Acquisition of digital chest images for pneumoconiosis classification: Methods, procedures, and hardware

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Transition to the digital era

Letter → Email

Hardcopy → Softcopy

Analog → Digital

Why digital radiography?

- Four function of film:
  - Image capture
  - Image processing
  - Image display
  - Image storage
- Separation of function enabling optimization of each towards improved image quality

Advantages
of digital radiography

- Improved dynamic range
  - Toleration for over-/under-exposure
- Image post-processing
  - Improved visualization
- Digital format
  - Enabling quantification and digital analysis
  - Electronic archival and distribution

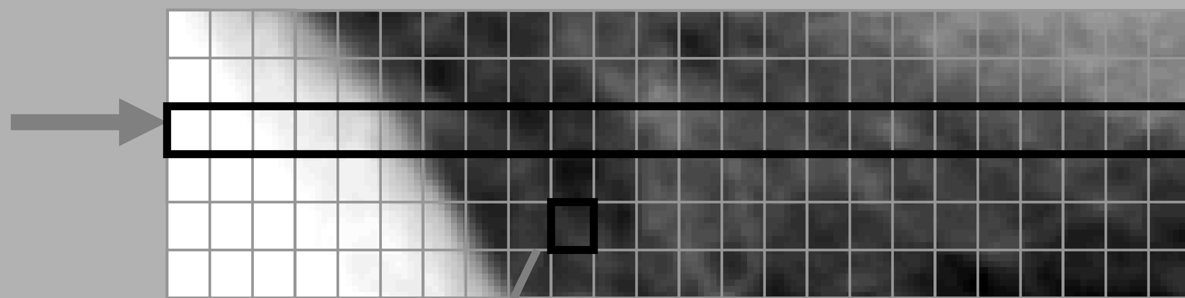
Digital radiography in classification of pneumoconiosis?

Notable advantages in potentially providing accessible, standardized image data for visual interpretation or automated classification

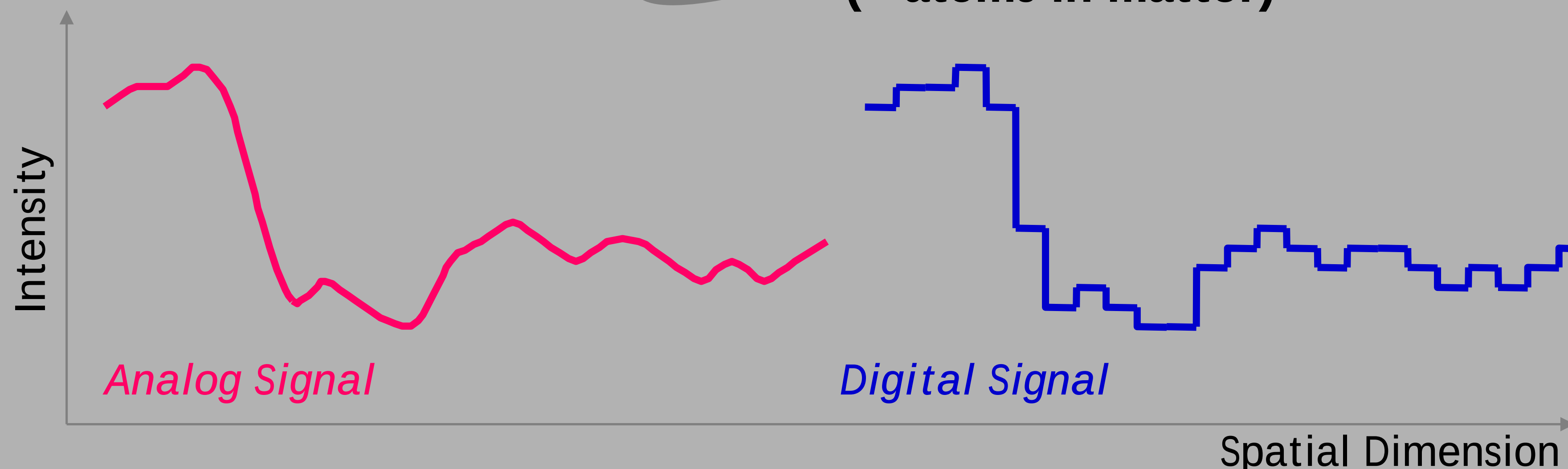
Digital radiography

- Radiography in which the image data are **sampled** into discrete elements in spatial and intensity dimension

Sampling



Pixel = a single spatial/intensity element (~ atoms in matter)



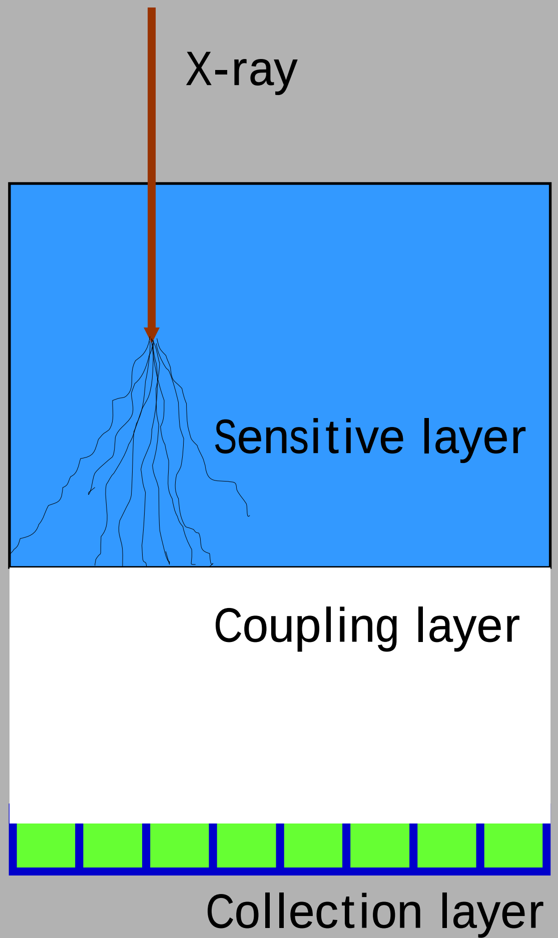
Common aspects of DR

1. Imaging geometry
2. Detrimental effect of x-ray scatter
3. Analog x-ray capture followed by digitization
4. Digital image
5. Required image pre- and post-processing

Differences between DR systems

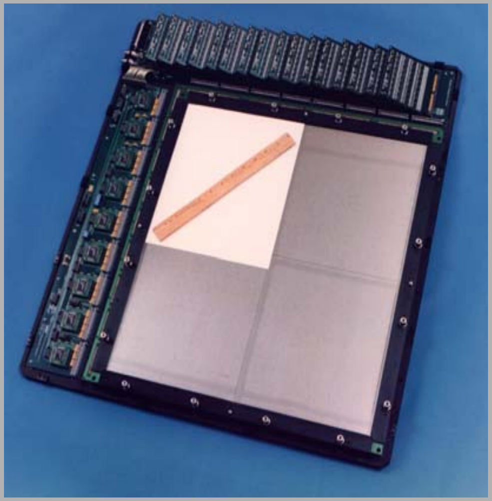
1. Detector technologies
2. Inherent image quality attributes
3. Reported exposure indicator
4. Required exposure
5. Image post-processing and appearance

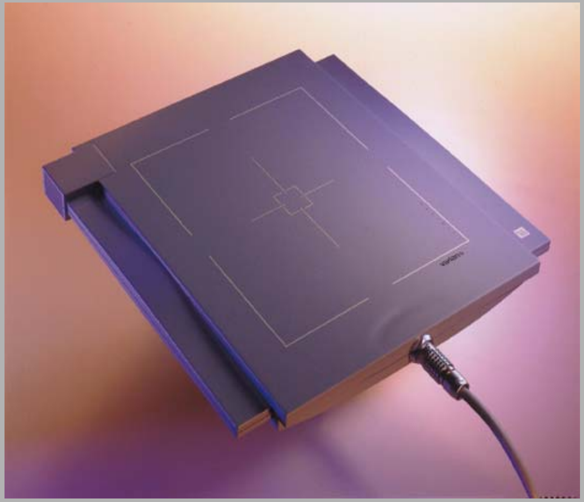
DR technologies



Computed Radiography (CR)	Indirect Flat-panel	Direct Flat-panel	CCD or CMOS-based
PSL phoshor(eg, BaFBr)	CsI or GSO phosphor	a-Se	CsI or GSO phosphor
PSL light-guide	Contact layer	None	Lens or fiber-optic taper
PSL signal digitiz.	Photo diode /TFT arrays	TFT arrays	CCD or CMOS

