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HAMAD DARWISH
KBR PART ONE PHYSICS SYLLABUS
PROJECTION IMAGING

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TOPICS
X-RAY TUBE
X-RAY BEAM
EXPOSURE FACTORS
DIGITAL RADIOGRAPHY
IMAGE QUALITY
IMAGE EVALUATION
KBR PART ONE PHYSICS SYLLABUS
PROJECTION IMAGING

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TOPICS
X-RAY TUBE
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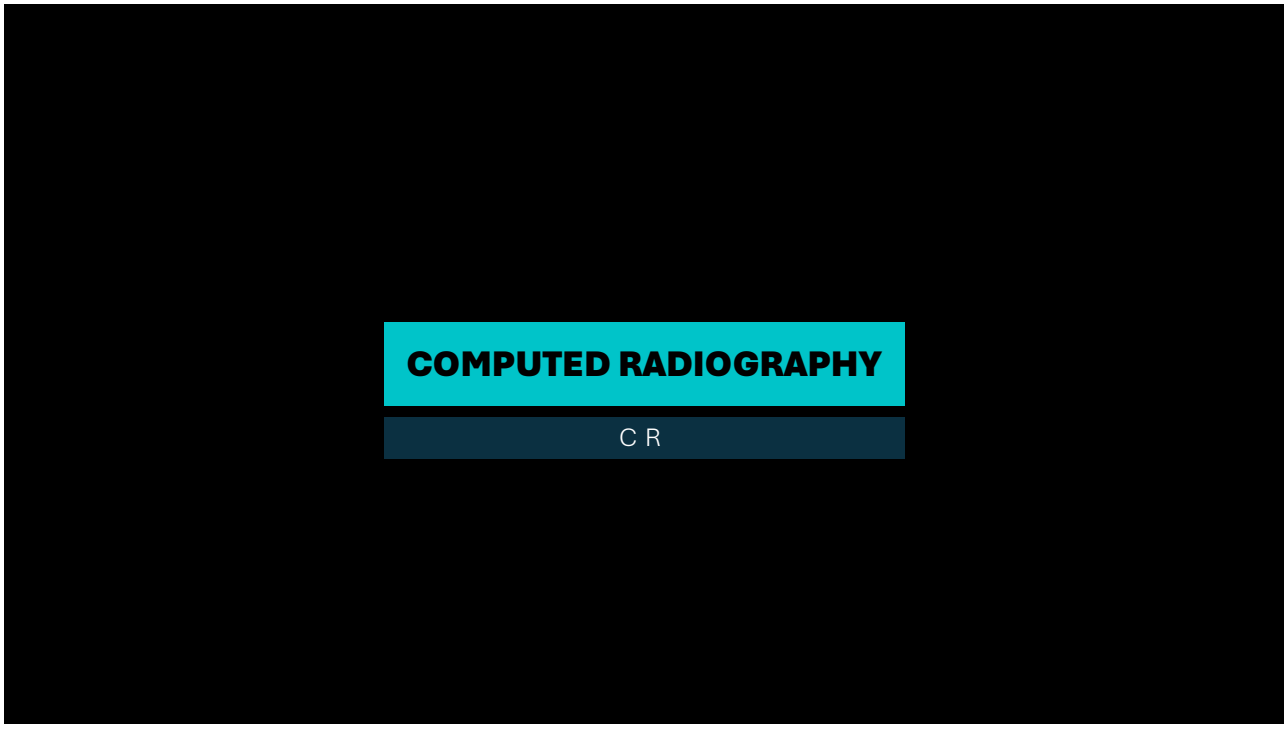
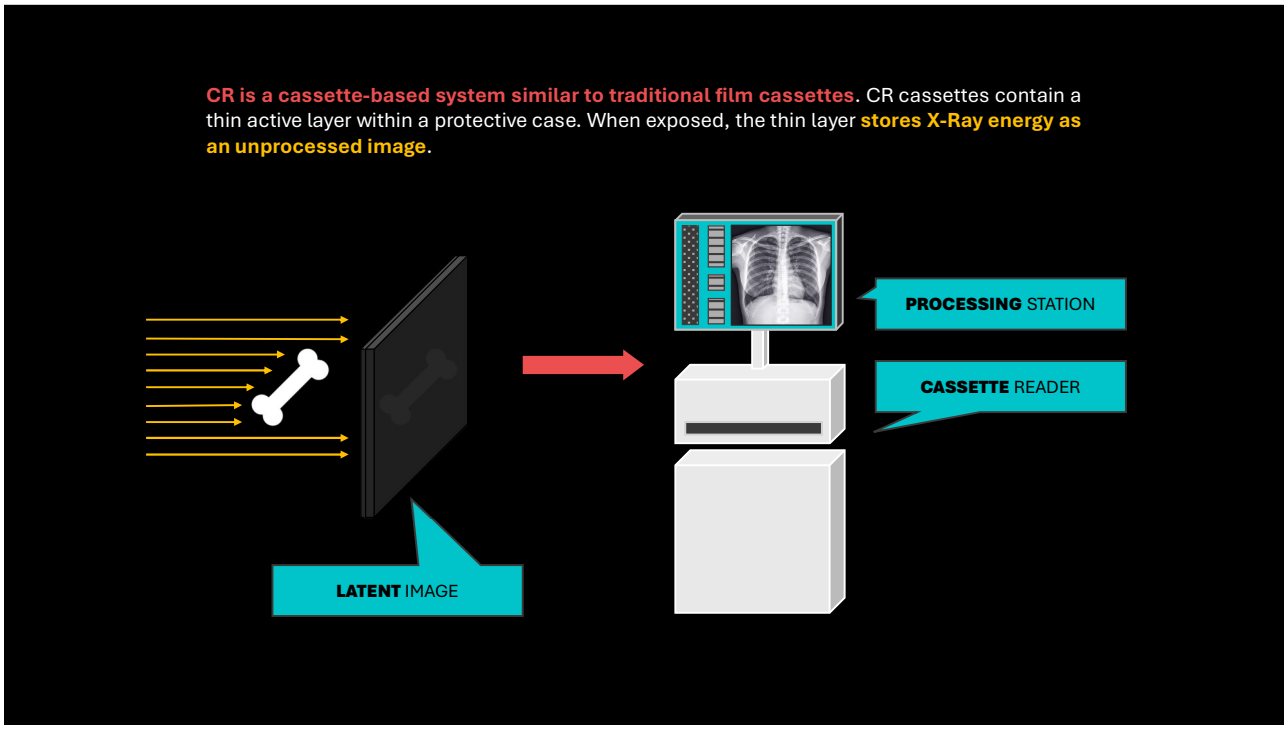
KBR PART ONE PHYSICS SYLLABUS
PROJECTION IMAGING

