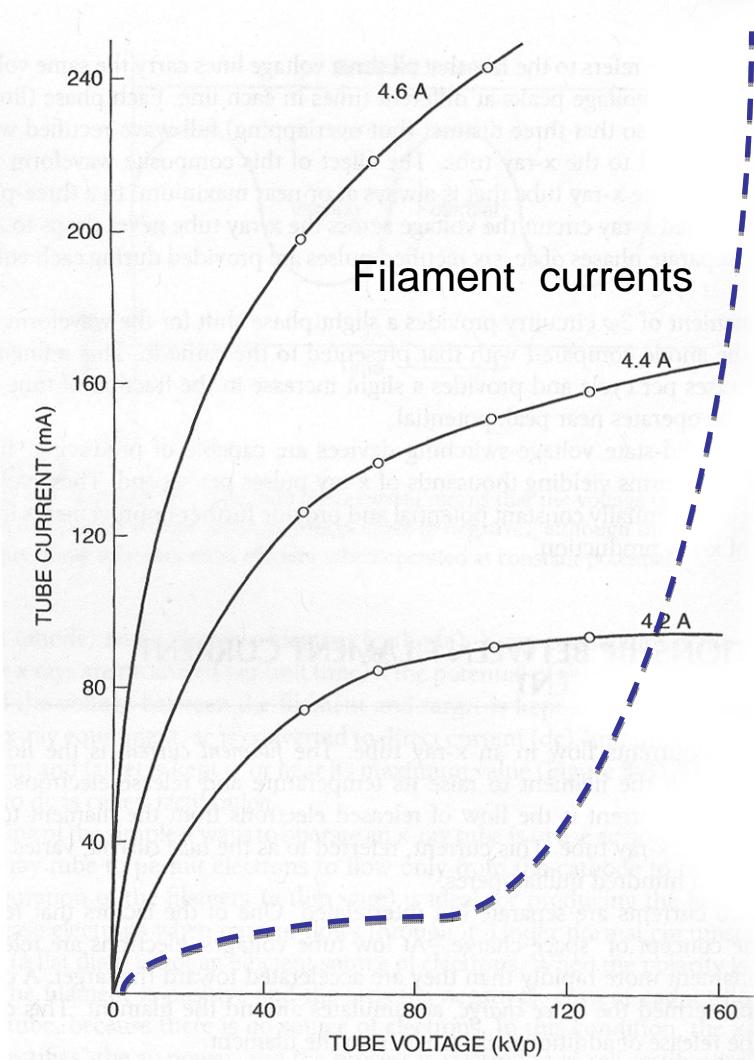


Tube voltage waveforms





Tube characteristics



At low tube voltages electrons are released from the filament more rapidly than they are accelerated toward the anode.

Space charge accumulates around the filament.

This charge opposes the release of additional electrons from the filament.

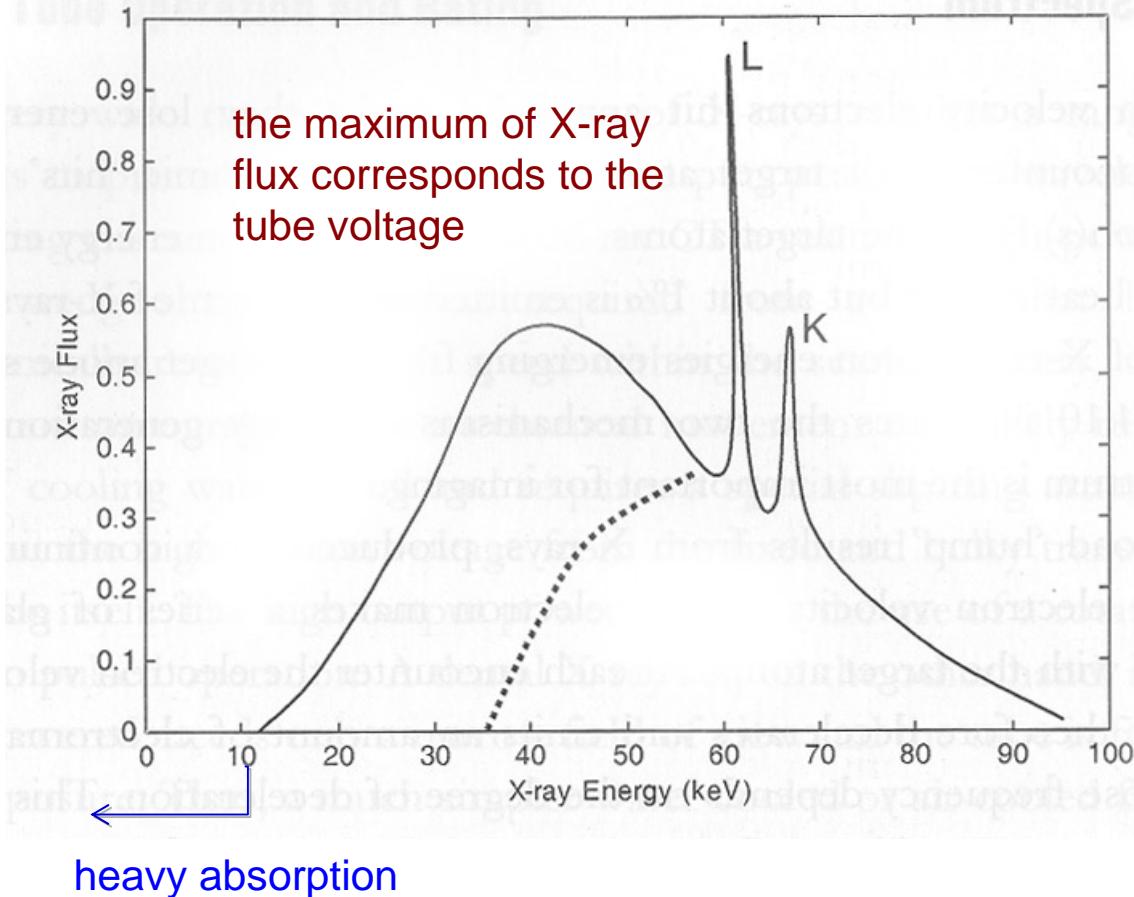
At the saturation voltage, tube current is limited by the rate at which electrons are released from the filament.

The current can be increased only by raising the filament temperature (increasing its current).





Emission spectra



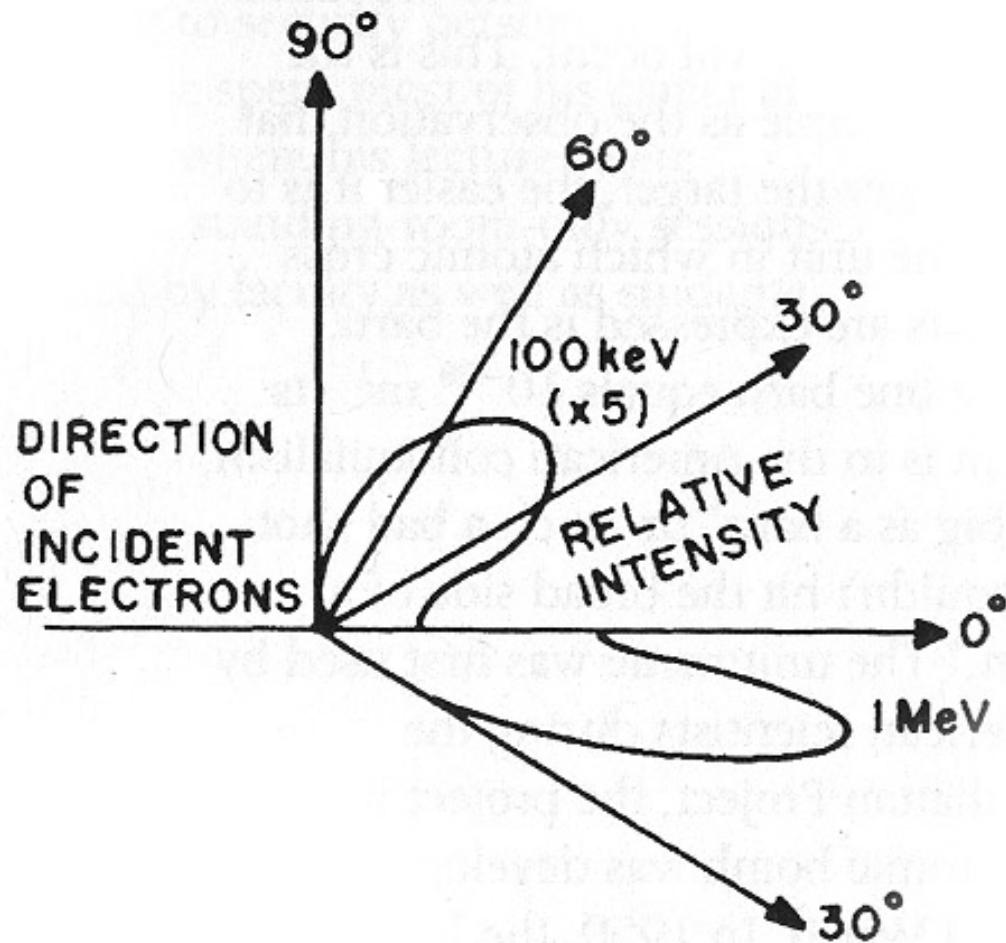
Two mechanism of x-ray generation:

1. Due to inelastic scattering energy in the form of electromagnetic radiation appears. This radiated energy is called “bremstrahlung” (breaking radiation).
2. The L, K peaks – anode atoms relax after losing an electron from a direct hit from the electron beam – additional photons are generated.





Emission spectra



The distribution of X-ray photons is uneven – it depends on incident electron energy (tube voltage)



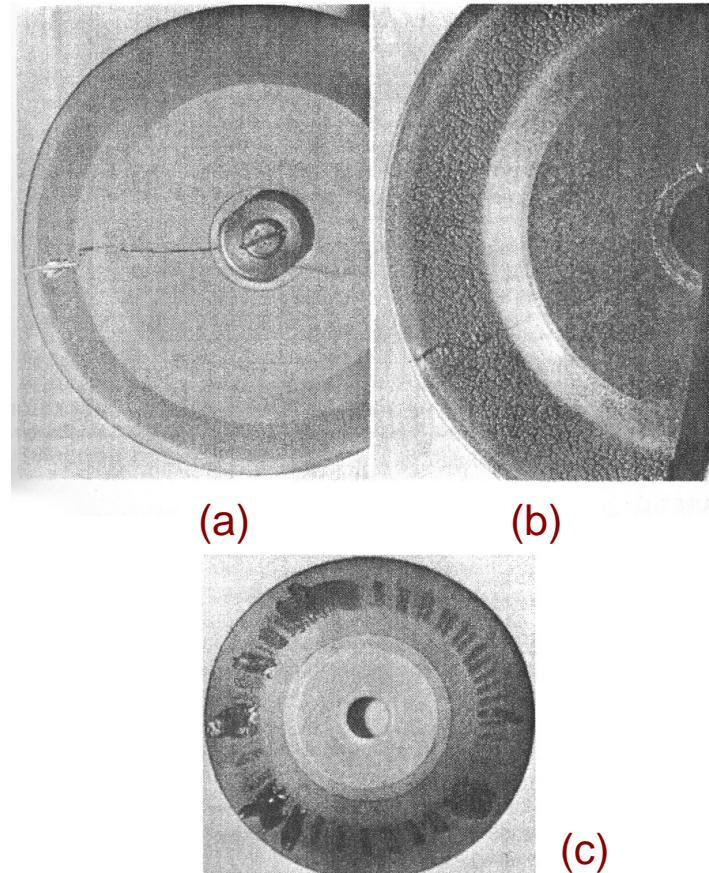
Tube ratings

Only 1% the beam electrons produce the useful X-rays. The energy of remaining 99% is converted into heat.

Safe operating conditions defined by Heat Units
 $HU = kV \text{ (tube voltage)} \times mA \text{ s (tube current in a given time)}$

[mAs – a measure of the radiation exposure of patient]

Different ratings defined for anode
($HU = 150000$) and tube ($HU = 1000000$)

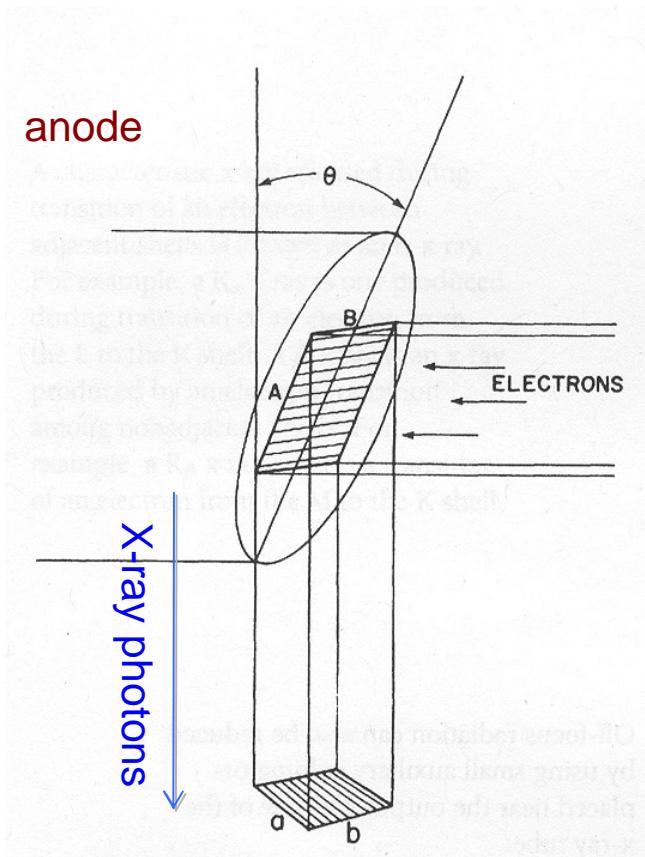


Damaged targets: no rotation (a), slow rotation, excessive load (b), slow rotation (c)





Improving the tube focus



Resulting X-ray appear to originate from a focal spot much smaller than the volume of the anode target absorbing the energy of the incoming electrons.

This reduction of focal spot size is termed “line-focus principle”

$$a < A, b = B$$

$$a = A \sin(\theta)$$

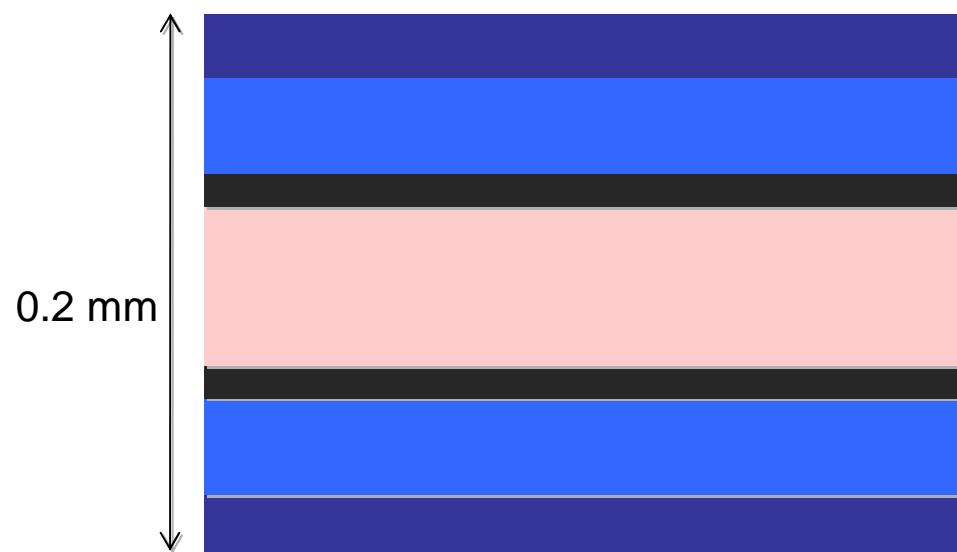
$$\theta = [6, \dots, 17]^\circ$$

$$\text{spot size} < 0.6 \text{ mm}^2$$





X – ray film



Emulsion – silver halide granules (silver bromide), suspended in a gelatin matrix. It is sensitive to visible/ultraviolet light and to ionizing radiation.