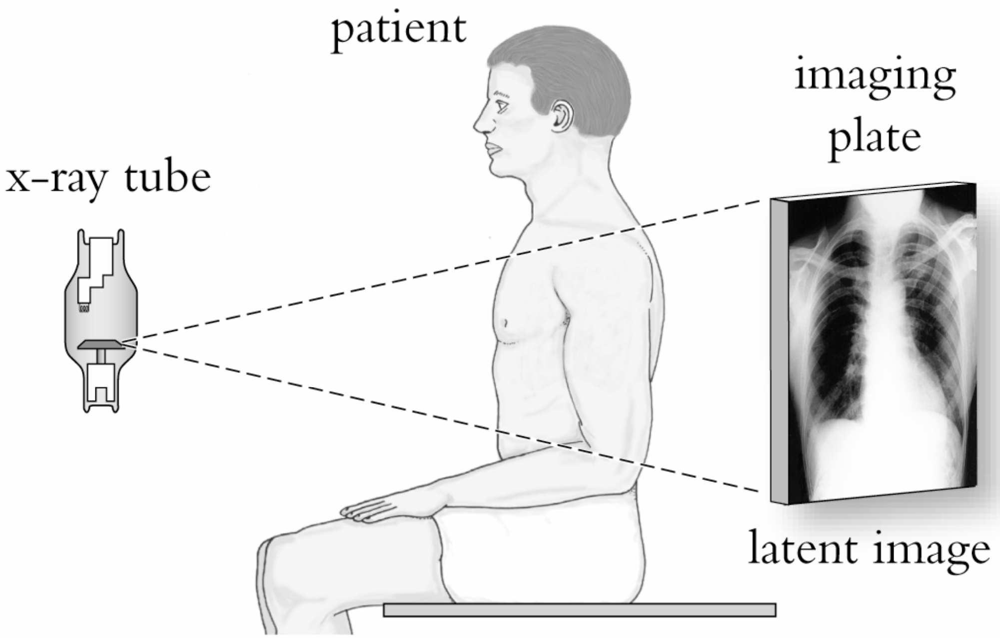
DR offerings

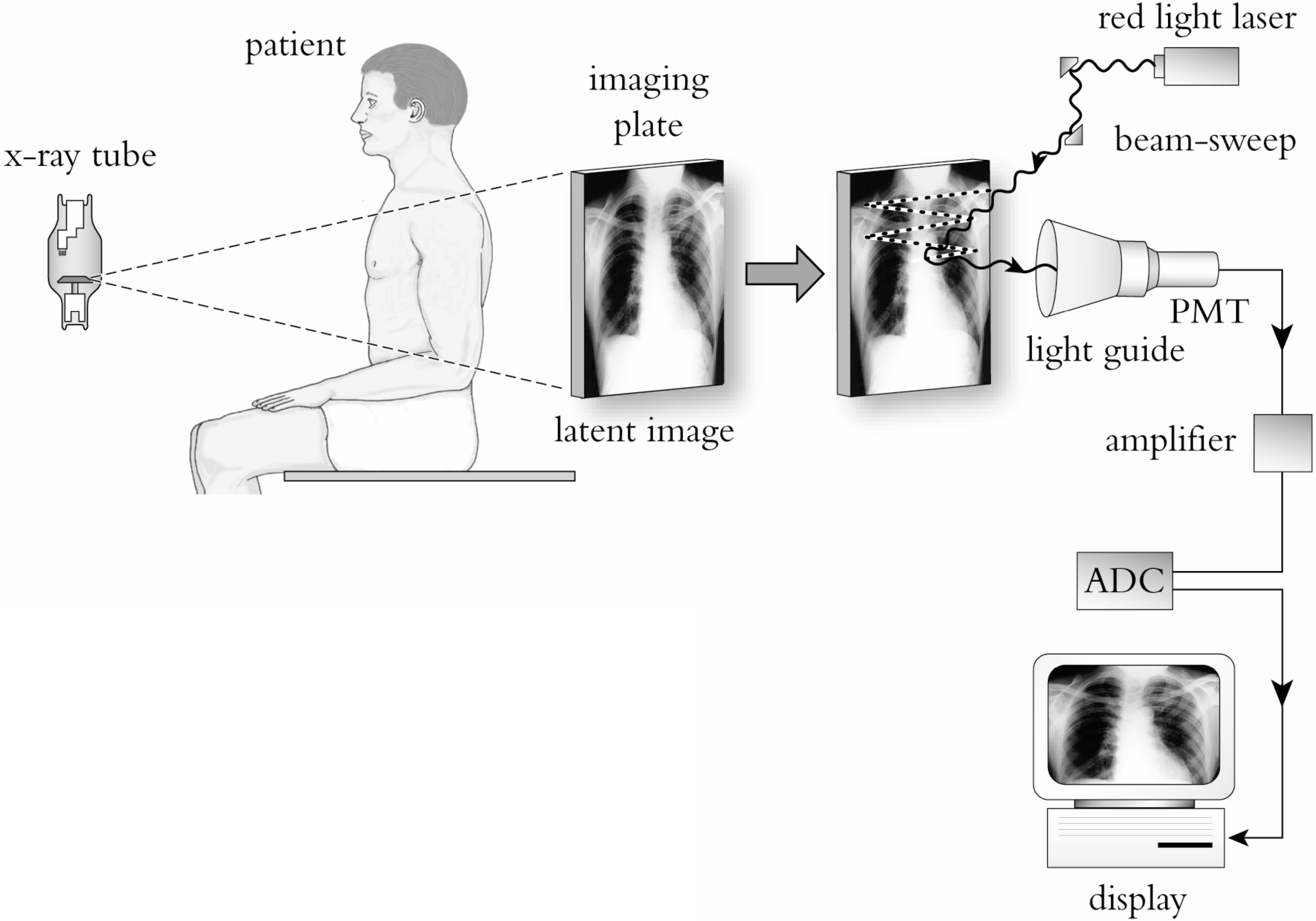


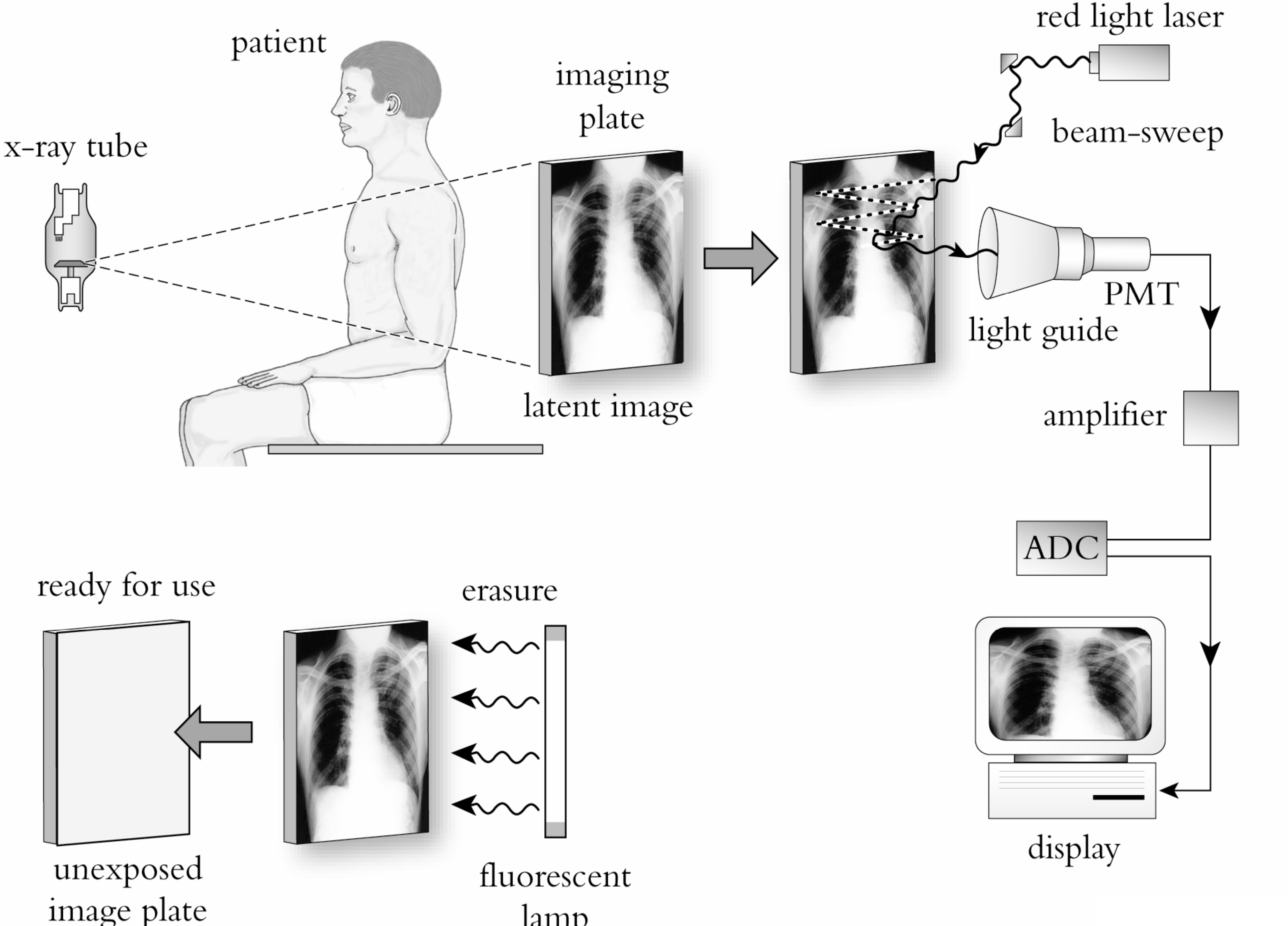


CR 101

- Invented 1975 by GW Luckey at Kodak
- First commercial unit in 1983 (Fuji FCR 101)
- Most common digital radiographic modality
- Easy retrofit and portable application
- The most economical digital option


