X-RAY FLUOROSCOPY IMAGING SYSTEMS

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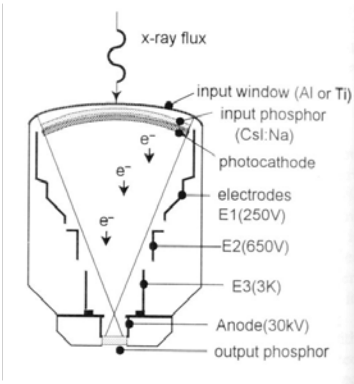
Luminescence:

Fluorescence - emitting narrow light spectrum (very short afterglow ~nsec) - PM detectors; II input screens (CsI:Tl)

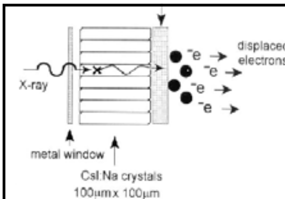
Phosphorescence - emitting broad light spectrum (light continues after radiation) - monitor screens, II output screens (ZnCdS:Ag)

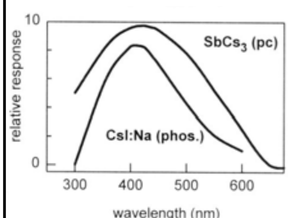
The old fluoroscopic screens are no longer used due to high dose and low resolution

Basic Components of an Image Intensifier



- Input window (Ti or Al) 95% transmission
- Input screen: CsI (new) or ZnS (old) phosphor
- Photocathode (a layer of $CsSb_3$)
- Accelerating electrodes zoom (e.g. 30/23/15 cm)
- Output screen (2.5 cm)
- II housing (mu-metal)
- Output coupling to the TV camera

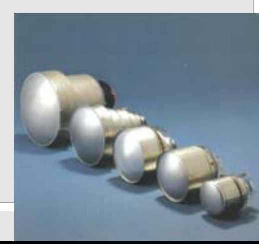




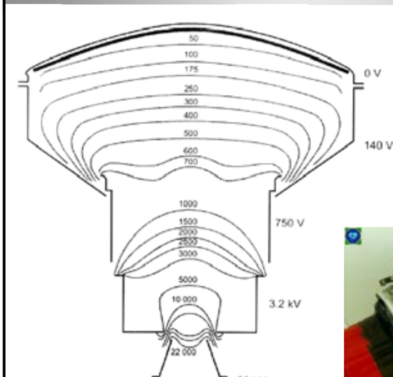
II Input screen:

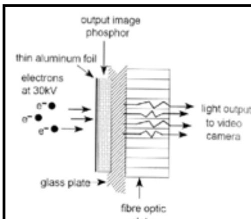
Columnar crystals of CsI which reduces dispertion (collimation); absorbs approx. 60% of X-rays

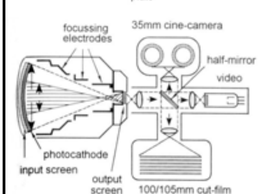
Photocathode applied directly to CsI both light spectrum match very well



II Accelerating electrodes







II Output screen:

Phosphor (ZnCdS:Ag) on glass base

The accelerated e⁻ produce multiple light photons; thin Al foil prevent return of light (veiling glare)

Coupling: fibre optic or tandem optic

Conversion factor ~100-1000 (cd.m^{-2}/μGy.s^{-1}) = (output phosphor light / input screen dose rate)

Total gain (inp. X photons / out. light photons)

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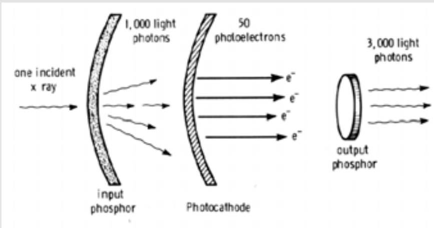
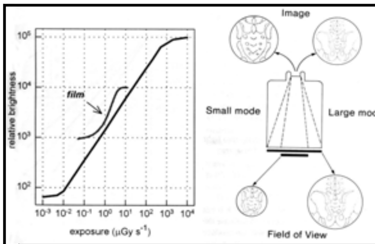
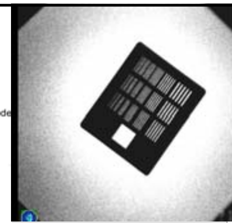
1 X-ray photon >> 1000 light photons (input screen) >>

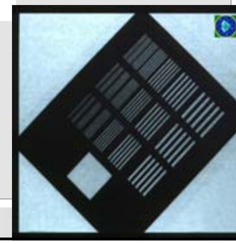
>>50 photo e⁻ >> 3000 light photons (output screen)

in the case above the total gain is 3000









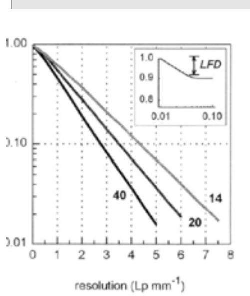
Dynamic range of II

-much larger than this of radiographic film (output luminance per dose unit)

Resolution and Magnification of II

- electronic zoom up to 4 times (lp/mm)

MTF of II depending on zoom (magnification)



Some II Characteristics:

Minification gain -D_m-inp./output diam. $(D_{inp} / D_{out})^2$

Flux gain - F_x (approx. 30-60):

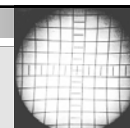
Out.scr. light photons / inp. ligh photons to photocath.