Base – cellulose acetate or polyester resin

Protective coating (T-coat)

Adhesive



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Photographic process

X-ray photons affects the emulsion -> released electrons are trapped in the crystal lattice and attract/neutralize silver ions (Ag^+) -> small quantities of metallic silver are deposited in the emulsion.

This deposition reflects the information transmitted to the film by the x radiation. This information is captured and stored as a latent image in photographic emulsion.

During development process, more silver is deposited on the film fragments affected by x radiation. Not affected film granules are removed by the fixing solution (it also hardens the emulsion).

The degree of blackening of the film region depends on the amount of free silver deposited in the region and, consequently, on the number of x rays absorbed in the region.





Film characteristics

Film transmittance $T = I_t/I_i$

I_i – amount of light incident to the film region

I_t – amount of light transmitted by the film region

The degree of film blackening is described as the optical density:

$$D = \log_{10}(1/T)$$

The exposure – amount of radiation hitting film fragment. It depends on tube voltage, amount of tube current in given time, and on attenuation of patient regions.

$$G(\text{relative exposure}) = \log_{10}(\text{exposure}_{\text{Region1}}/\text{exposure}_{\text{Region2}})$$



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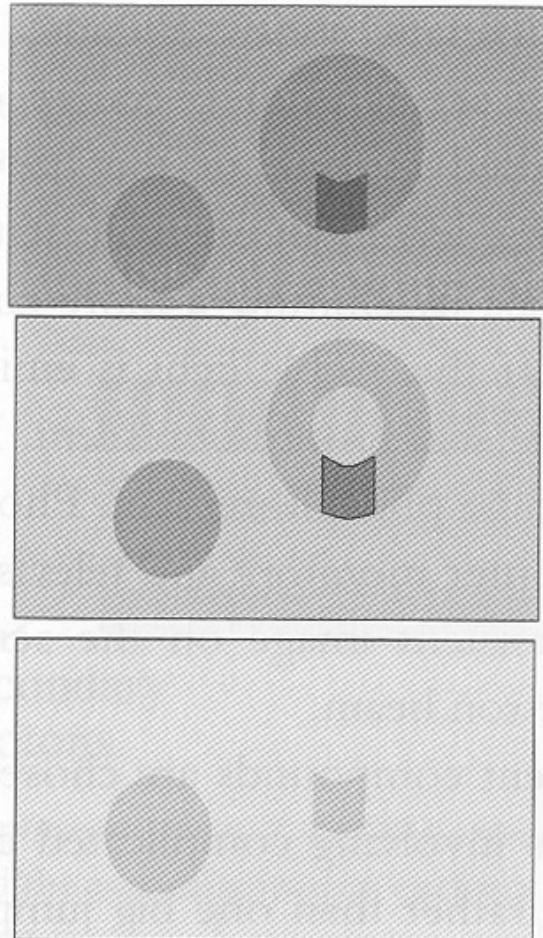
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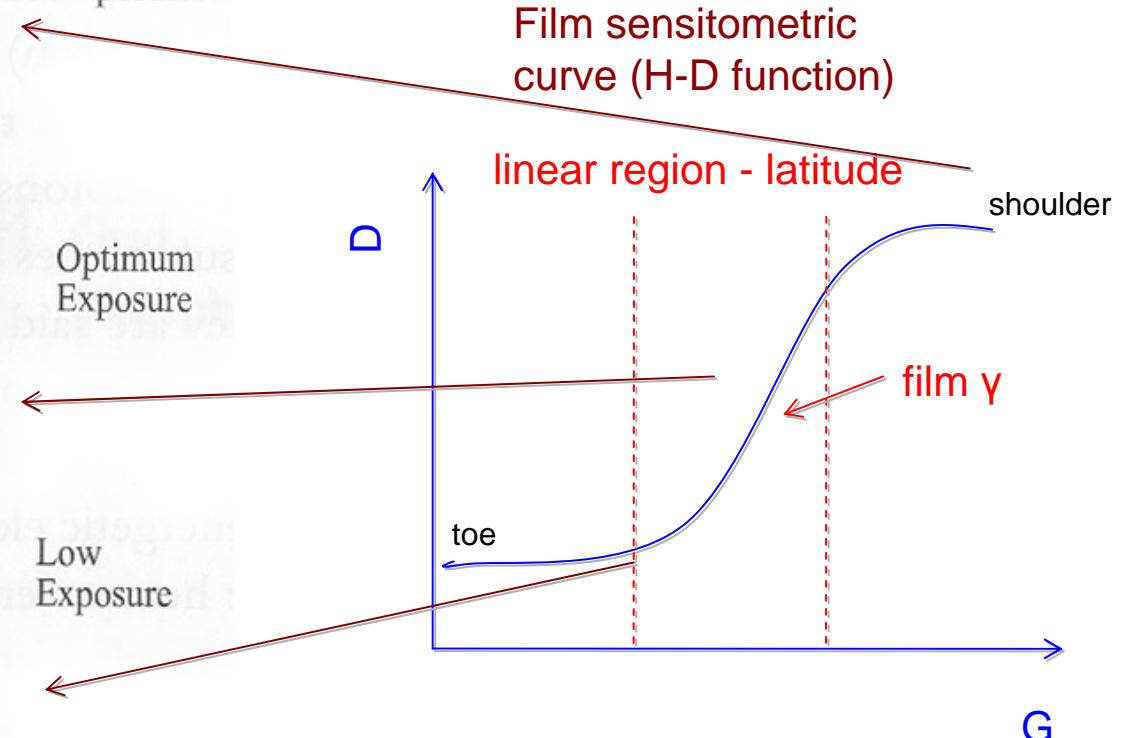