146

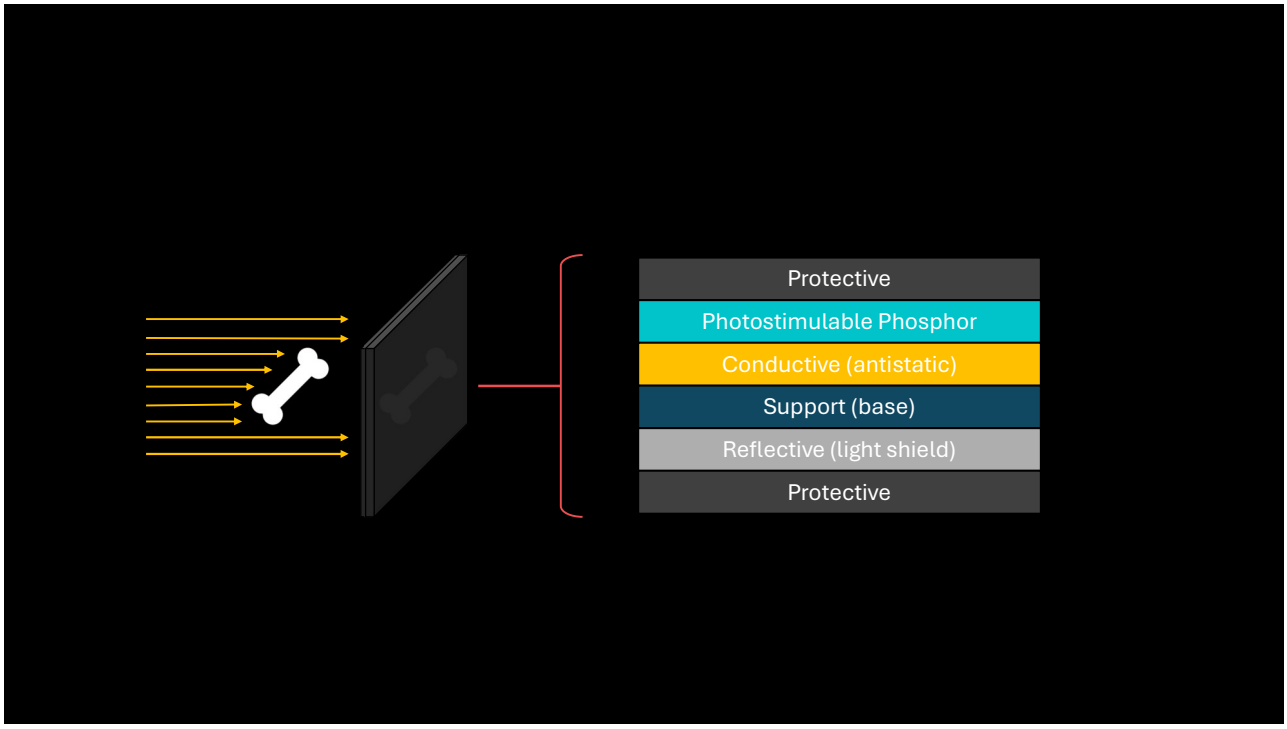
147



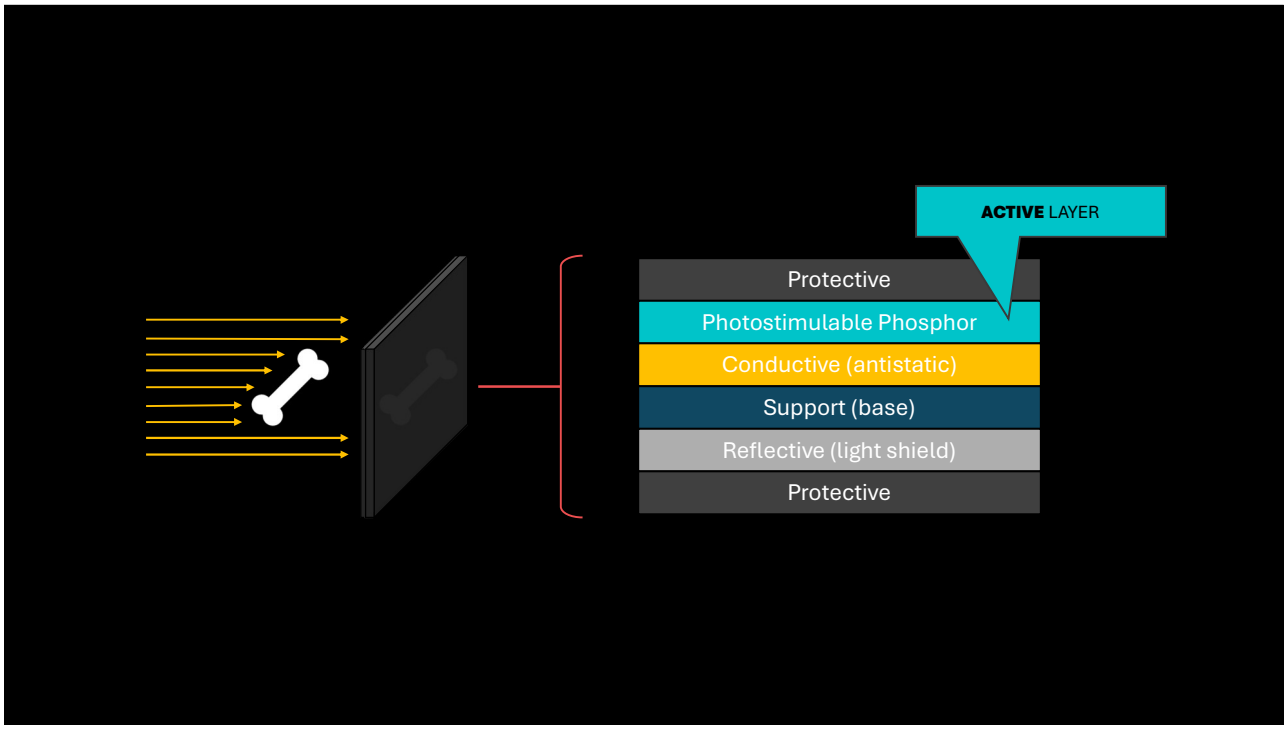
148


CR is a cassette-based system similar to traditional film cassettes. CR cassettes contain a thin active layer within a protective case. When exposed, the thin layer stores X-Ray energy as an unprocessed image.
PROCESSING STATION
CASSETTE READER
LATENT IMAGE