patient
imaging
plate
x-ray tube
latent image

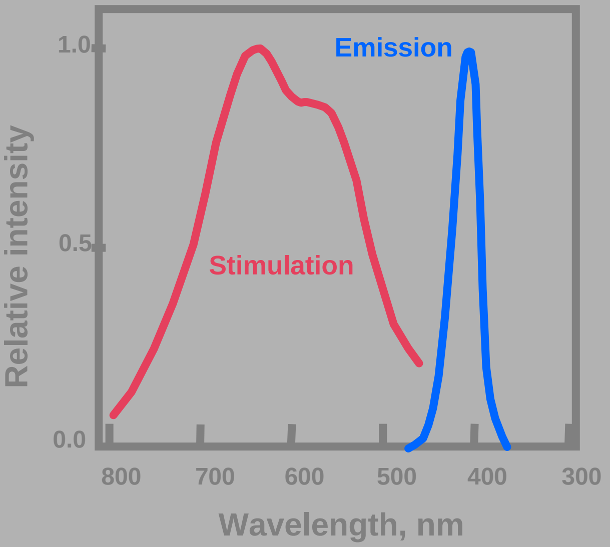

patient
imaging
plate
x-ray tube
latent image
red light laser
beam-sweep
PMT
light guide
amplifier
ADC
display


patient
x-ray tube
imaging
plate
latent image
red light laser
beam-sweep
light guide
PMT
amplifier
ADC
display
ready for use
erasure
unexposed
image plate
fluorescent
lamp

How CR Works?

Photostimulable luminescence (PSL)

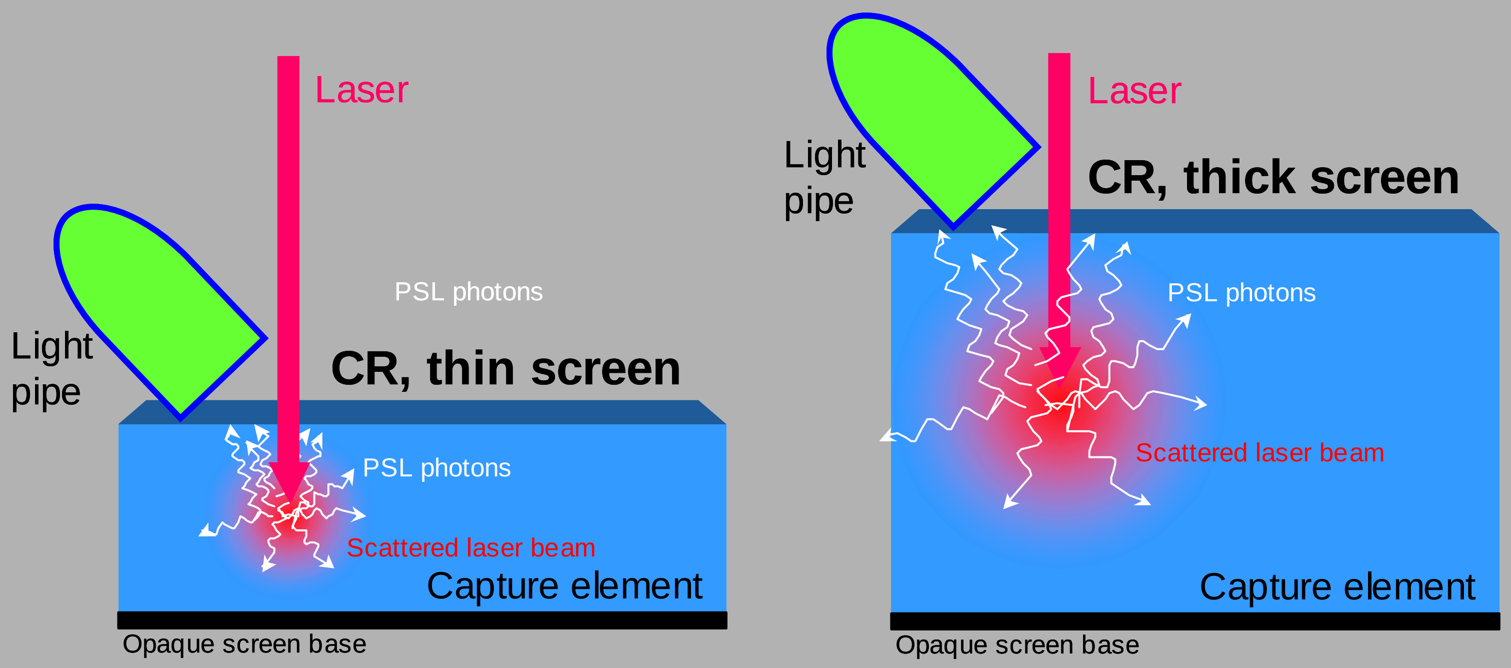
1. Phosphor excitation (by x-rays)
2. Formation of latent image
3. Stimulation by light (scanning laser)
4. Emission of light (PSL signal)
5. Light collection (PSL signal)



6. Signal digitization and image formation

CR image quality

- Inherent image quality governed by lateral spread of the laser light, and phosphor thickness



Flat-panel 101

- Technology development facilitated with advancements in TFT array fabrications for flat-panel displays
- First detectors introduced in late 90’s
- Quality and speed out-performs CR
- Cost is still the prohibitive utilization factor

Two types of flat-panel detectors

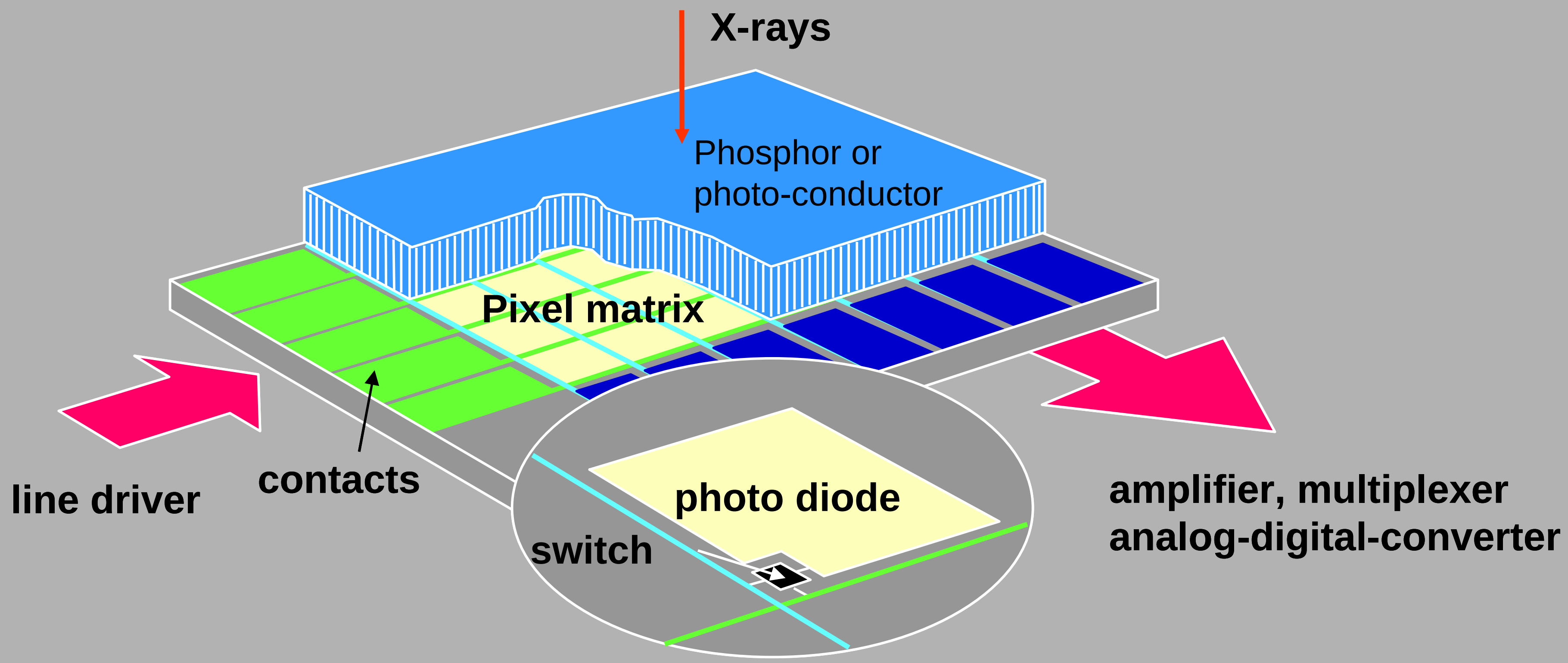
Direct:

X-ray → Detection by a photoconductor (eg, Se, PbI) → Charge collected by a a-Si array

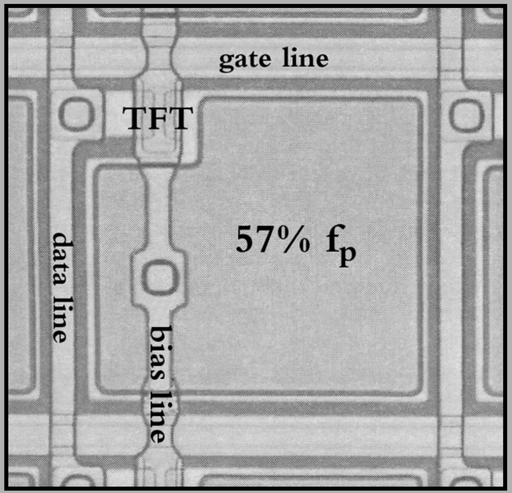
Indirect:

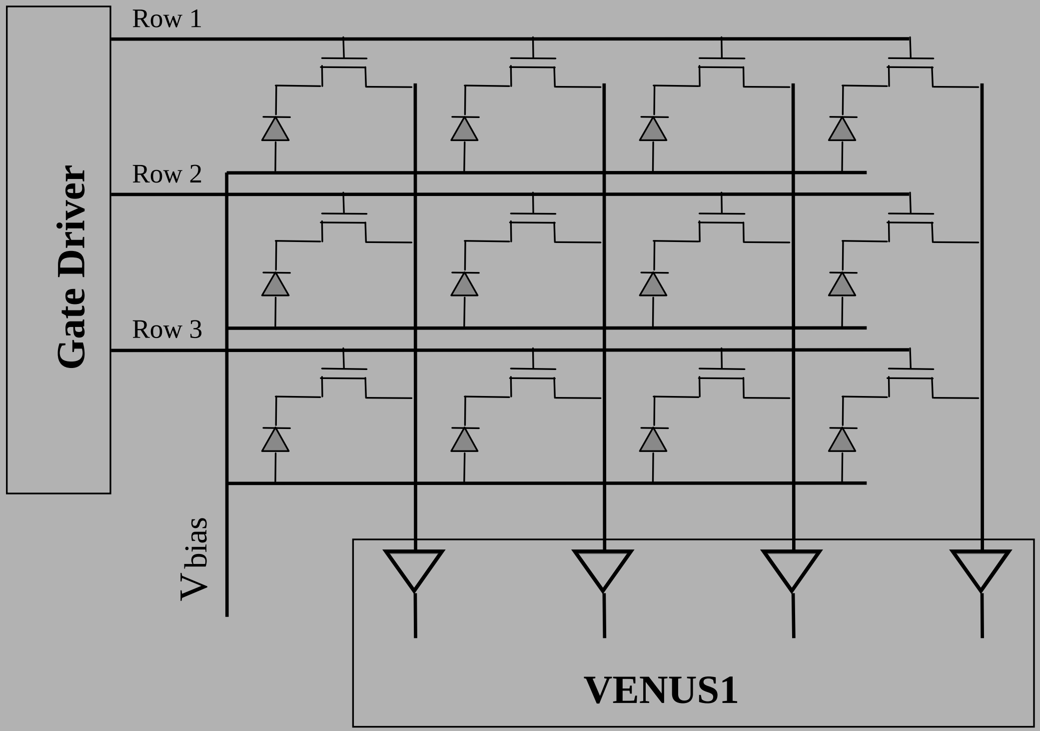
X-ray → Detection by a phosphor (eg, structured CsI) → Light collected by a a-Si array

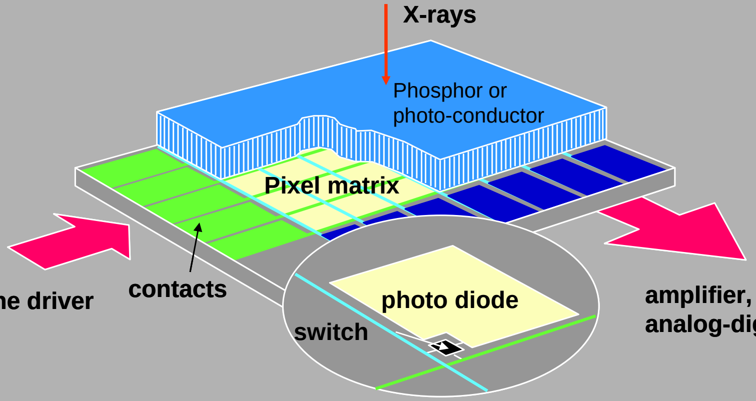
Detector structure



Detector structure





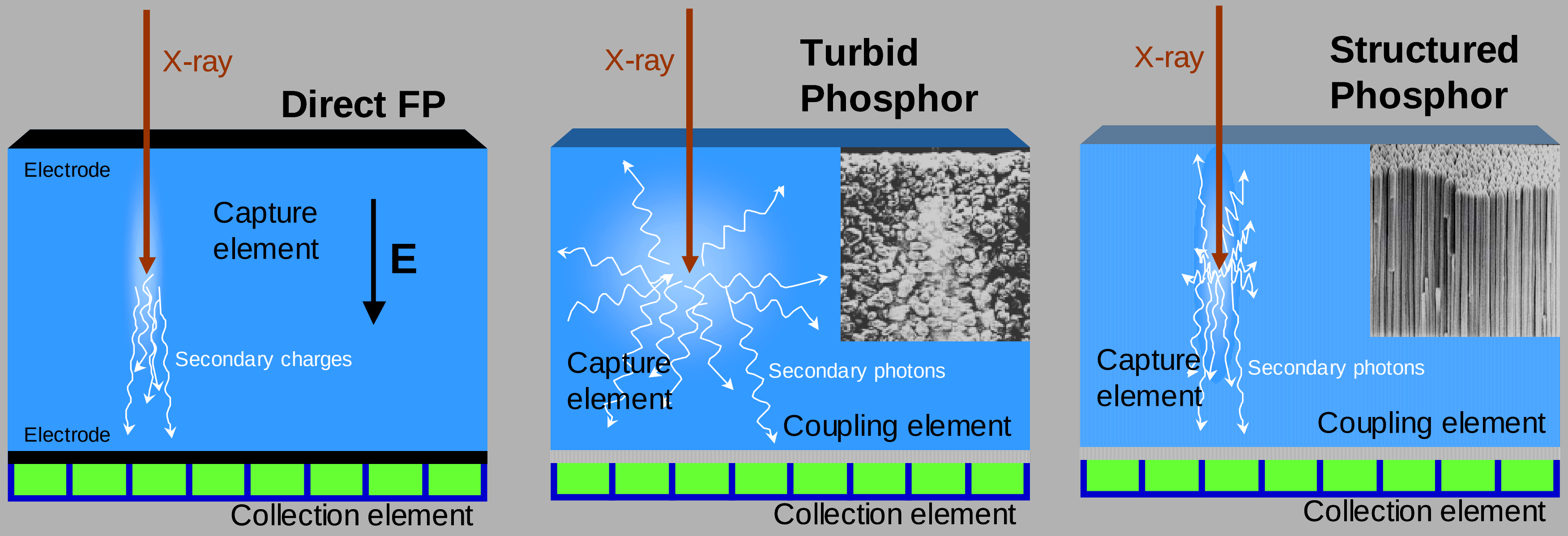


How flat-panel detectors work?