Film properties



Influence of exposure (X-ray dose in given time) to image contrast

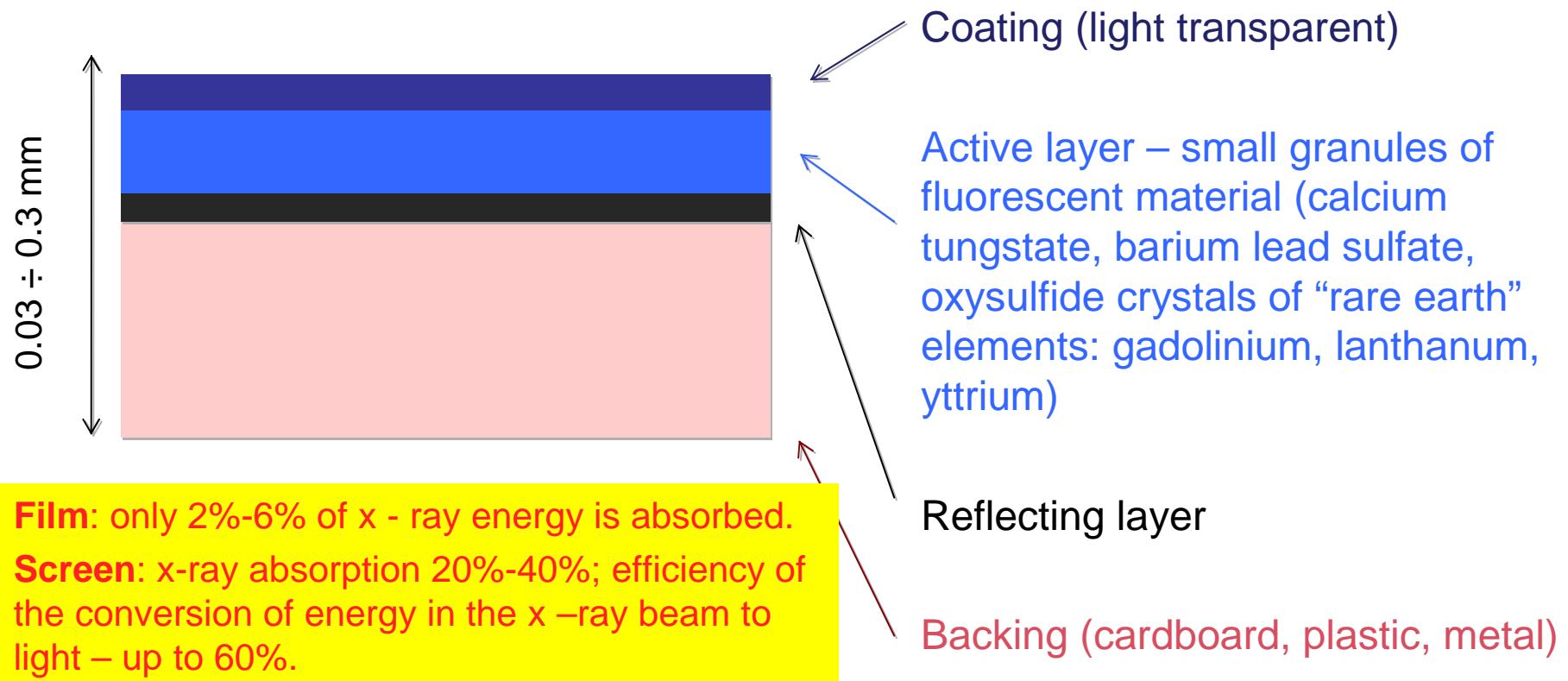




Intensifying screen

Intensifier screen acts as photon energy converter.

X-ray photon absorption -> unstable atom state (electron missing) -> relaxation with emission of visible photons





Intensifying screen

Advantages:

- Reduced exposure time and decreased motion unsharpness in the image
- Reduced tube current -> smaller focal spots
- Reduced tube voltage
- Reduced production of heat in x-ray tube
- Reduced patient radiation dose

$$\text{Intensification Factor} = \frac{\text{Exposure required to produce D=1.0 (without screen)}}{\text{Exposure required to produce D=1.0 (with screen)}}$$
$$\text{IF} = 50 \div 100$$



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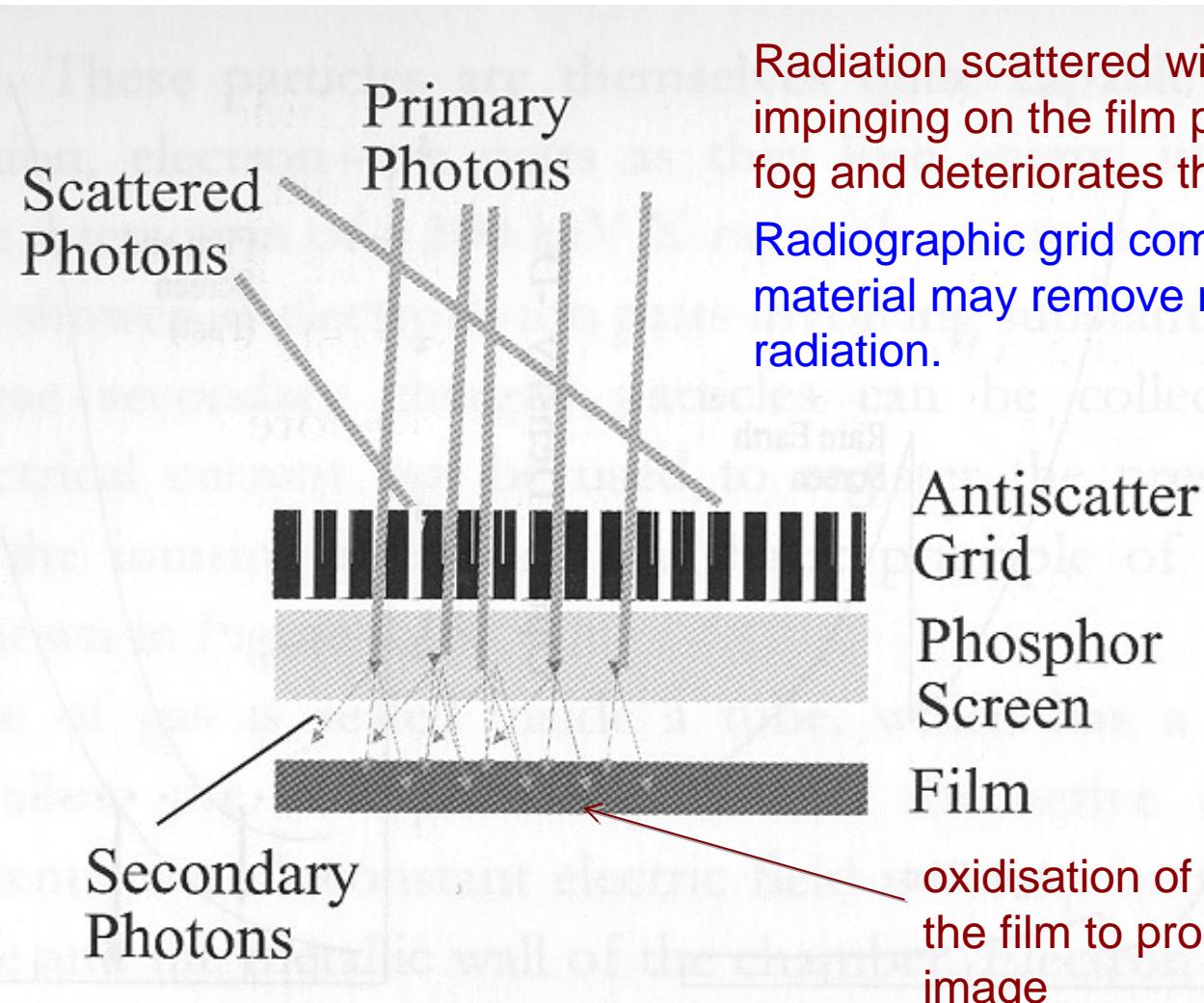
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Radiographic grids



Radiation scattered within the patient and impinging on the film produces the photographic fog and deteriorates the image quality.

Radiographic grid composed of dense, high-Z material may remove much of scattered radiation.

Antiscatter
Grid

Phosphor
Screen

Film

oxidisation of halide silver grains in the film to produce the shadow image





Digital Radiography

The quality of x-ray image recorded on the film may be considered as very good.

However, the imaging demands that required digital techniques were identified:

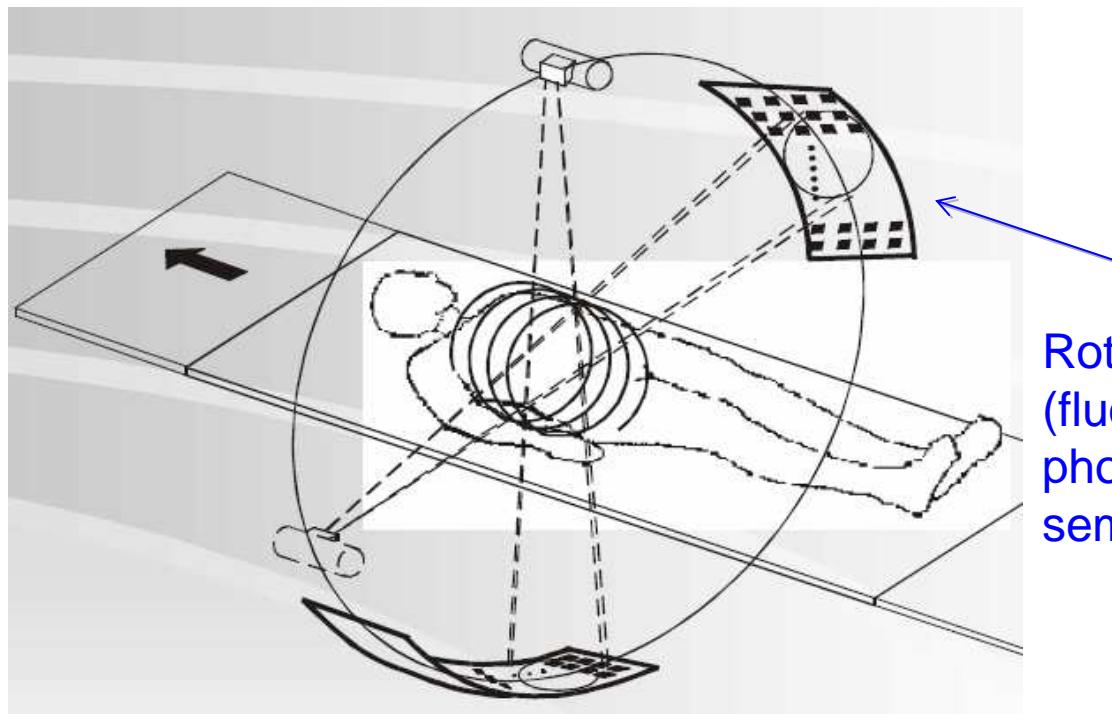
- Computed Tomography
- Increasing of image dynamic range
- Simultaneous viewing at different locations (telemedicine)
- Image processing and enhancement
- Image storage