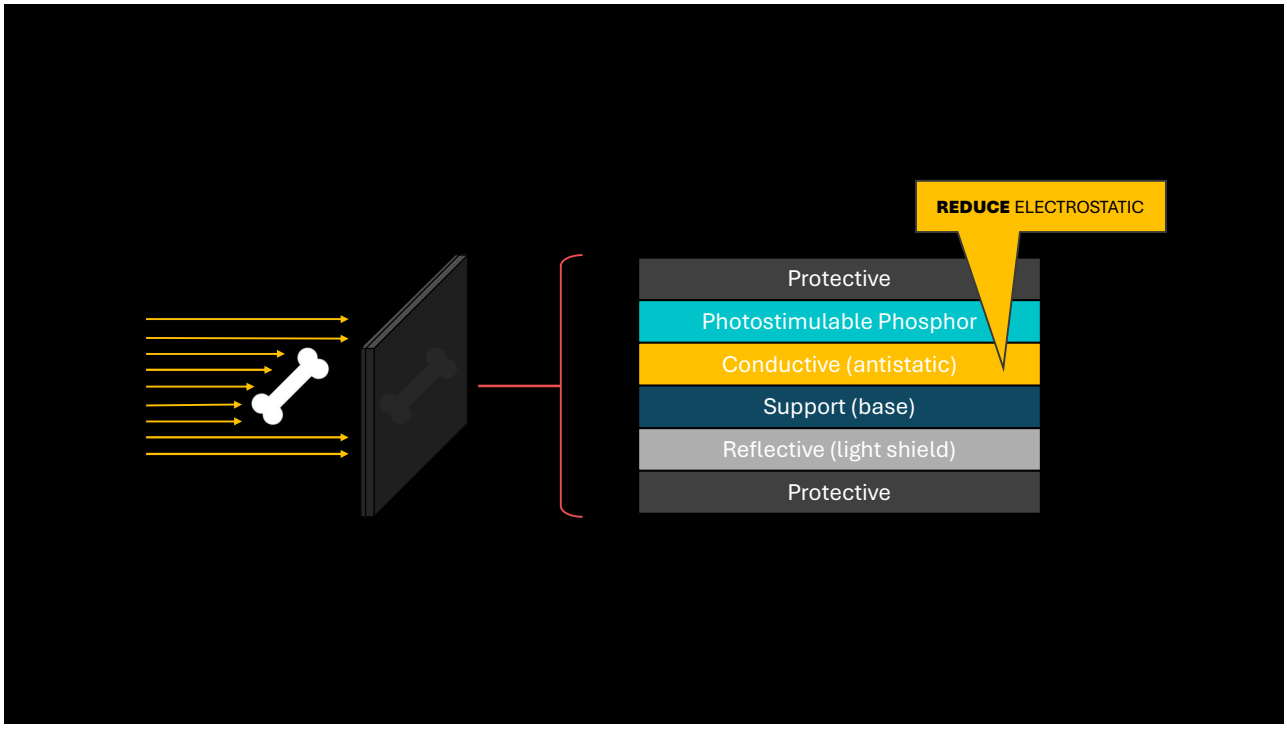
149


Protective
Photostimulable Phosphor
Conductive (antistatic)
Support (base)
Reflective (light shield)
Protective