1. Pixels are formed by the photodiode/TFT elements coupled with unpixelated capture medium
2. X-ray energy conversion to charge (with intermediary light conversion for indirect detectors)
3. Charge collected in pixel capacitors
4. Pixels read line-by-line after the exposure

Flat-panel image quality

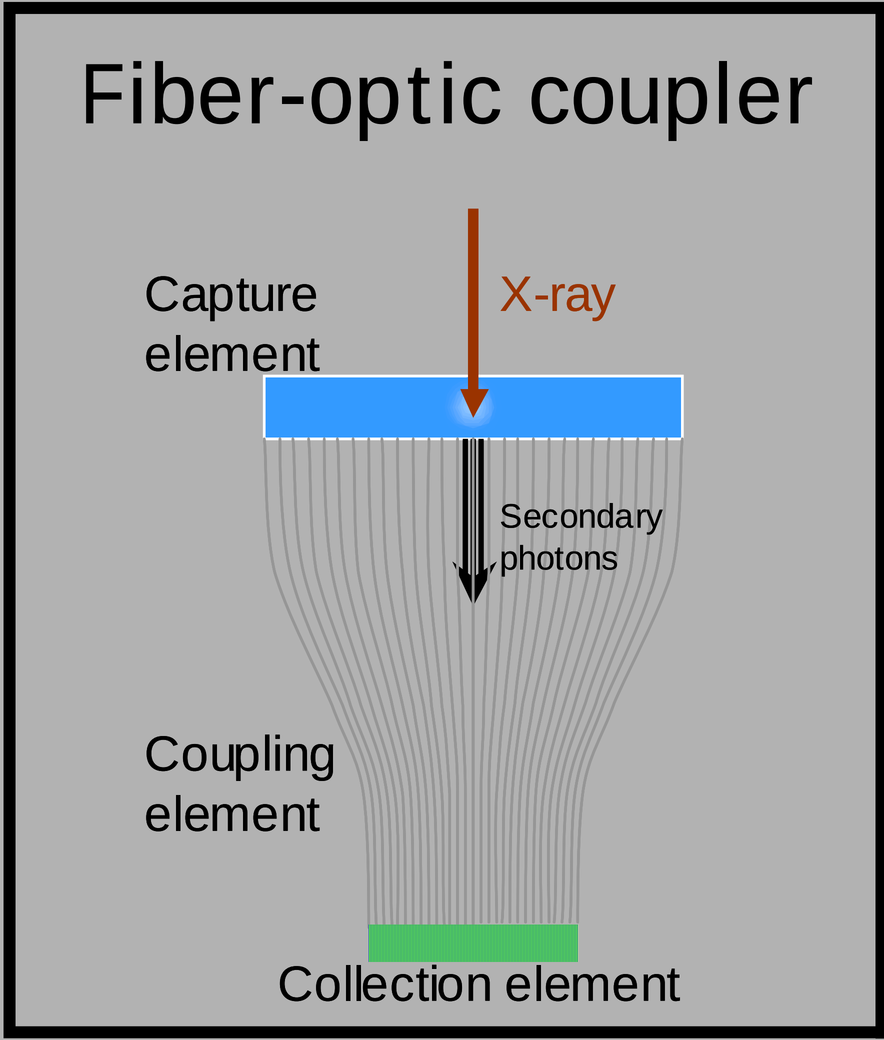
- Inherent image quality governed by lateral spread of light/charge, and phosphor/photo-conductor thickness

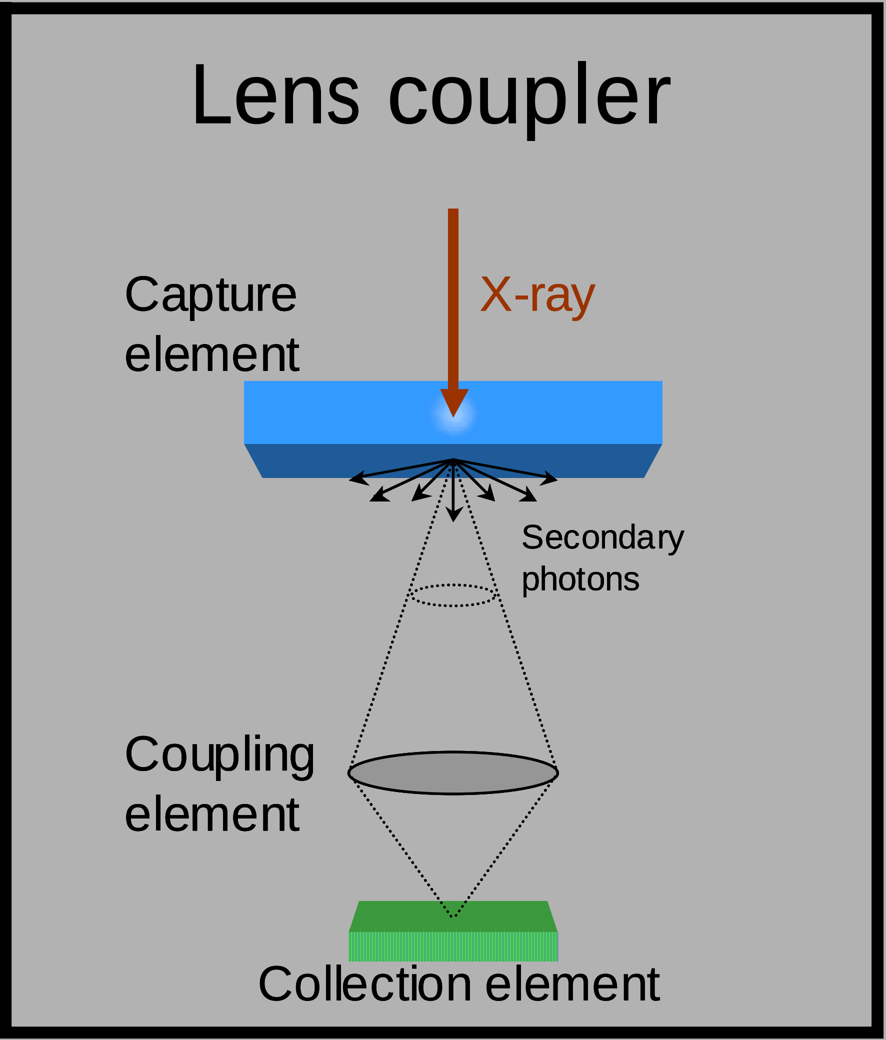


CCD/CMOS-based DR 101

- First systems introduced in 90's
- Phosphor-based
- Based on lower-cost Charged Couple Device (CCD) and Complementary metal–oxide–semiconductor (CMOS) light sensors
- Small sensor size requires demagnification
- Quality comparable to CR
- Lower-cost alternative to flat-panel DR

CCD/CMOS-based DR structure



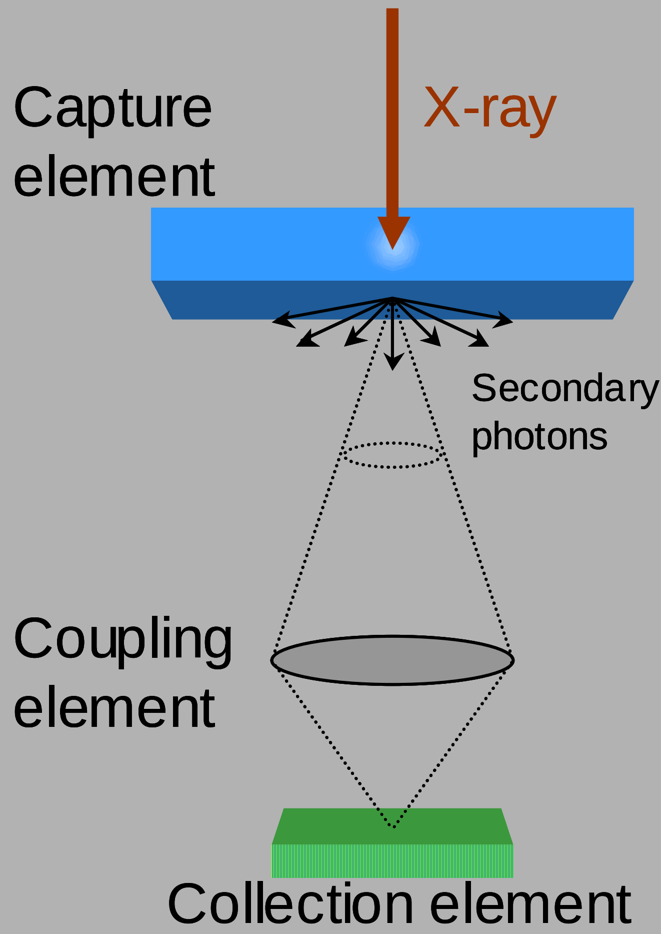


How CCD/CMOS-based DR detectors work?

1. X-ray capture by a phosphor
2. Recording the emitted light by the CCD/CMOS sensor
3. Pixels read line-by-line after the exposure

CCD/CMOS-based DR image quality

- Inherent image quality governed by lateral spread of light, phosphor thickness, and loss of light ("quantum sink")