Digital Radiography

Discrete digital detectors



Rotating array of detectors
(fluorescent crystals,
photodiodes, other
semiconductor devices)

4th generation scanners, resolution 0.4mm, acquisition time < 1s



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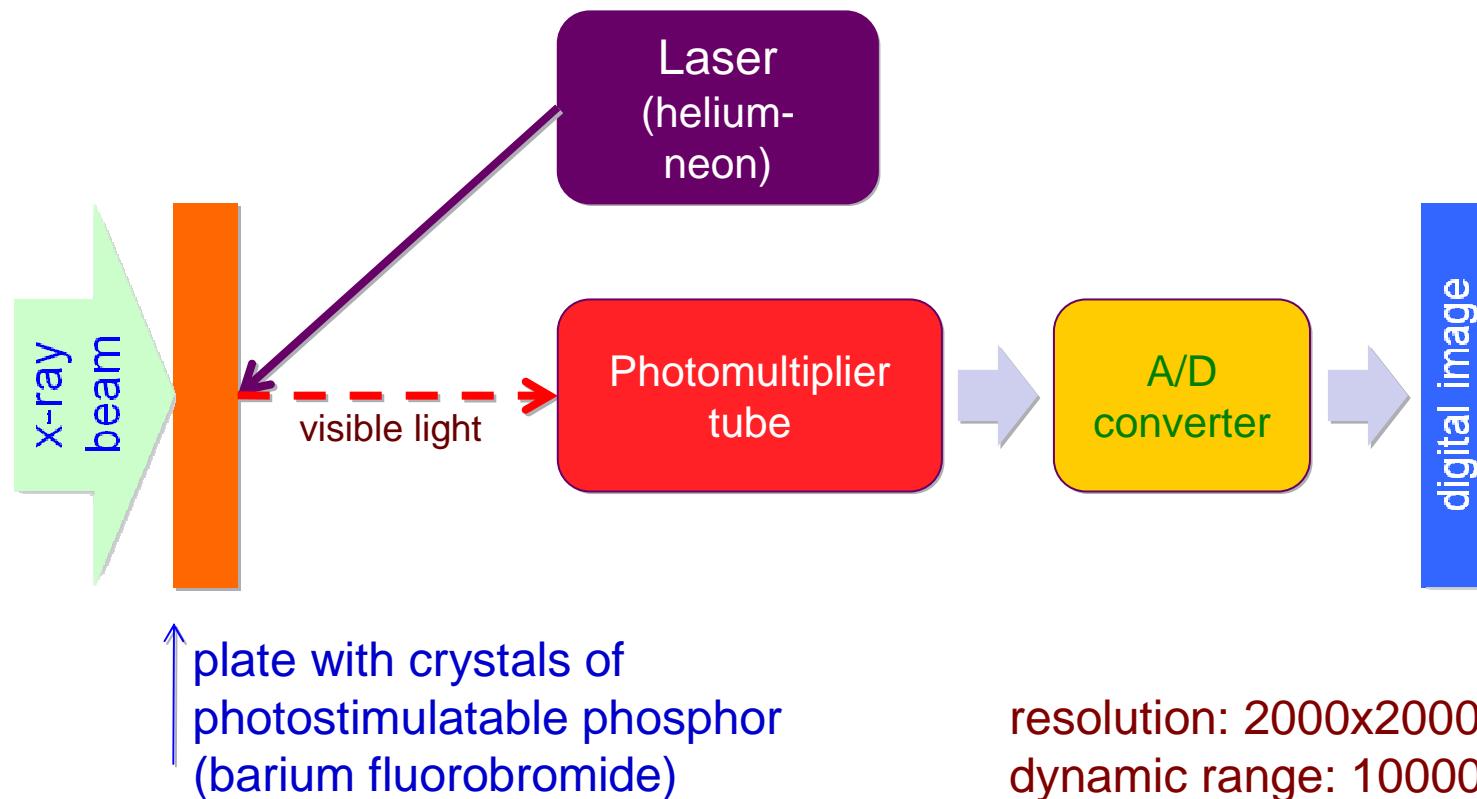
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Digital Radiography

Storage Phosphor (Computed Radiography)





Digital Radiography

Film Scanning

Laser beam is scanned across the film => optical densities modulates the transmitted light => light detector converts the light energy to an electrical signal => it is digitized by A/D converter => stored in memory

- + do not disrupt routine image procedures
- inability to correct gray scale mapping, need for handling individual sheets of film, time consuming scanning procedure

resolution: 2000x2000, 10-12 bits/pixel





Digital Fluoroscopy

Fluoroscopy is able to reflect almost instantaneous changes occurring in the patient.

X-ray hit the fluoroscopic screen, then the light is emitted from the screen reflecting x-ray energy.

Television fluoroscopy system

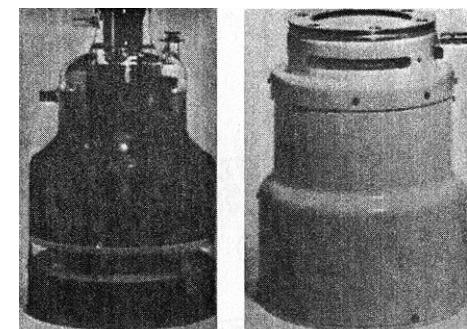
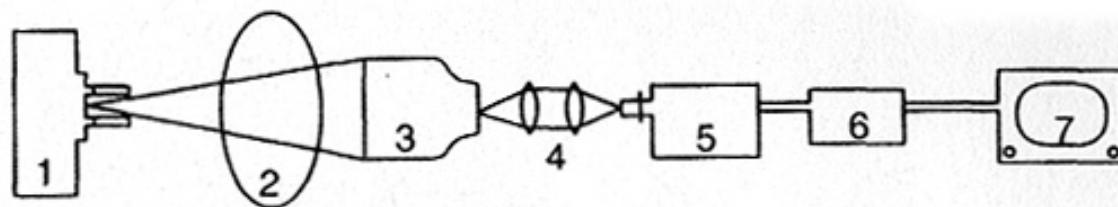


image intensifier

1 – x-ray tube, 2 – patient, 3 – image intensifier, 4 – optical system, 5 – TV camera, 6 – camera control unit, 7 – TV monitor





Angiography

Angiography or arteriography is a medical imaging technique used to visualize the inside, or lumen, of blood vessels and organs of the body, with particular interest in the arteries, veins and the heart chambers.

This is traditionally done by injecting a radio-opaque contrast agent into the blood vessel and imaging using X-ray based techniques such as fluoroscopy.

