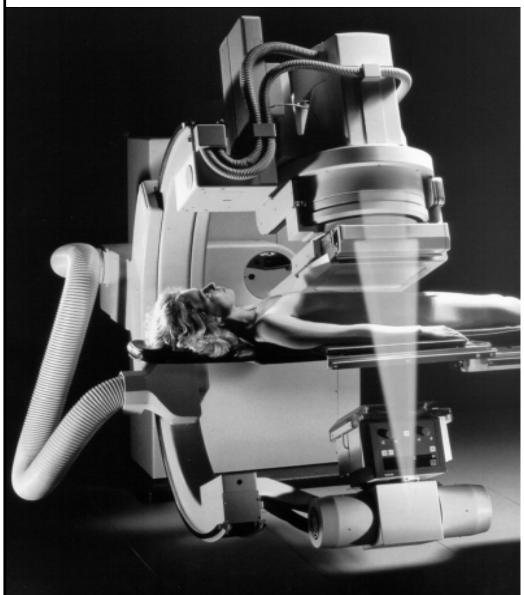

X-RAY FLUOROSCOPY IMAGING SYSTEMS

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OBJECTIVES

- Fluoroscopic patient dose
- Image Intensifier construction
- Input window
- Accelerating and focusing electrodes
- Output window
- Conversion factor
- II characteristics
- TV camera tubes
- Modulation Transfer function
- DSA
- Digital fluoroscopy
- Unsharp masking
- Roadmapping
- Flat panel fluo parameters

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)

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

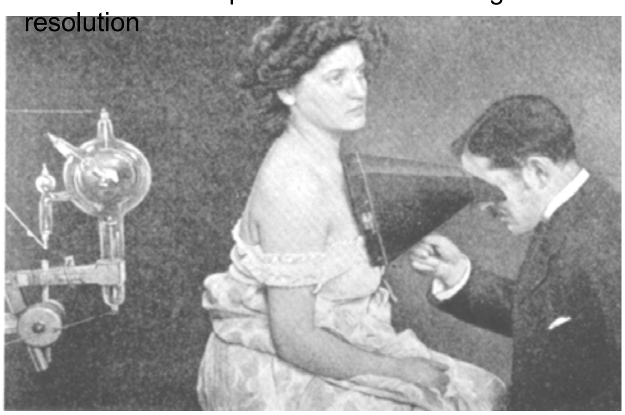
In this example fluoroscopy delivers approx. 6 times more X-ray energy (dose)

Luminescence:

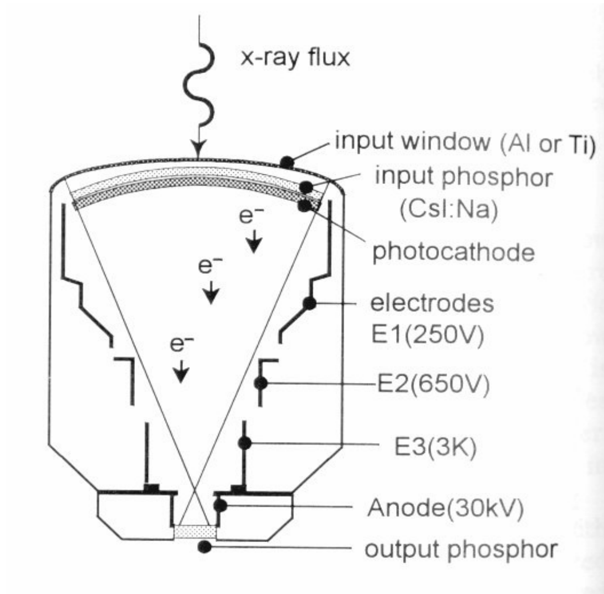
Fluorescence - emitting narrow light spectrum (very short afterglow ~nsec) - PM detectors; II input screens (CsI:Tl)