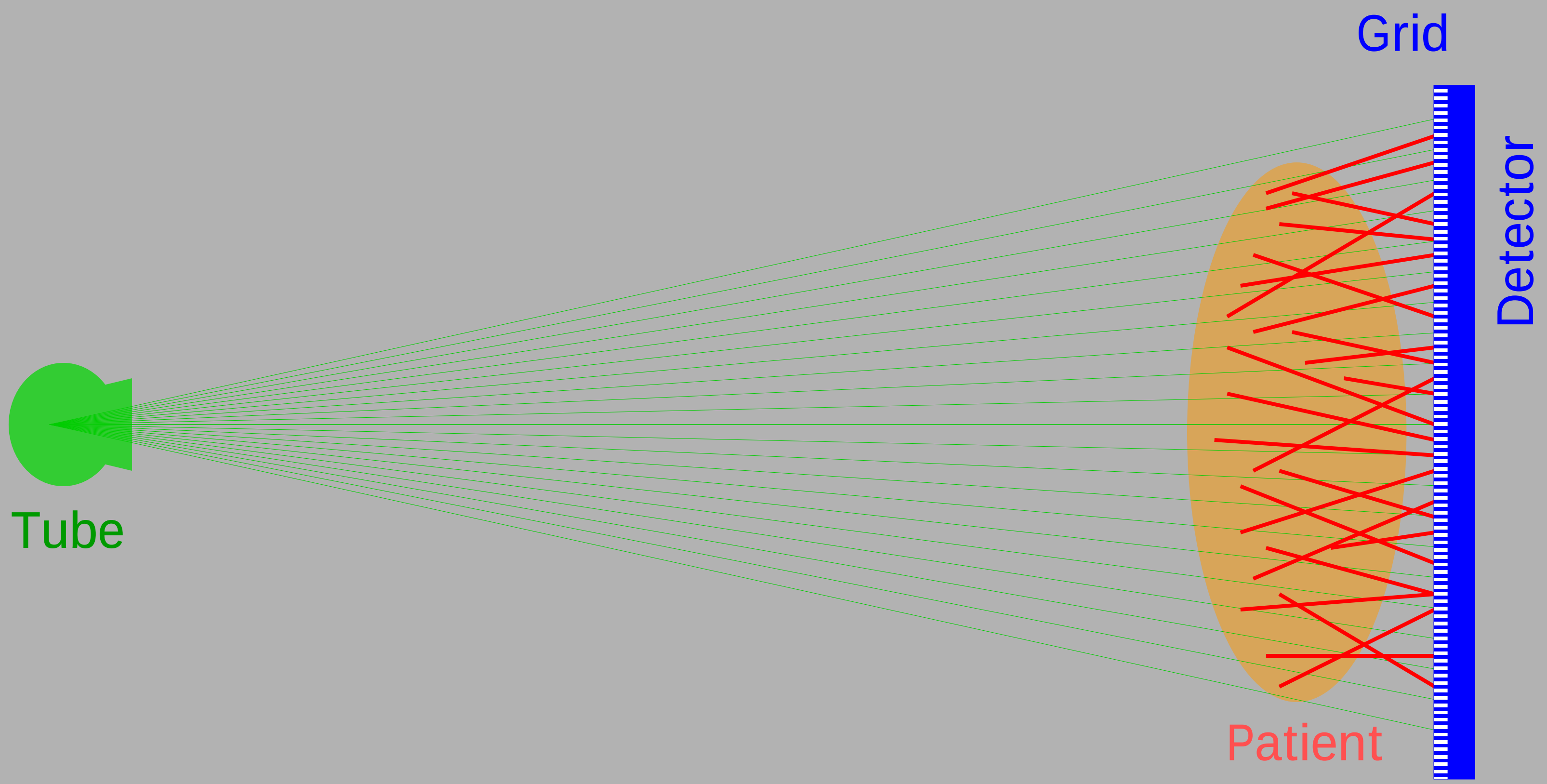


Effect of scatter

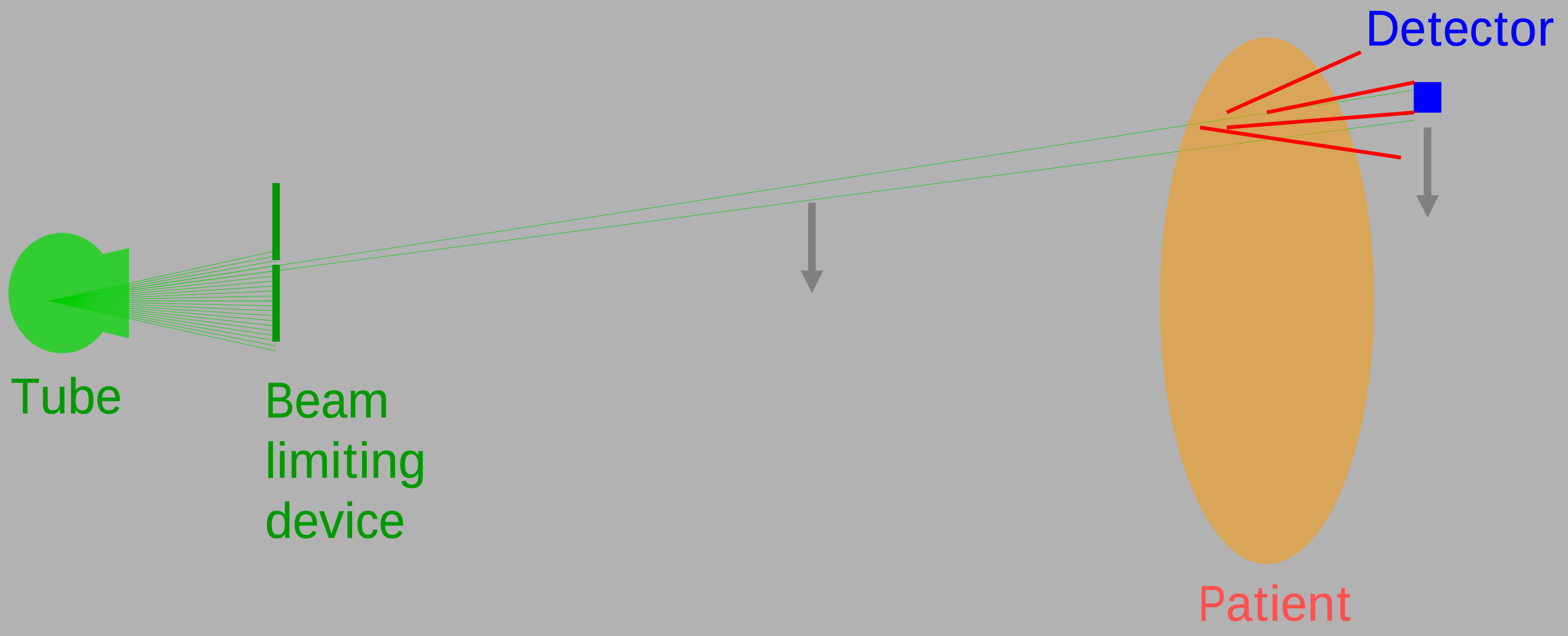
- An ever present attribute of chest radiography (analog AND digital)
  - Scatter Fraction: 60-90%
  - Scatter Fraction: 40-70% with grid
- Reduces image quality
  - **Reduces SNR^2/dose by 2.5-5 times!**

Samei et al, *Med Phys*, Sept 2004; Boyce and Samei, *Med Phys*, April 2006.