Brightness gain - G_B

$G_B = D_m \times F_x$

* Zooming increases the resolution, but requires higher dose rate !!

Contrast Ratio



-X-ray scatter at input window, input phosphor

-Light scatter within phosphor, not-absorbed light by phosphor

-Back scatter from output phosphor (to photocathode), at output window

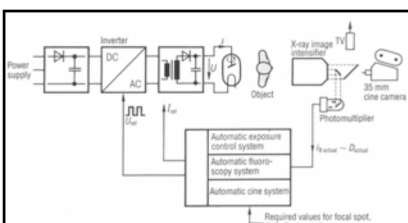
L_c – light intensity at centre of image (pure white)

Cont. Ratio (C_v)= L_c/L_d *: ideally max/0 ; in reality approx. 30/1*

L_d - light intensity at centre of image (cover with Pb)

II field size	40 cm (16")	32 cm (12.5")	20 cm (8")	15 cm (6")
Resolution (Lp/mm)	4.0	4.2	5.5	6.0
Contr. ratio	20:1	25:1	30:1	35:1
Convers. Factor (cd/m / mR/s)	166	100	60	50
Distortion (pincushion %)	9	4.5	1.4	1
Dose (relative)	0.25	0.5	0.75	1

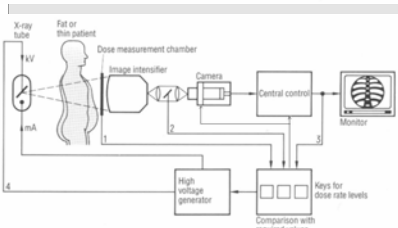
Table from: D.Dowsett, P.Kenny, E.Johnston



Automatic Brightness Control System (ABS)

- produces images with constant brightness by keeping constant entrance dose rate to the II

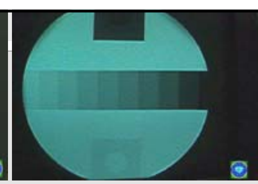
* II entr. dose rate is approx. 1 μGy/sec and should not exceeds 2 μGy/sec.
* The maximal patient entrance skin dose should not exceed 0.01 Gy/min).



- different types and characteristic curves of changing the kV/mA

Graphs from: E Krestel (SIEMENS)

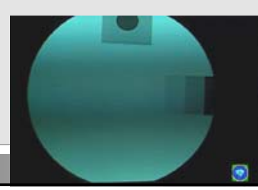
60 kV

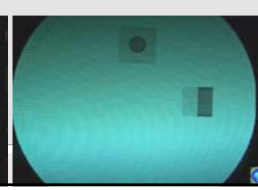


70 kV

II contrast with different kV (constant mA)

90 kV



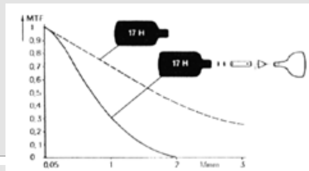


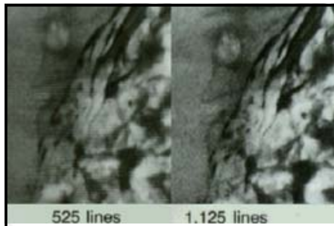
100 kV

TV camera types:

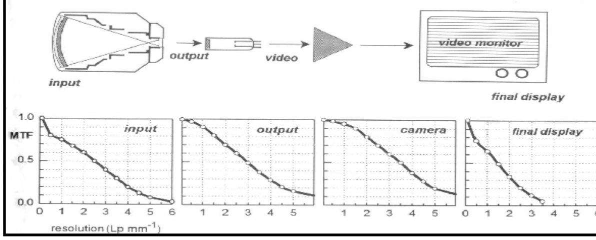
Vidicon - gamma 0.7; slow response, some contrast loss (light integration), high dark current, but low noise - suitable for organs

Plumbicon - gamma 1; quick response, small dark current, but high noise - suitable for cardiac examinations