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

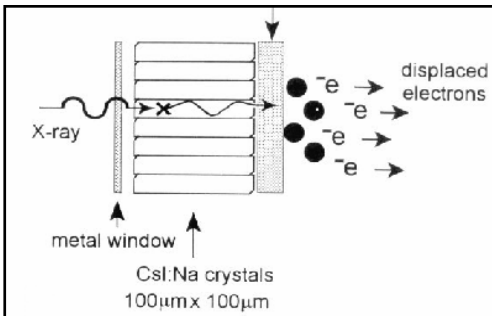
The old fluoroscopic screens are no longer used due to high dose and low resolution

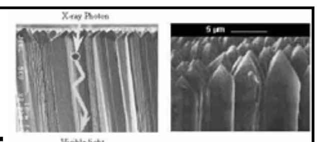


Basic Components of an Image Intensifier



- 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

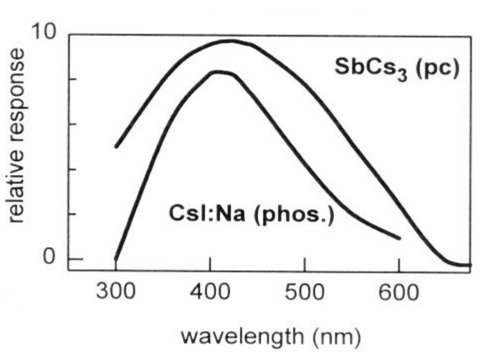


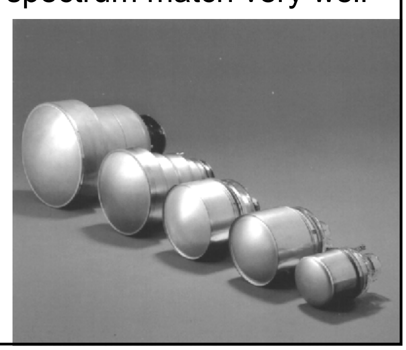


II Input screen:

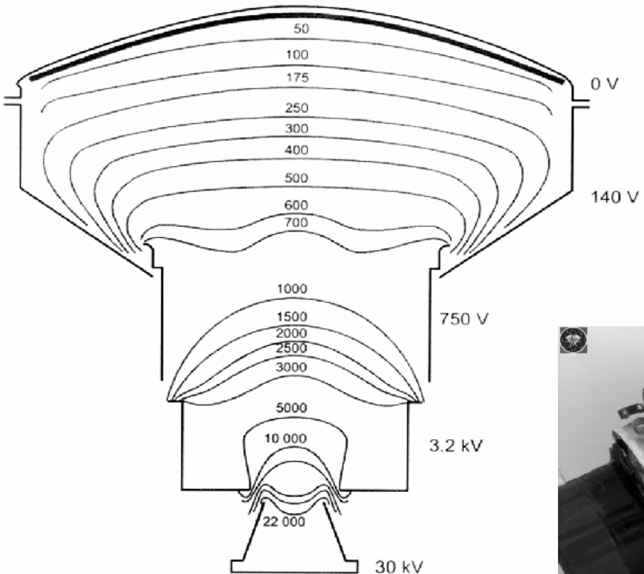
Columnar crystals of CsI which reduces dispertion (collimation); absorbs approx. 60% of X-rays

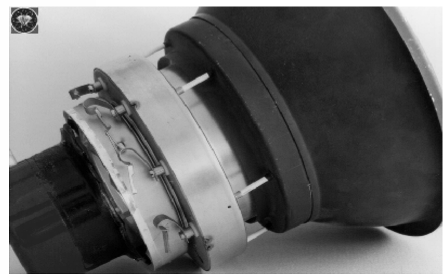
Photocathode applied directly to CsI both light spectrum match very well

