

X-RAY FLUOROSCOPY IMAGING SYSTEMS

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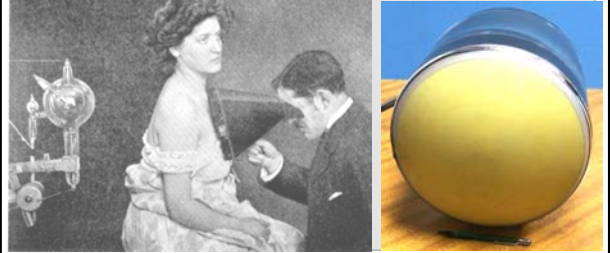
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Luminescence:

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

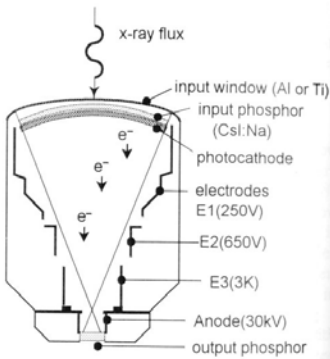
Phosphorescence - emitting broad light spectrum (light continues after radiation) - monitor screens, II output screens (ZnCdS:Ag)

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



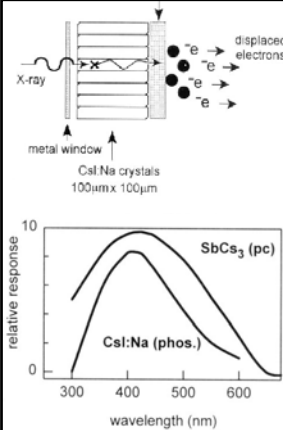
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Basic Components of an Image Intensifier



- Input window (Ti or Al) 95% transmission
- Input screen: CsI (new) or ZnS (old) phosphor
- Photocathode (a layer of CsSb₃)
- Accelerating electrodes zoom (e.g. 30/23/15 cm)
- Output screen (2.5 cm)
- II housing (mu-metal)
- Output coupling to the TV camera

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II Input screen:

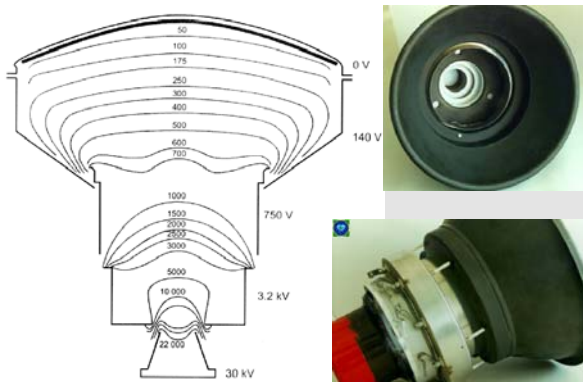
Columnar crystals of CsI which reduces dispersion (collimation); absorbs approx. 60% of X-rays

Photocathode applied directly to CsI both light spectrum match very well

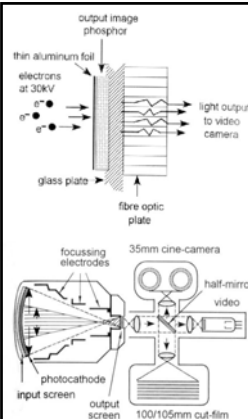


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II Accelerating electrodes



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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)

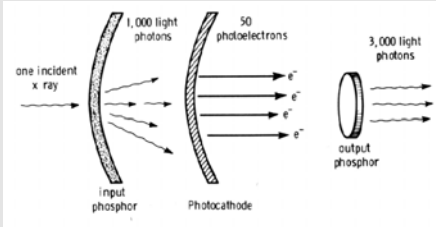
Coupling: fibre optic or tandem optic

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

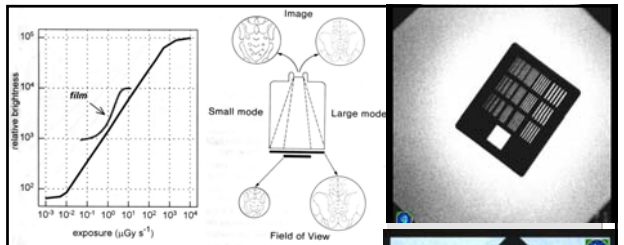
Total gain (inp. X photons / out. light photons)

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



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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)

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MTF of II depending on zoom (magnification)

Some II Characteristics:

Minification gain - D_m - inp./output diam.

$$(D_{inp} / D_{out})^2$$

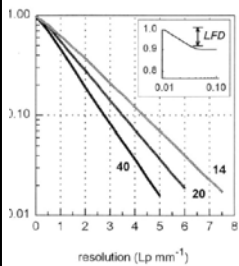
Flux gain - F_x (approx. 30-60):

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

Brightness gain - G_B

$$G_B = D_m \times F_x$$

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



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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)