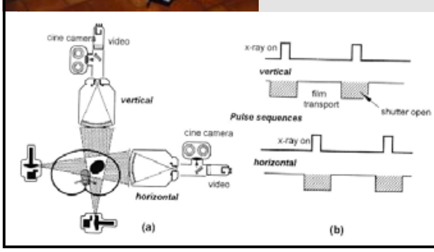


Overall II-TV system MTF = $MTF_1 \times MTF_2 \times \ldots \times MTF_n$



Typical Fluoro accessories (fluorographic): cine camera, 100 mm spot camera, also fast film changer (cut or roll films)

Bi-plane fluoroscopic system (for cardiac axams) normally linked with two cine cameras



N.B. The patient dose at cine-fluo is many times larger than the dose at normal fluoroscopy

Fluoroscopy delivers very high patient dose. This can be illustrated with an example:

The electrical energy imparted to the anode during an exposure is

$$A = C_1 \,.\, U_a \,.\, I_a \,.\, T$$

The X-ray tube anode efficiency is

$$E = C_2 \,.\, Z.\, U_a$$

From the two equations follows that the energy produced in a single exposure will be

$$X = C \,.\, A \,.\, E = C \,.\, Z \,.\, (U_a)^2 \,.\, I_a \,.\, T = (C.\, Z) \,.\, kV^2 \,.\, mAs$$

Radiography of the lumbar spine (with parameters 80 kV, 30 mAs):

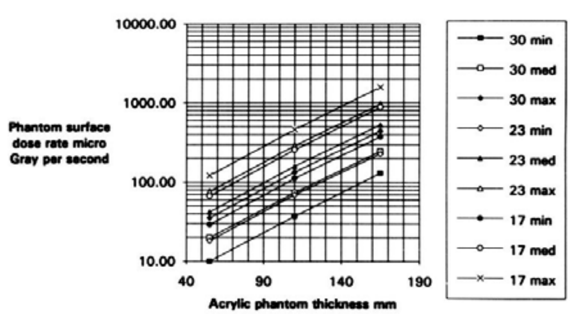
$$X = k.\ 80.80.30 = k.\ 192{,}000$$

Fluoroscopy - 3 minutes Barium meal (with parameters 80 kV, 1mA)

$$X = k.\ 80.80.1.3.60 = k.\ 1{,}152{,}000$$

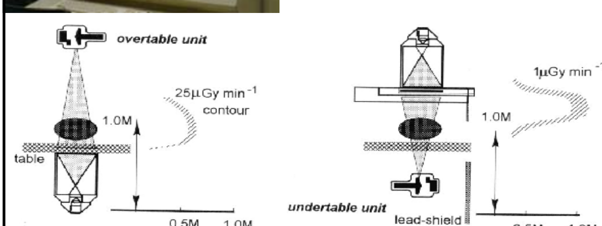
In this example fluoroscopy delivers approx. 6 times more X-ray energy (dose)

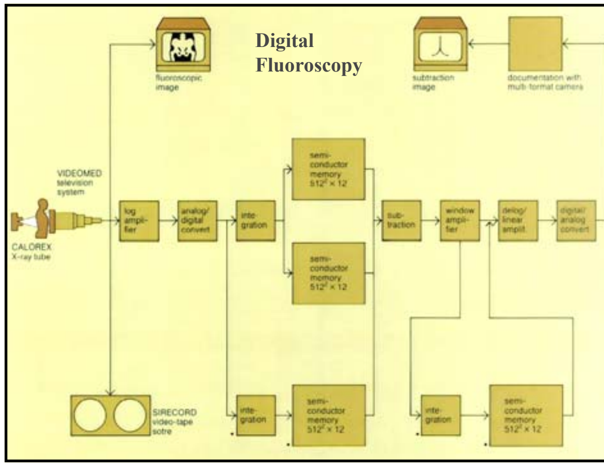
Typical phantom surface (patient entrance) doses in ABS fluoroscopy

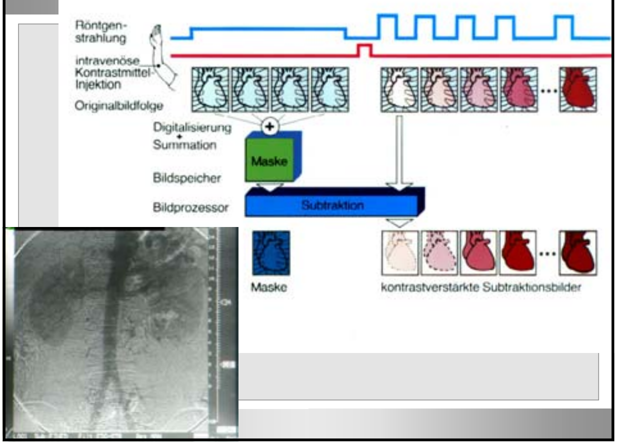


Scatter radiation in fluoroscopy

when the II is above the patient table the scatter radiation to staff is lower







Mathematical operation in DSA: Functional imaging; Logarithmic & Square_Root Subtraction, etc