[<http://en.wikipedia.org/wiki/Angiography>]

The contrast agent (contrast media) contains mainly iodine ($Z=53$) or barium ($Z=56$). For soft tissue $Z_{\text{eff}}=7.4$, thus attenuation coefficients significantly differs in value and, consequently it is possible to clearly distinguish the structure containing contrast from adjacent tissue.

$$\sigma = \frac{Z^5}{E^2}$$

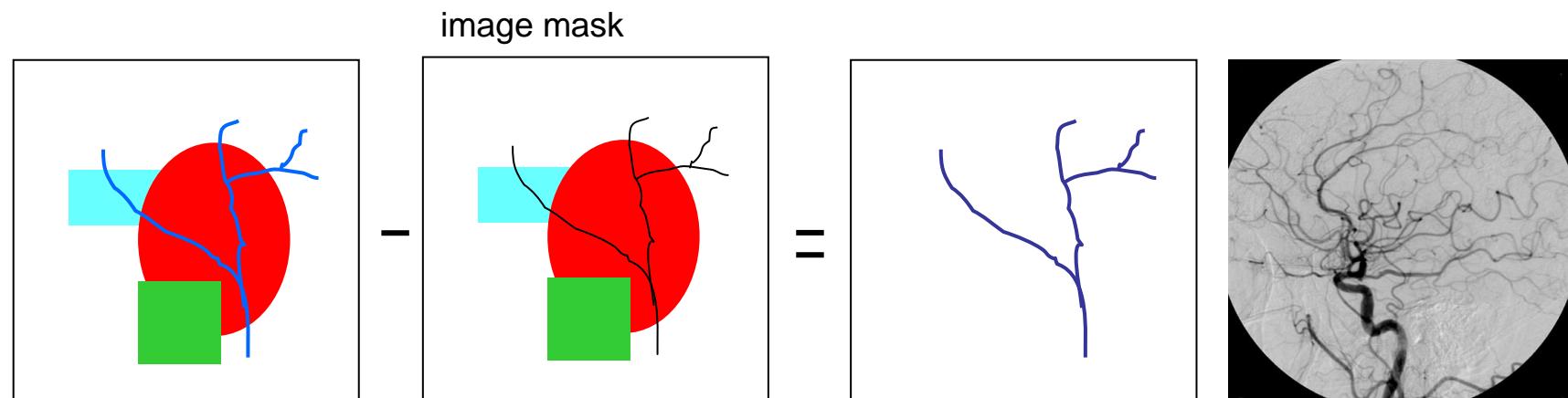




Digital Subtraction Angiography

Images acquired pre- and postinjection of contrast may be digitally subtracted to yield images of vessel structure only without the distraction of other tissues.

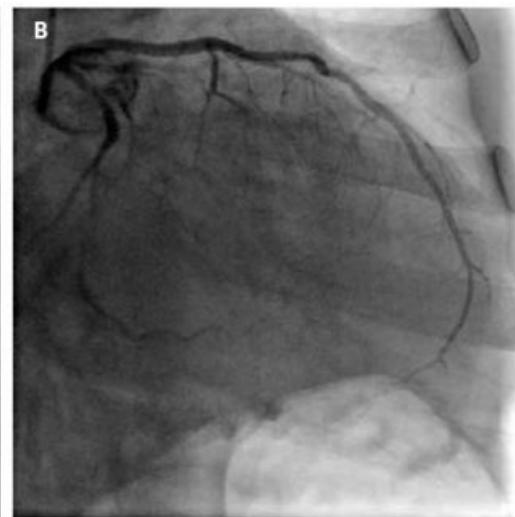
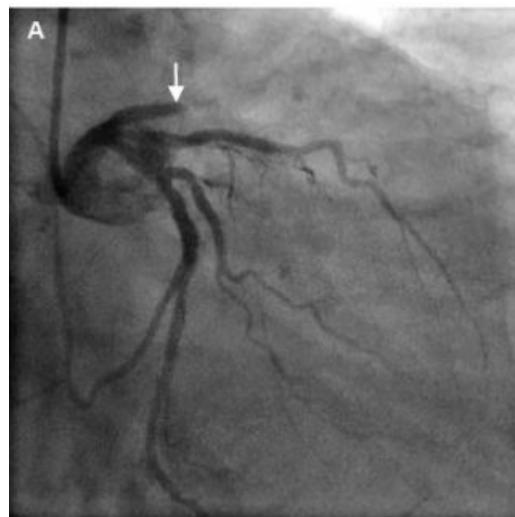
If motion occurs, then new image mast should be selected or mask image can be shifted accordingly to the motion direction.





Coronary Angiography

One of most common angiograms performed is to visualize the blood in the coronary arteries. A long, thin, flexible tube called a catheter is used to administer the x-ray contrast agent at the desired area to be visualized. The catheter is threaded into an artery in the forearm, and the tip is advanced through the arterial system into the major coronary artery.



[<http://en.wikipedia.org/wiki/Angiography>]

www.mp.pl/artykuly/?aid=31704



http://commons.wikimedia.org/wiki/File:Hk_coronary_big_bionerd.gif



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Image acquisition

Image acquisition is the process of converting light energy radiating from image scene points into an electrical signal (suitable for storing or transmission).

Image acquisition devices: CCD/Video camera, Scanner, Digitizer

There are two basic schemes of converting optical images into electrical signals:

- without accumulation of photo-charges (eg. optical scanner),
- with accumulation of photo-charges (np. vidicon, CCD array)