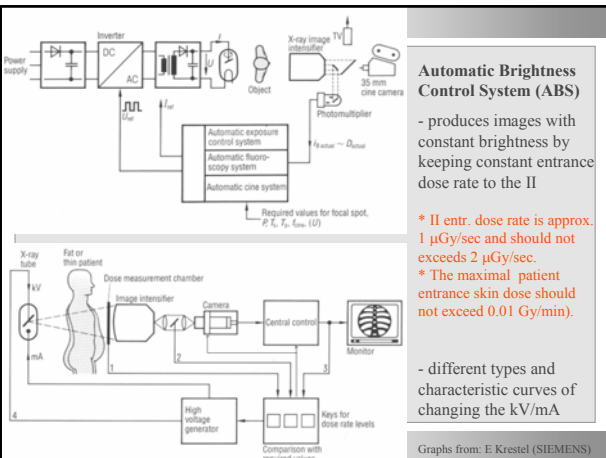
Contr. Ratio (C_c) = L_c / L_d : ideally max/0 ; in reality approx. 30/1

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

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



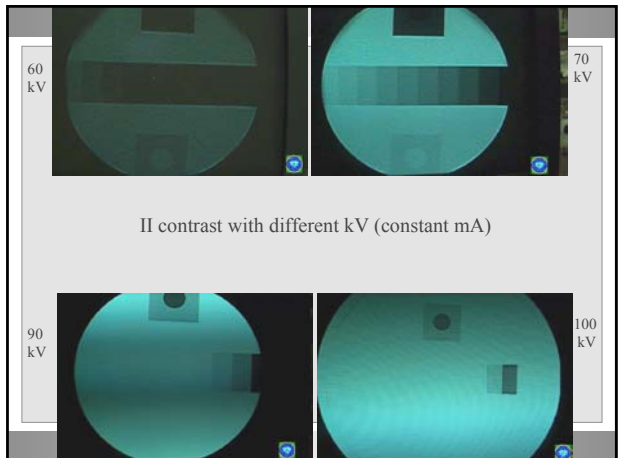
Automatic Brightness Control System (ABS)

- 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 exceed 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)


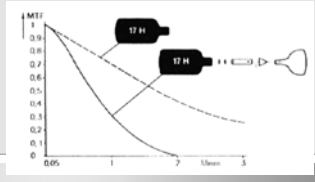


II contrast with different kV (constant mA)

TV camera types:

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

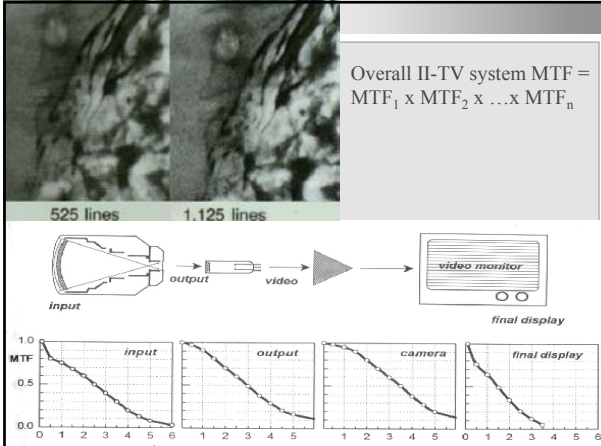
Plumbicon - gamma 1; quick response, small dark current, but high noise - suitable for cardiac examinations

The graph shows MTF on the y-axis (0 to 1) and resolution in Lines/mm on the x-axis (0.05 to 3). Two curves are shown: a solid line for Vidicon and a dashed line for Plumbicon. The Plumbicon curve is consistently higher than the Vidicon curve, indicating better MTF performance at higher resolutions.

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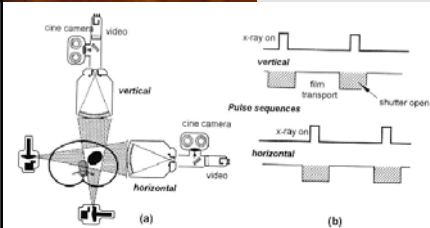
Overall II-TV system MTF = $MTF_1 \times MTF_2 \times \dots \times MTF_n$



The diagram illustrates the II-TV system flow: input (525 lines) → output → video → video monitor → final display (1,125 lines). Below, four MTF graphs are shown for 'input', 'output', 'camera', and 'final display', each plotting MTF (0.0 to 1.0) against resolution in LP mm^{-1} (0 to 6).

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

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

The schematic (a) shows a vertical and horizontal cine camera setup. The pulse sequences (b) show the timing for 'x-ray on', 'film transport', and 'shutter open' for both vertical and horizontal planes.