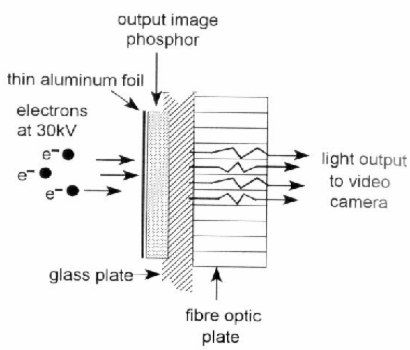


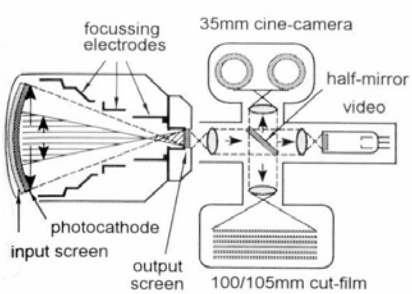


II Accelerating electrodes









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 ($cd.m^{-2}/\mu Gy.s^{-1}$) =

(output phosphor light / input screen dose rate)

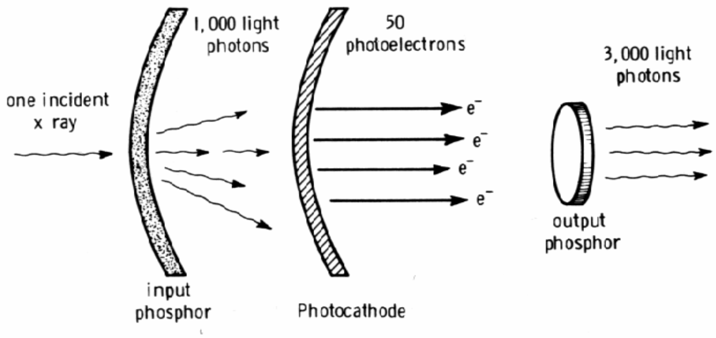
Total gain (out. light photons /inp. X photons)

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

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

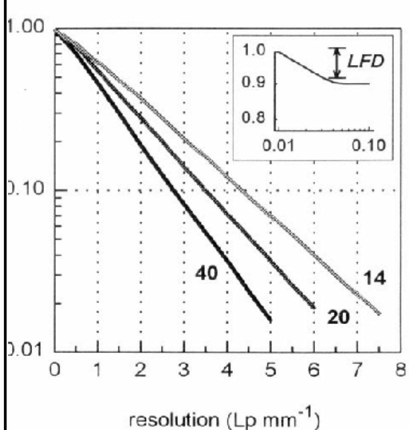
>>50 photo e^- >> 3000 light photons (output screen)

in the case above the total gain is 3000



Some II Characteristics:

MTF of II depending on zoom (magnification)



<u>Minification gain</u> -D_m-inp./output diam.

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

<u>Flux gain</u> - F_x (approx. 30-60):

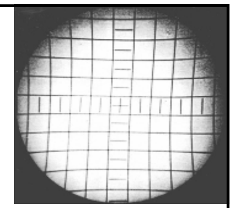
Out.scr. light photons / inp. ligh photons to photocath.

<u>Brightness gain</u> - G_B

$\mathbf{G_B = D_m \times F_x}$

***** 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

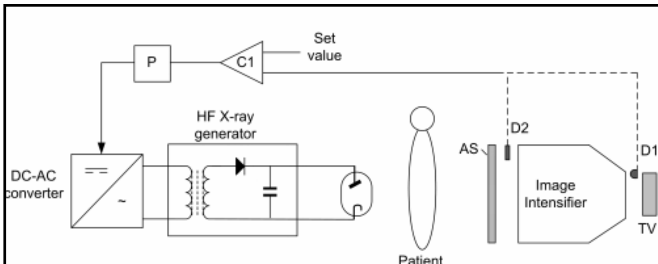
L_c – light intensity at centre of image (pure white)

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

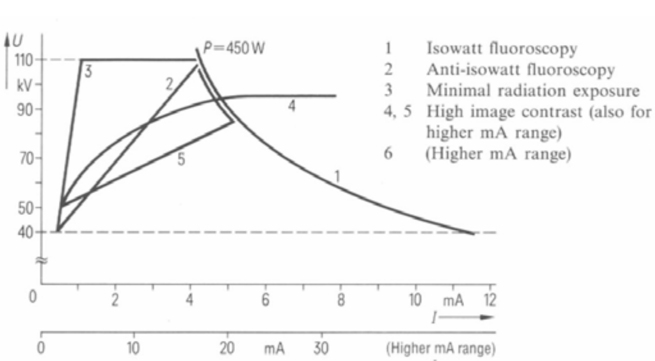
Table from: D.Dowsett, P.Kenny, E.Johnston



Automatic Brightness Control System (ABS)

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

The feedback C1 have two options - taking signal from D1 (dosimeter) or D2 (photometer).