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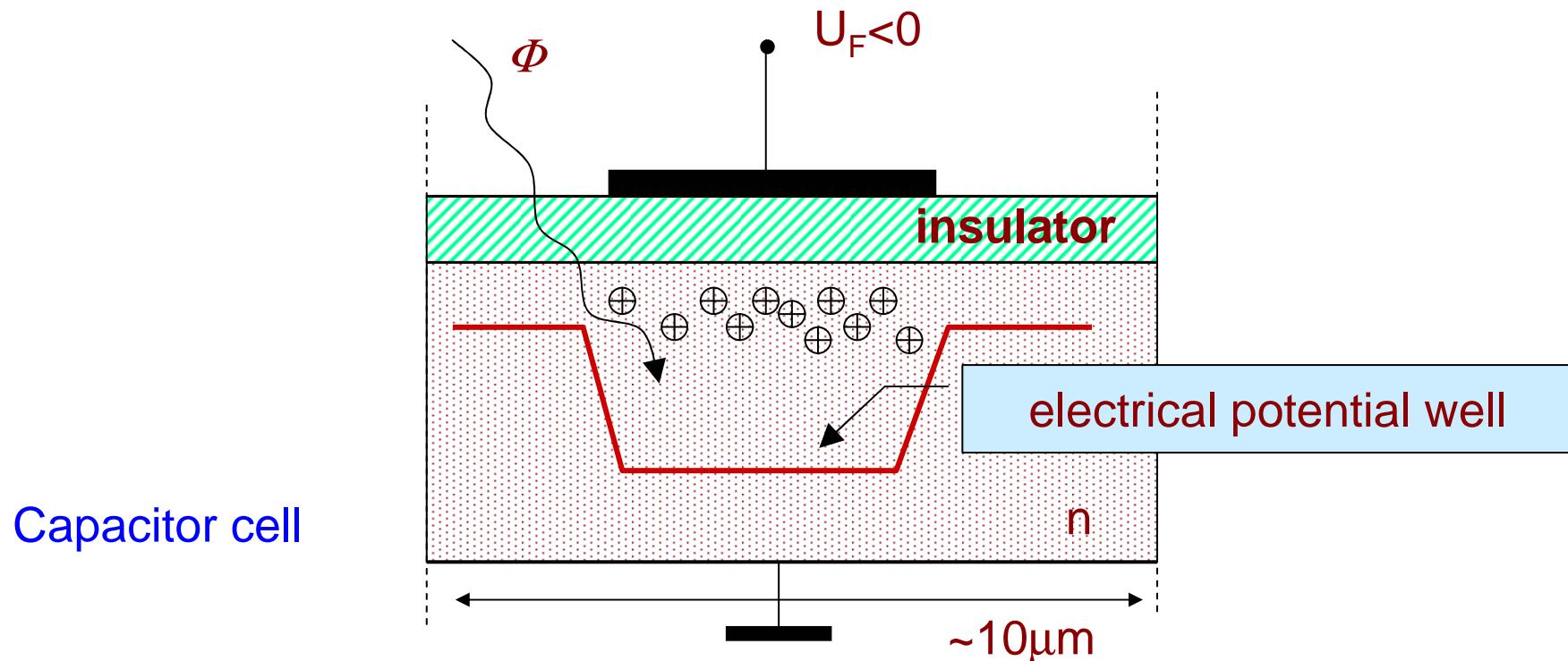
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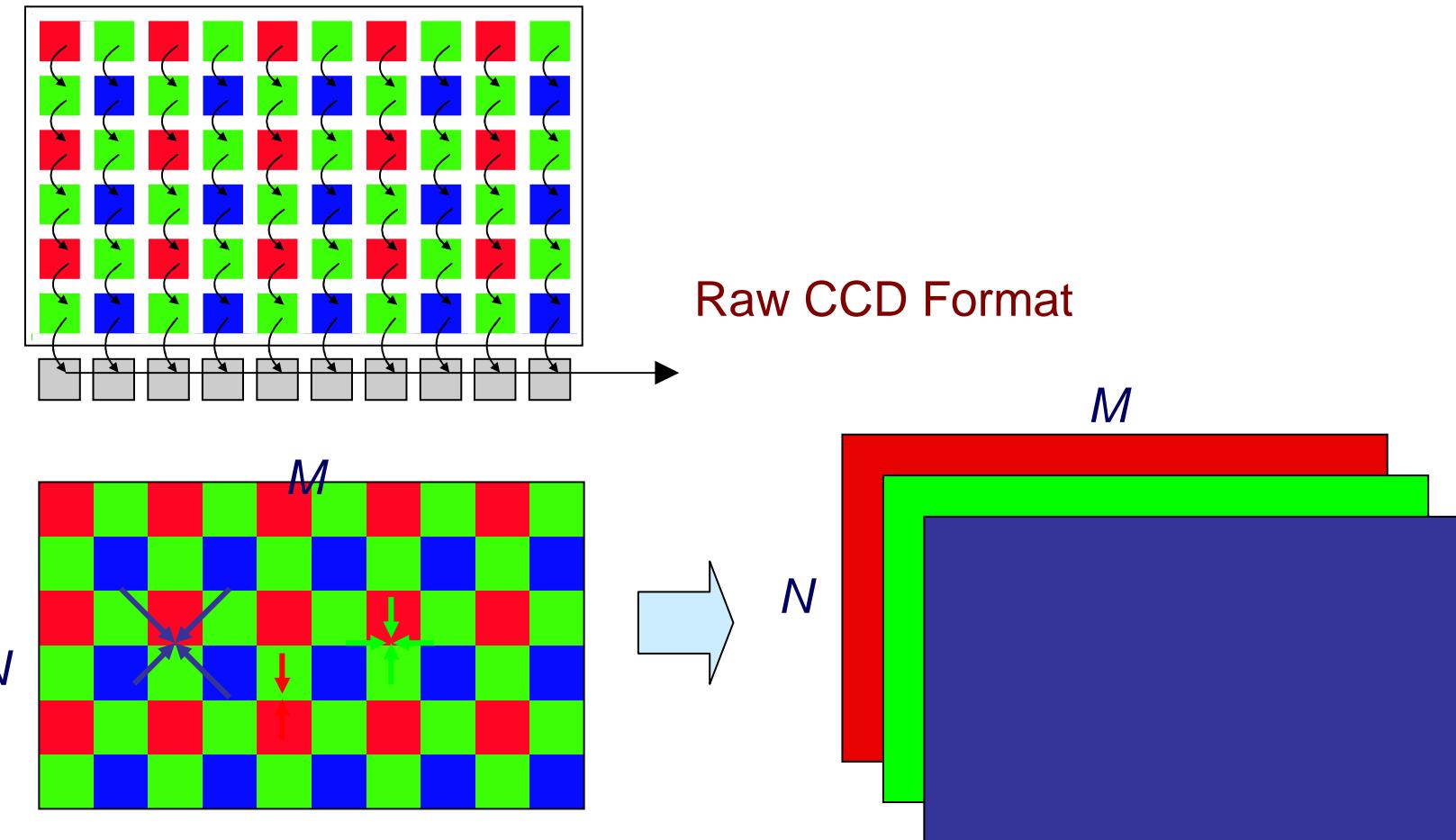
CCD array (accumulation of photo-charges)

Image formation is based on the internal photo-electric phenomenon





The Bayer matrix

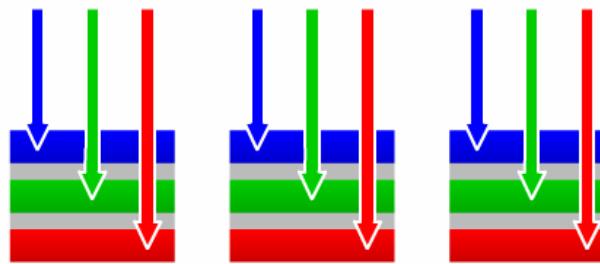
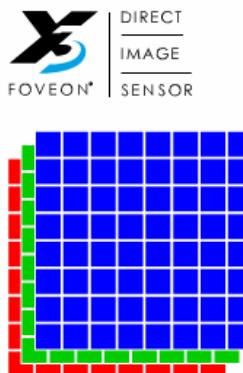


Calculate RGB image by interpolating colour components from the Bayer matrix





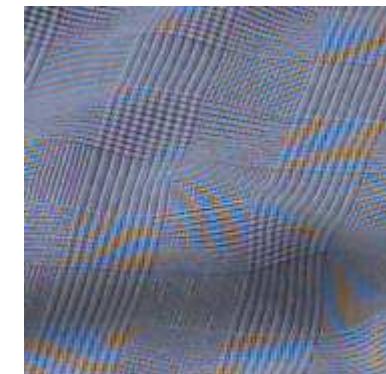
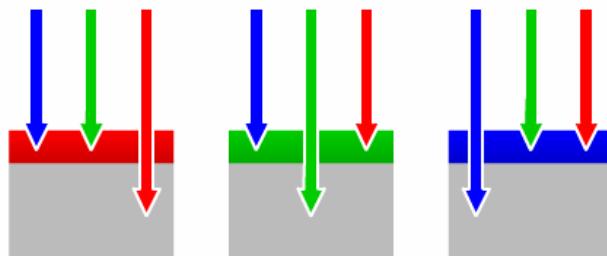
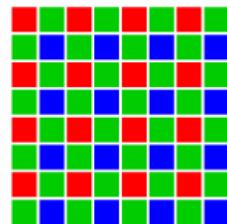
The FOVEON matrix



Three layers of pixels capture all of the light.



Typical CCD



www.foveon.com



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Pixim – Digital Pixel System (DPS)



A/D converter for each pixel
(no charge couplings)

Single A/D converter



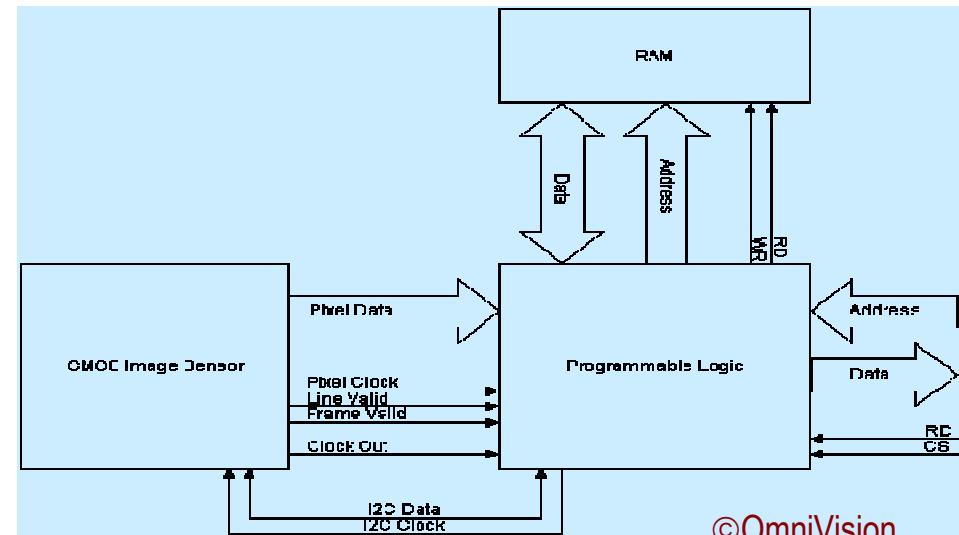
CMOS image sensors

Pros:

- cheap technology (used for fabricating memory and CPU modules),
- low power consumption (100 times!)
- random access to pixel regions (block image processing)
- no „charge leaking” typical for CCD technology
- on-chip analog-to-digital conversion and signal processing

Cons:

- more susceptibel to noise than CCD
- lower light sensitivity due to many transistors used for single pixel

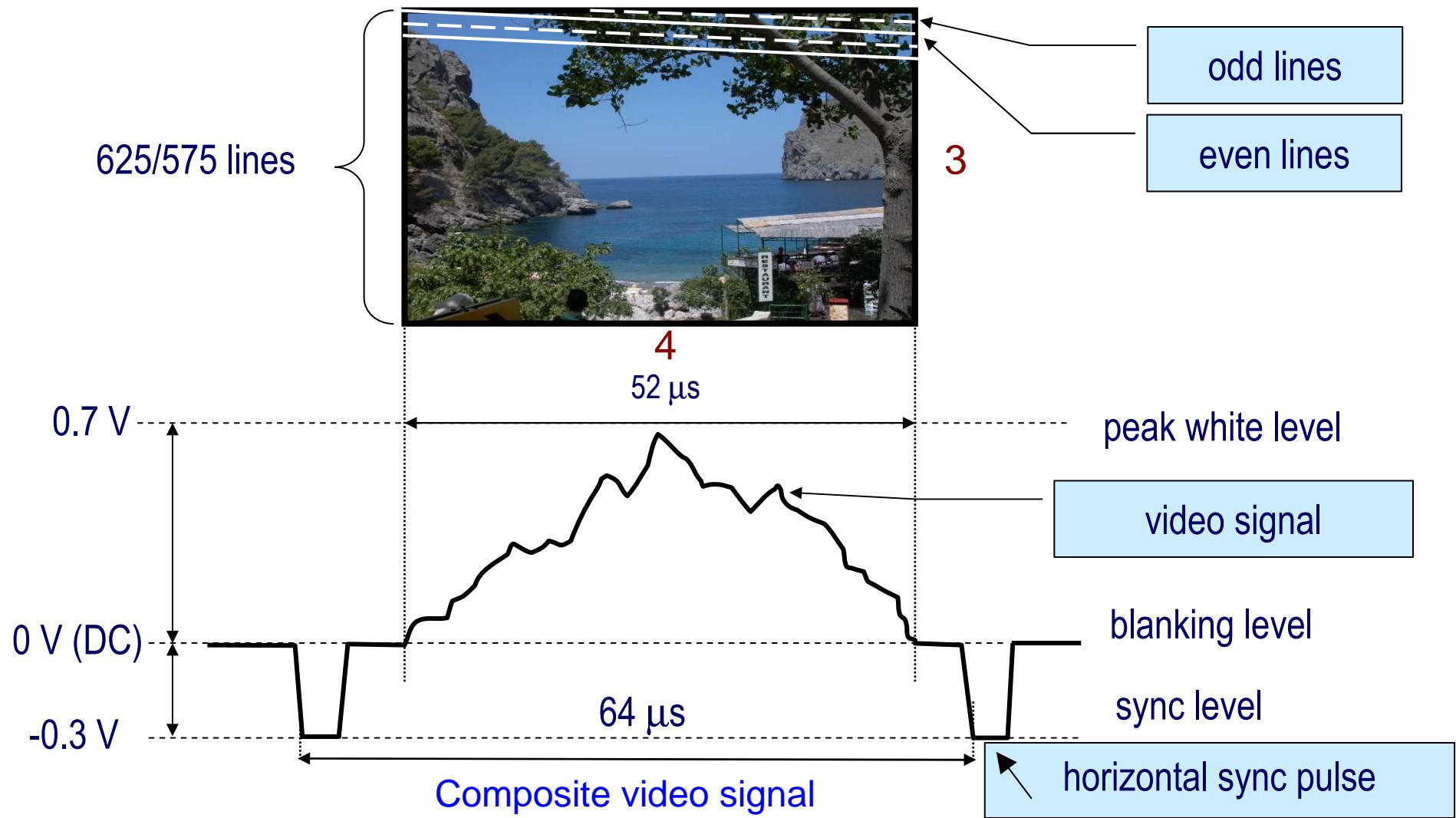


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TV CCIR standard





COHU® CCD camera



Specification Highlights

Imager:

1/2" interline transfer CCD

Picture Elements:

RS-170A: 768 (H) x 494 (V);
CCIR: 752 (H) x 582 (V)

Pixel Cell Size:

RS-170A: 8.4 µm (H) x 9.8 µm (V);
CCIR: 8.6 µm (H) x 8.3 µm (V)

Resolution:

RS-170A: 580 horizontal TVL, 350 vertical TVL; CCIR: 560 horizontal TVL,
450 vertical TVL

Synchronization:

Crystal/H&V/Asynchronous, standard

Shutter: 1/60 to 1/10,000

AGC: 20 dB

Integration: 2 - 16 Fields

Sensitivity:

Full video, No AGC: 0.65 lux; 80% video, AGC on: 0.04 lux; 30% video, AGC on: 0.008 lux

S/N Ratio (Gamma 1, gain 0 dB): 55 dB





CCD image sensors characteristics

- small size,
- robust to mechanical vibrations (70 G),
- no geometrical distortions,
- low supply voltage (12 V, 1.4W),
- SNR ~70 dB,
- linear (gamma coefficient),
- no intra-frame photo-charge accumulation,
- high resolution,
- reliable
- cheap





Image frame grabber

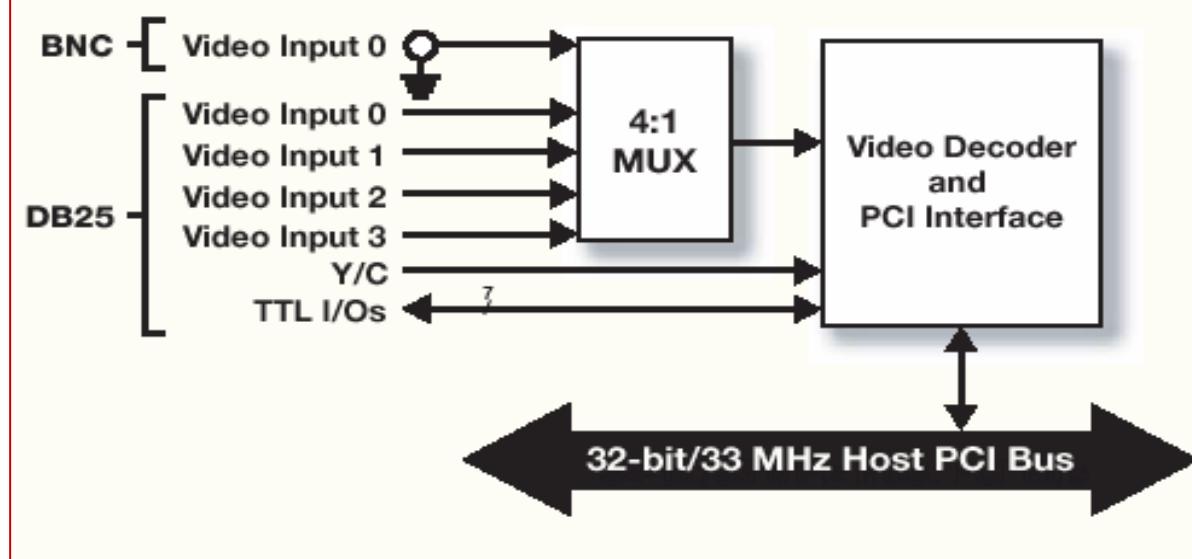
Matrox CronosPlus

Video capture board for PCI captures from **NTSC**, **PAL**, **RS-170** and **CCIR** video sources,
connect up to 4 CVBS or 1 Y/C trigger input,
7 TTL auxiliary I/Os,
32-bit/33MHz PCI-bus master



Matrox ®

Software is sold
separately, includes
e.g., **Matrox ®**
Imaging Library for
Microsoft® Windows®





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