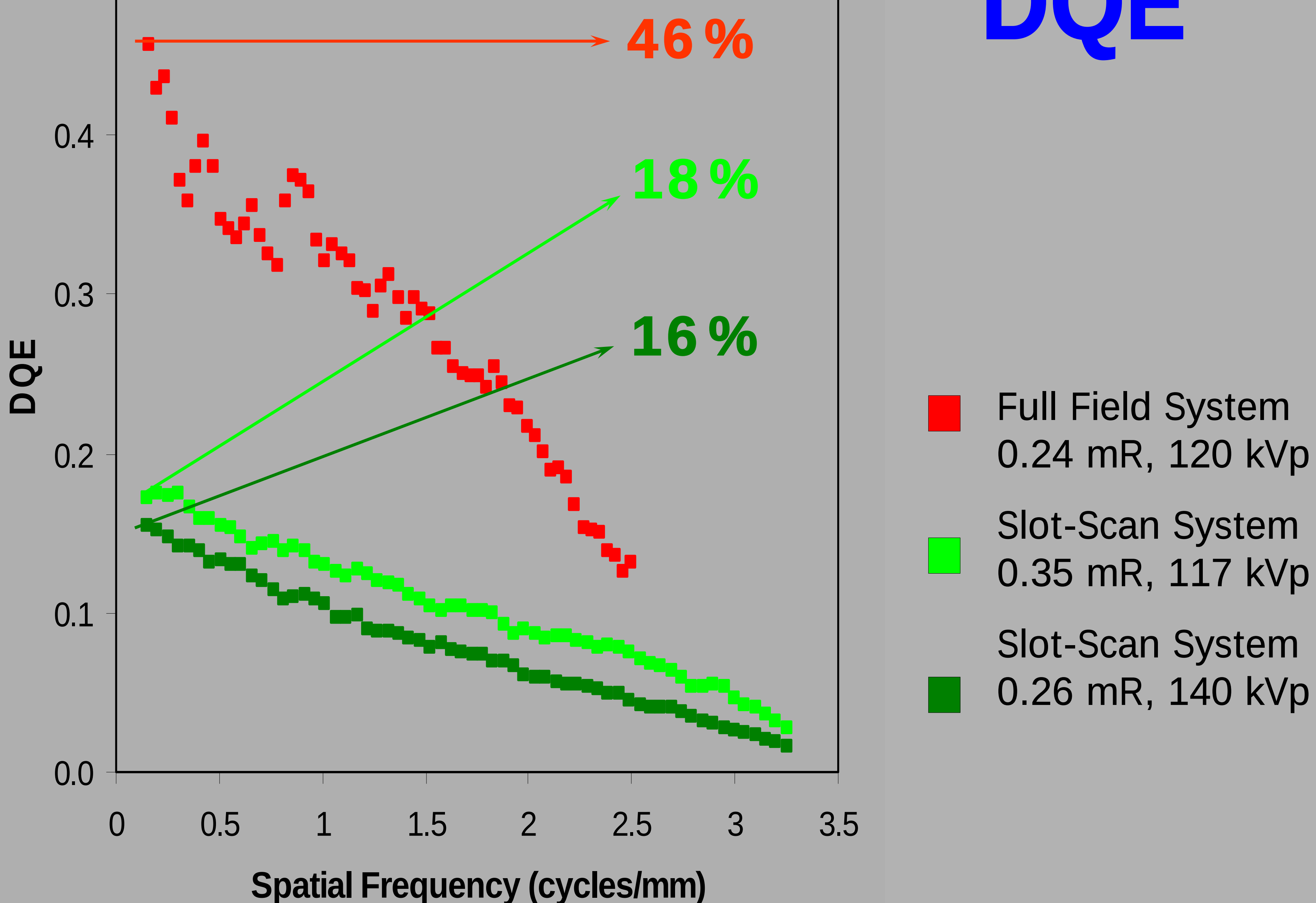
Full-field DR



Slot-scan DR

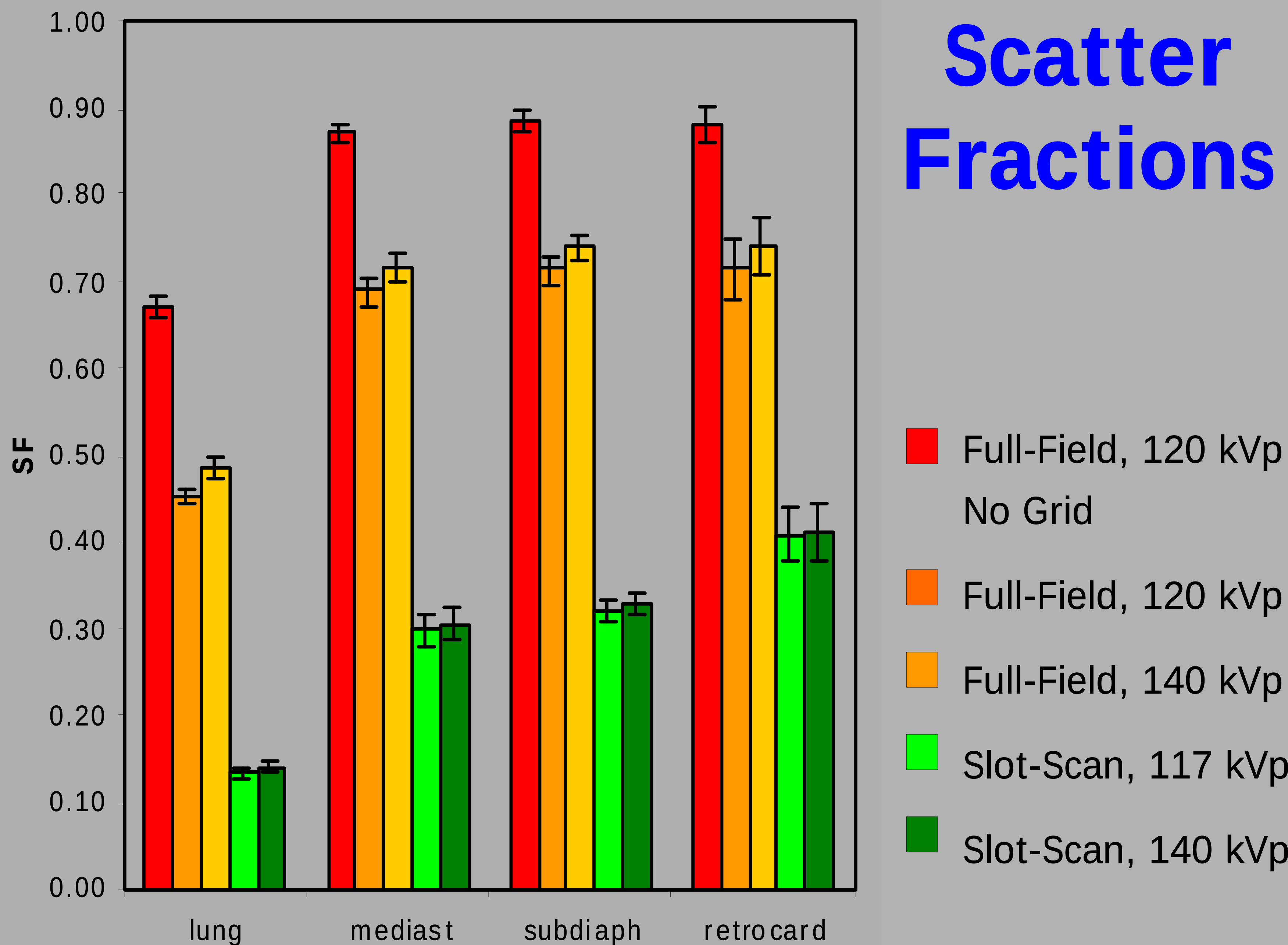


DQE

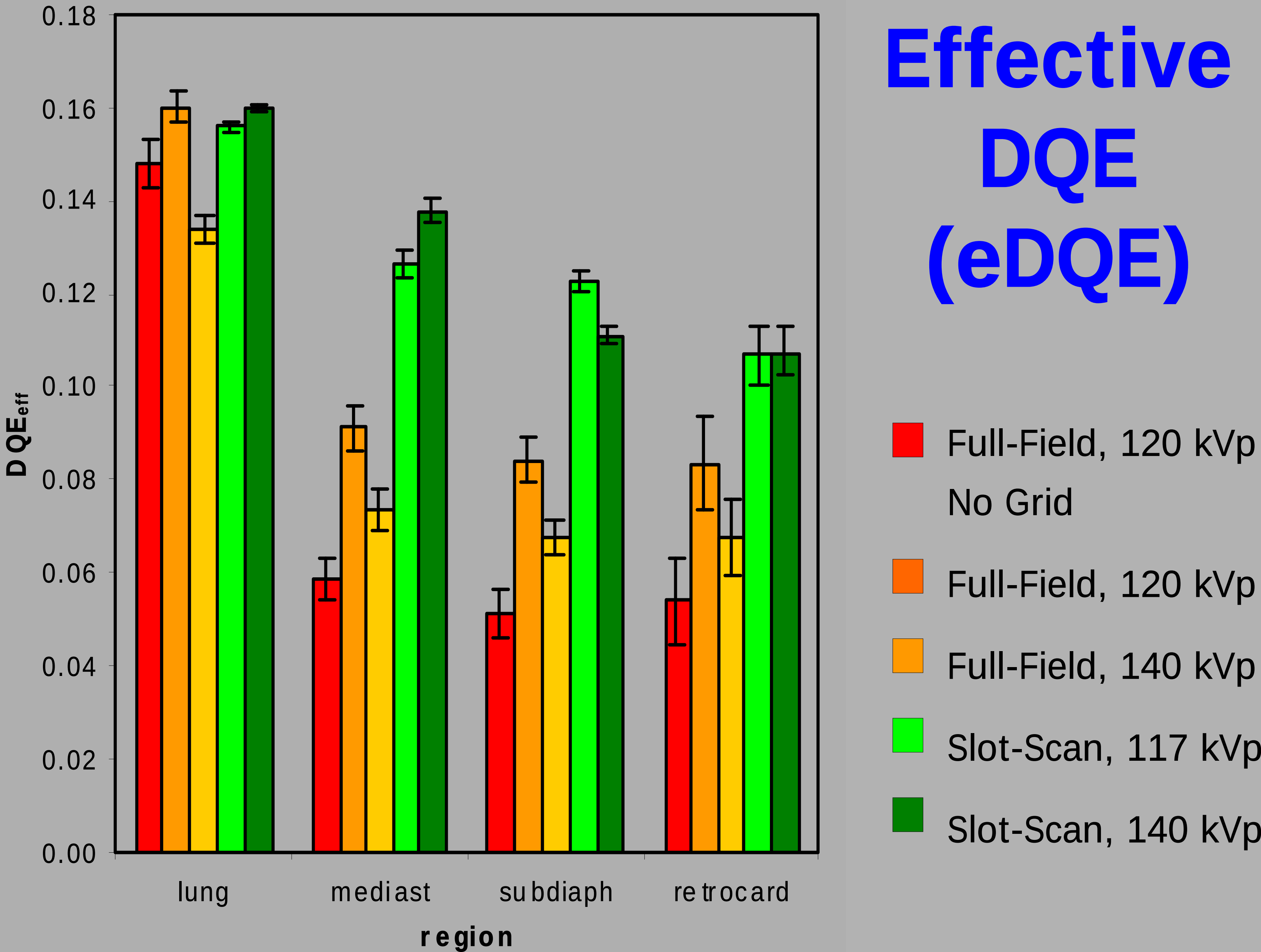


46 %
18 %
16 %
0.5
0.4
0.3
0.2
0.1
0.0
DQE
0
0.5
1
1.5
2
2.5
3
3.5
Spatial Frequency (cycles/mm)
Full Field System
0.24 mR, 120 kVp
Slot-Scan System
0.35 mR, 117 kVp
Slot-Scan System
0.26 mR, 140 kVp