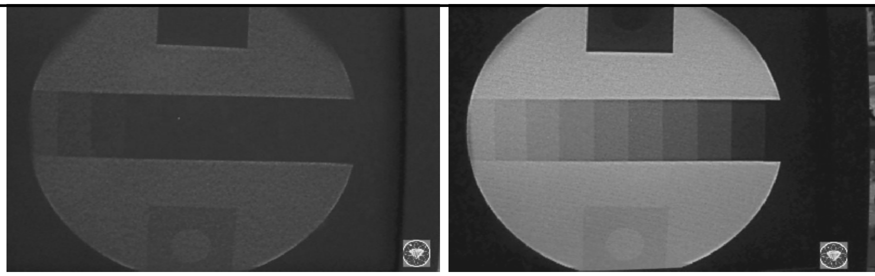
*** II entr. dose rate is approx. 1 μGy/sec and should not exceeds 2 μGy/sec.**
*** The maximal patient entrance skin dose should not exceed 0.01 Gy/min).**

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

Graph from: E Krestel (SIEMENS)

60 kV

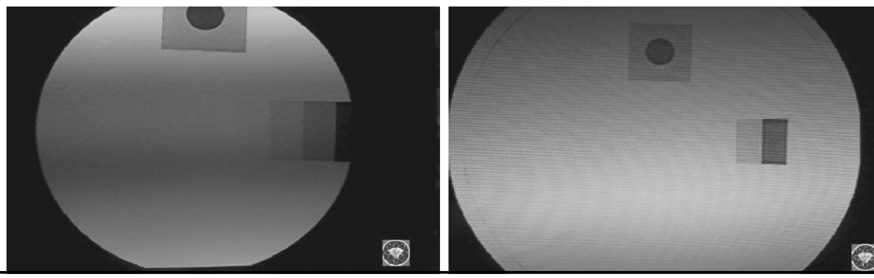
70 kV

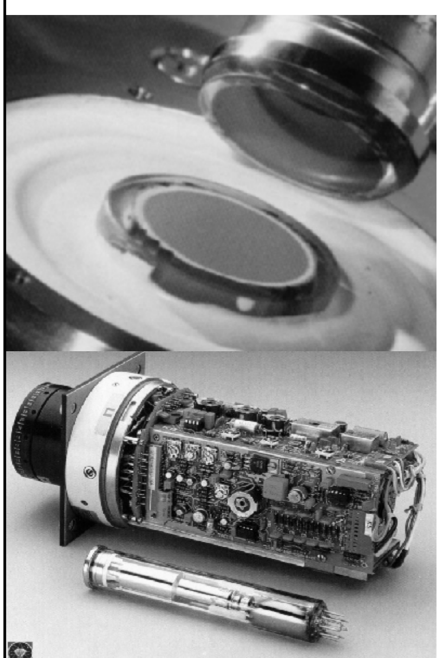


II contrast with different kV (constant mA)

90 kV

100 kV

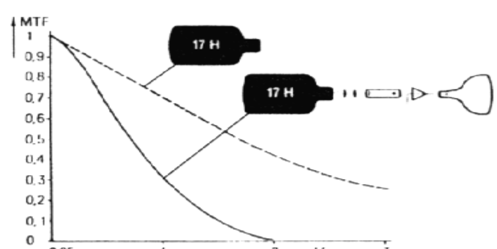


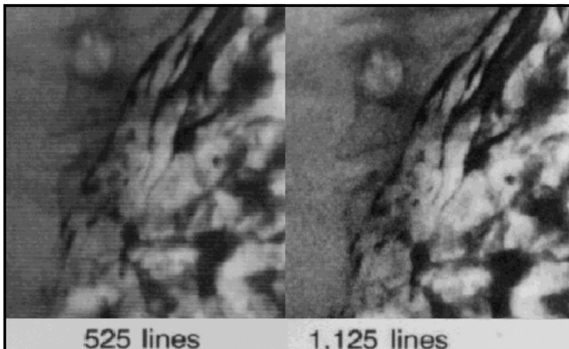


TV camera types:

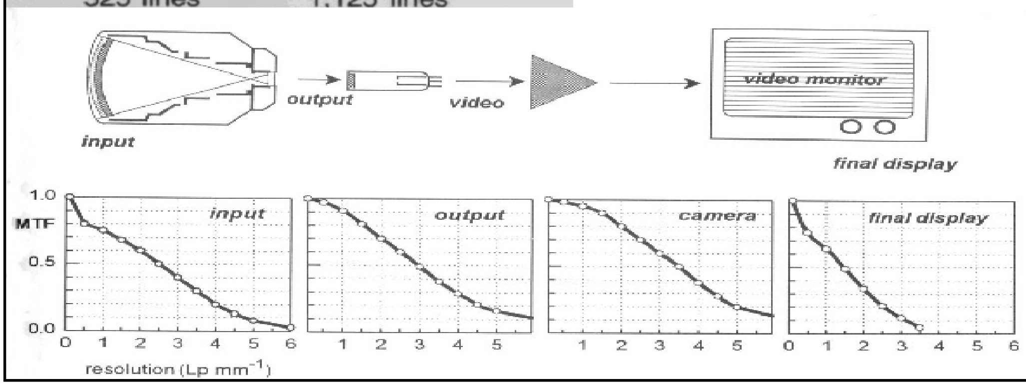
Vidicon - gamma 0.7; slow response, some contrast loss (light integration), high dark current, but low noise - suitable for organs

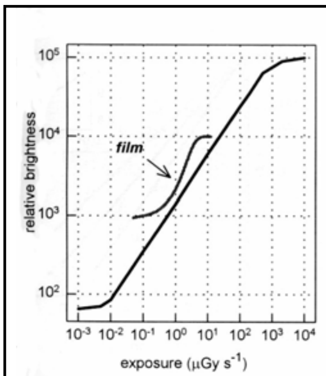
Plumbicon - gamma 1; quick response, small dark current, but high noise - suitable for cardiac examinations

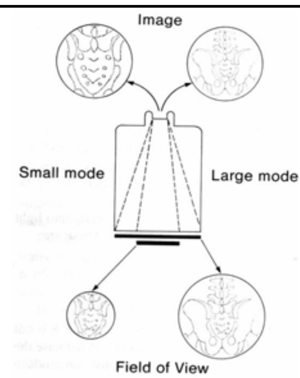


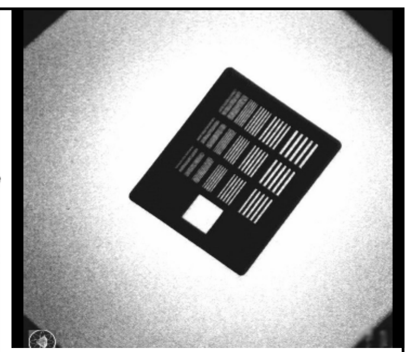


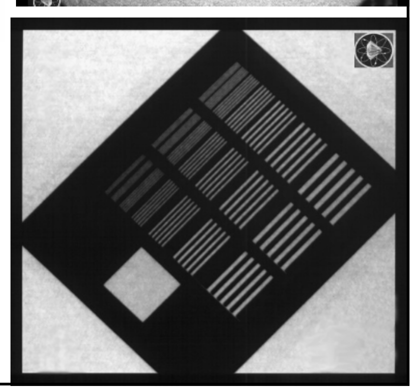
Overall II-TV system MTF = MTF_1 x MTF_2 x …x MTF_n