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

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

The electrical energy imparted to the anode during an exposure is

$$A = C_1 \cdot U_a \cdot I_a \cdot T$$

The X-ray tube anode efficiency is

$$E = C_2 \cdot Z \cdot U_a$$

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

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

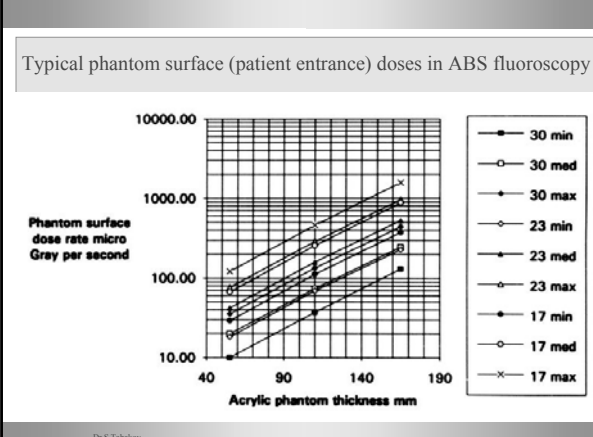
Radiography of the lumbar spine (with parameters 80 kV, 30 mAs):
 $X = k \cdot 80 \cdot 80 \cdot 30 = k \cdot 192,000$

Fluoroscopy - 3 minutes Barium meal (with parameters 80 kV, 1mA):
 $X = k \cdot 80 \cdot 80 \cdot 1.3 \cdot 60 = k \cdot 1,152,000$

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

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Typical phantom surface (patient entrance) doses in ABS fluoroscopy

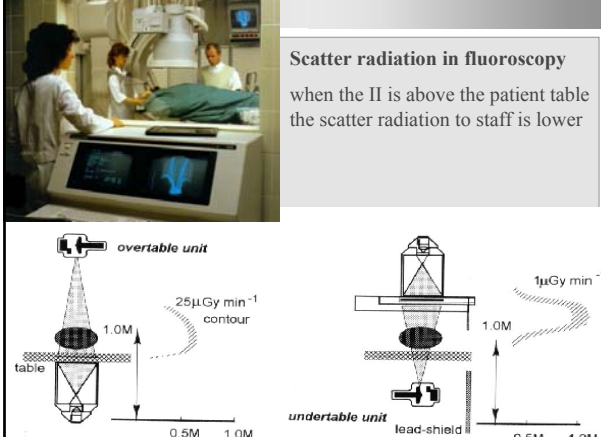


The graph plots 'Phantom surface dose rate micro Gray per second' on a logarithmic y-axis (10.00 to 10000.00) against 'Acrylic phantom thickness mm' on a linear x-axis (40 to 180). Multiple lines represent different settings: 30 min, 30 med, 30 max, 23 min, 23 med, 23 max, 17 min, 17 med, and 17 max. Dose rate increases with both time and thickness.

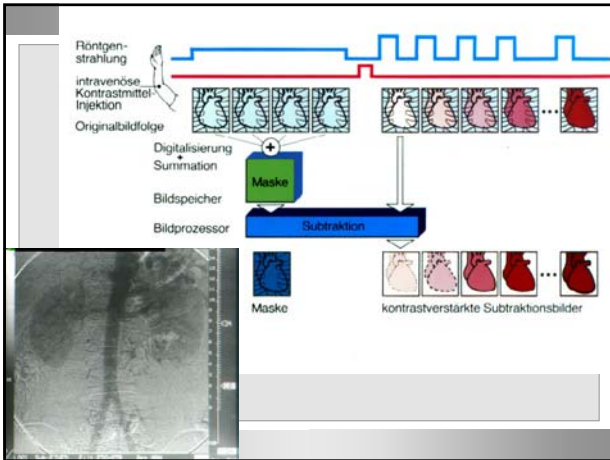
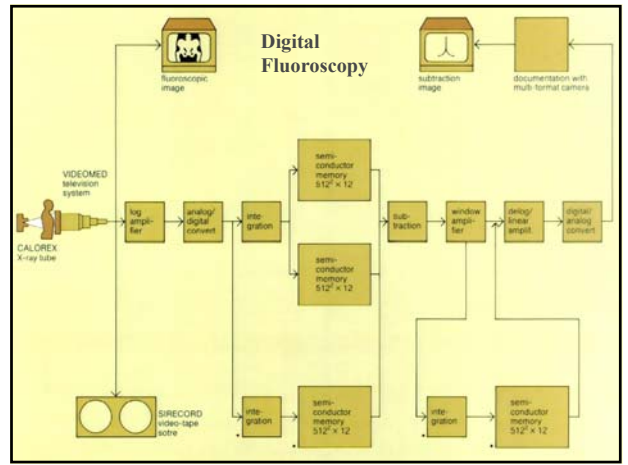
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Scatter radiation in fluoroscopy

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



The diagram shows an 'overtable unit' where the X-ray tube is above the patient table, resulting in a '25 $\mu\text{Gy min}^{-1}$ contour' at 1.0M distance. The 'undertable unit' has the X-ray tube below the table with a 'lead-shield' between the tube and staff, resulting in a lower dose rate of '1 $\mu\text{Gy min}^{-1}$ ' at 1.0M distance.



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