Scatter Fractions

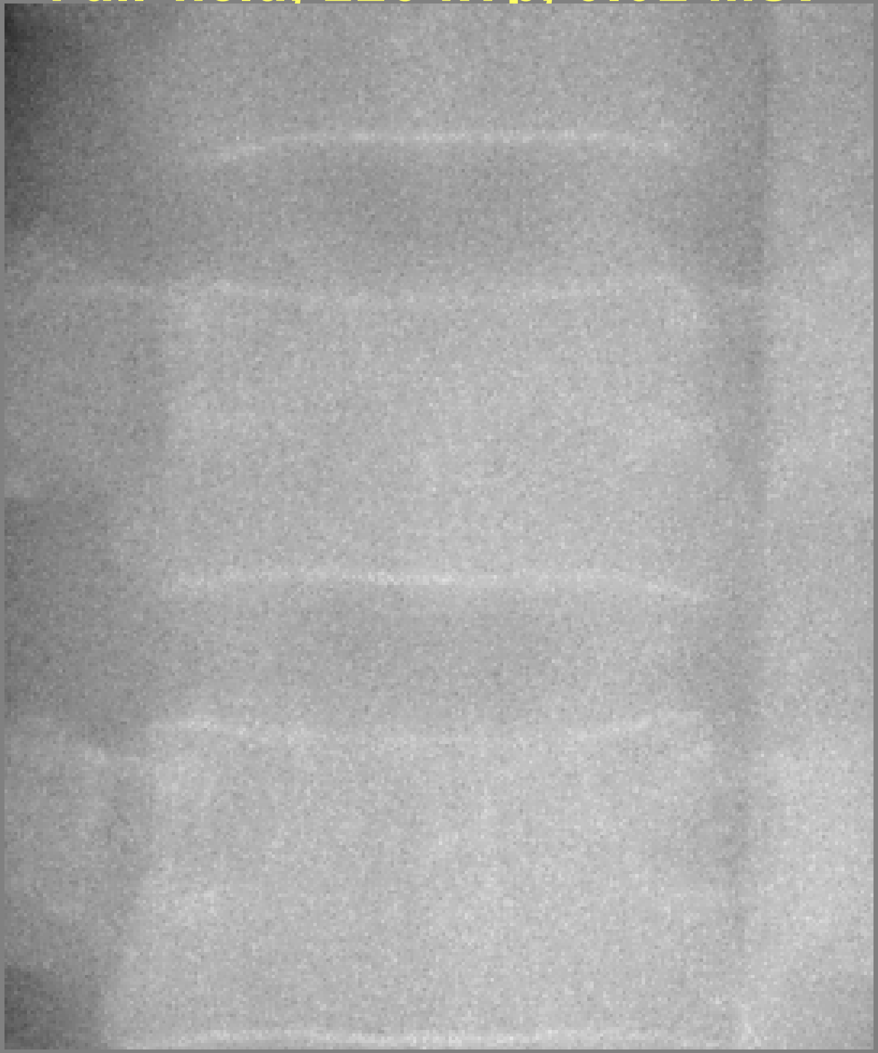


Effective DQE (eDQE)

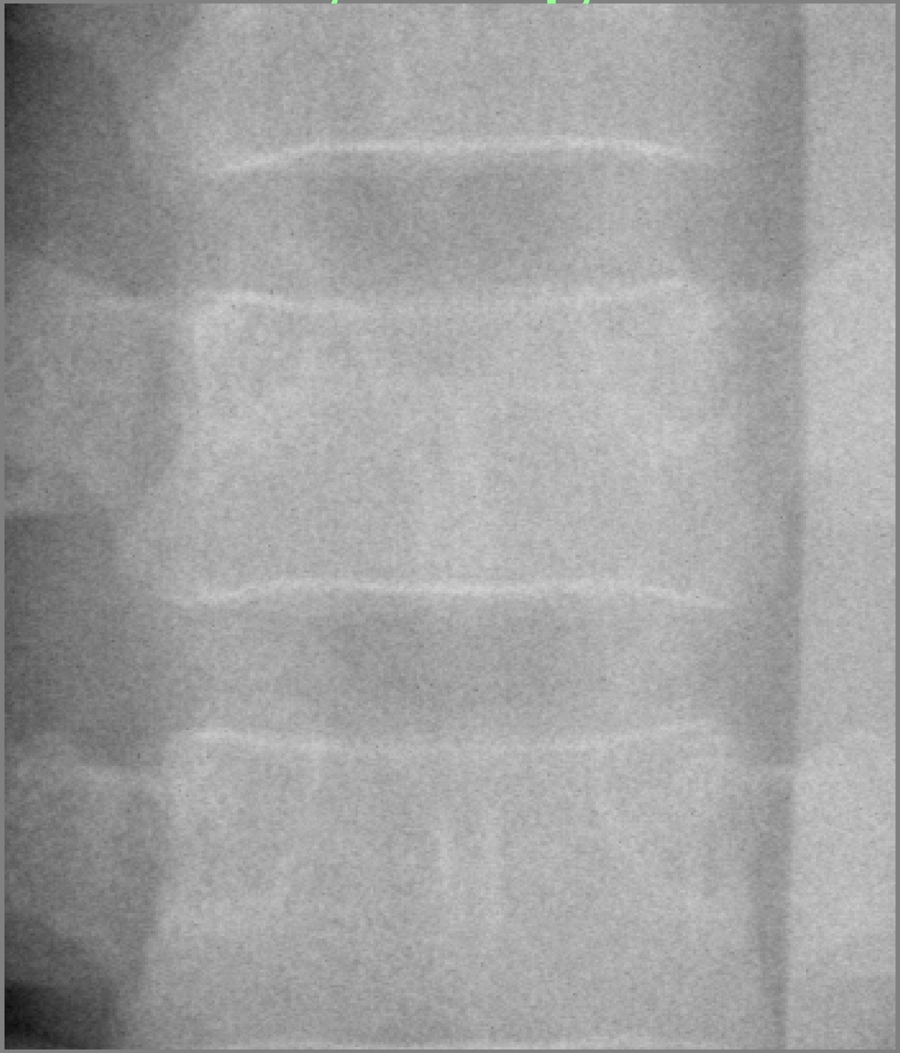


Demonstration

Full-field, 120 kVp, 0.02 mSv



Slot-scan, 140 kVp, 0.02 mSv



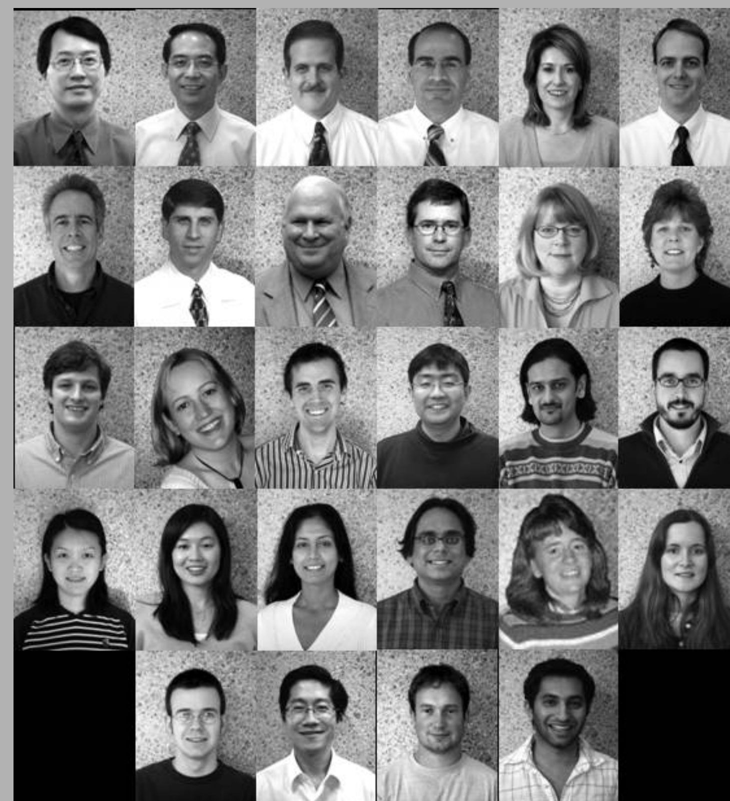
Conclusions

- Digital radiography offers distinct advantages
- Current commercial offerings represent differing technologies with differing image quality attributes
- An initiative involving diverse systems needs to
  - take their similarities and differences into consideration
  - employ controlled unifying conditions

Recommendations

- Standardized image acquisition and processing protocols
- Robust quality control and preventative maintenance programs
- Facility and equipment accreditation programs

Thank you for your attention



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