Dynamic range of II

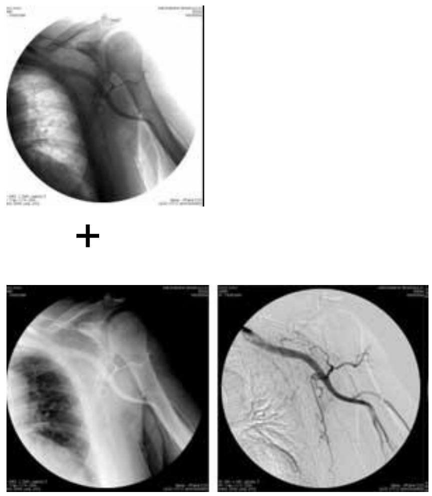
-much larger than this of radiographic film (output luminance per dose unit)

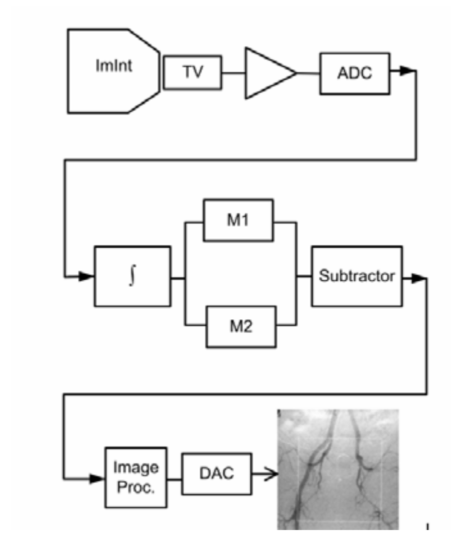
Resolution and Magnification of II

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

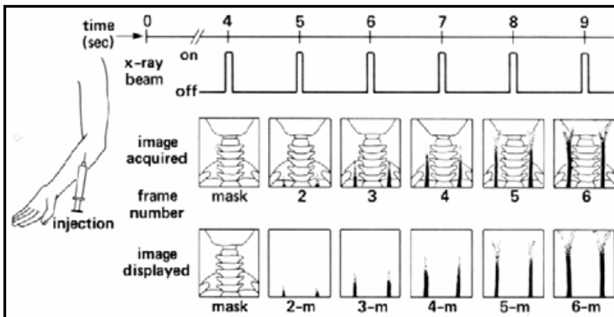
Digital subtraction angiography (DSA)

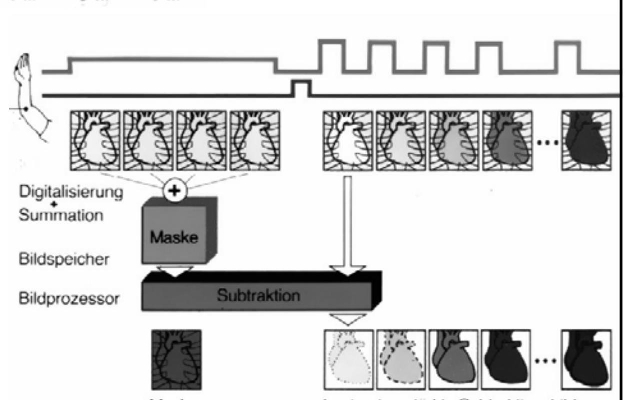
Image intensifier with TV camera and video signal digitisation (ADC)





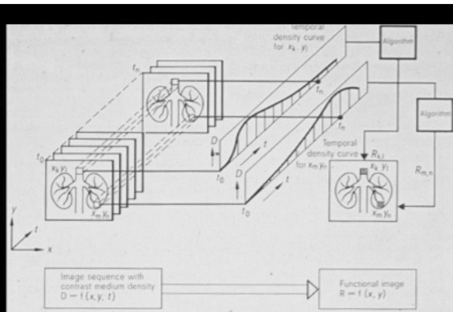
Digital subtraction and unsharp masking

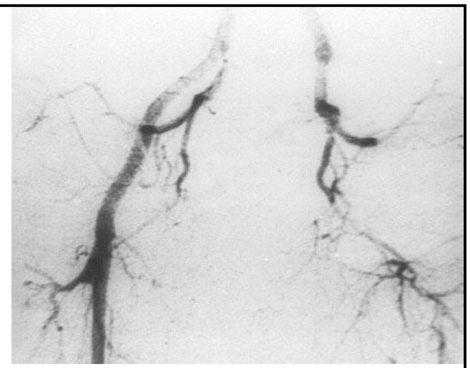


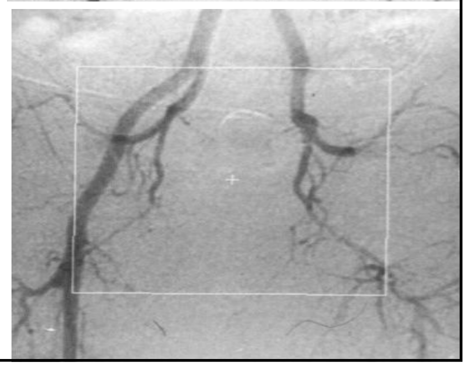


Mathematical operation in DSA: Functional imaging; Logarithmic & Square Root Subtraction, etc.

Functional Imaging

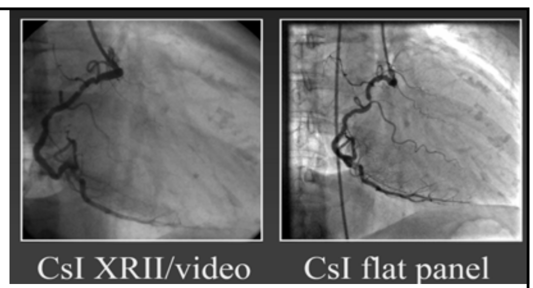


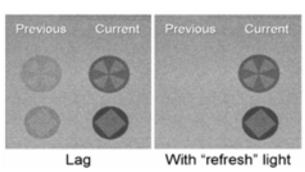




FPD Digital Flouroscopy

High cost, but more compact with better uniformity and without geometric distortion. Improved high-dose examinations as cine mode (at lower dose). Not enough strong signal at low dose examinations (II better). FPD with indirect technology still have insufficient temporal resolution (lag), but direct FPD are better.



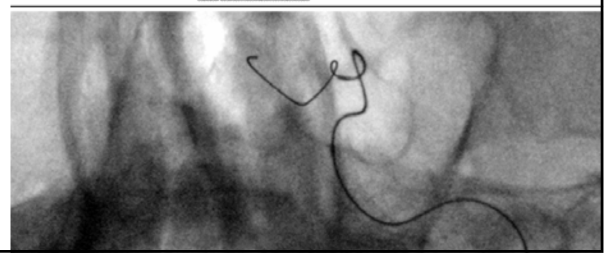


Feature comparison of II/TV and FPD systems

Feature	Digital flat panel	Conventional II/TV
Dynamic range	Wide, about 5,000:1	Limited by TV, about 500:1
Geometric distortion	None	Pin-cushion and 'S–distortion
Detector size (bulk)	Thin profile	Bulky, significant with large FOV
Image area FOV	41×41 cm	40 cm diameter (25% less area)
Image quality	Better at high dose	Better at low dose

Digital fluoroscopy roadmapping (biplane):

2D image, 3D reconstruction, guide wire and stereo guiding



<u>Some parameters of contemporary Digital Fluoroscopic systems (CsI)</u>

15 pulses per sec with 10msec pulse duration = 150msec X-ray time (15% from continuous fluoroscopy dose)

Resolution 1024x1024 matrix at 200mm view field = pixel 0.2mm =2.5 lp/mm (new FP fields 400mm and 2048 x 2048 matrix)

Contrast 1024 grey levels (10 bits)

Dynamic capture (digital cine) up to 30 fr./sec (digital cine-mode)

Dose saving pulse fluoroscopy (with last image hold)

Cost 3x the normal fluoroscopic cost