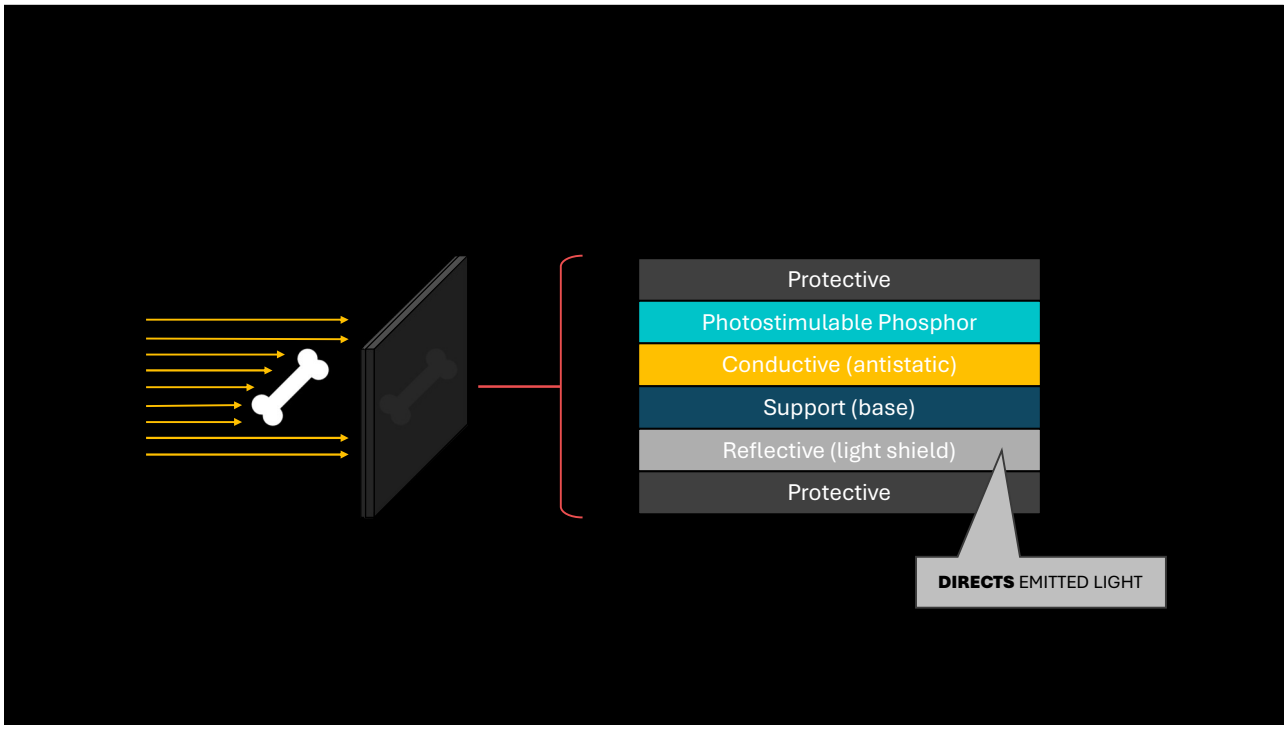
150


ACTIVE LAYER
Protective
Photostimulable Phosphor
Conductive (antistatic)
Support (base)
Reflective (light shield)
Protective

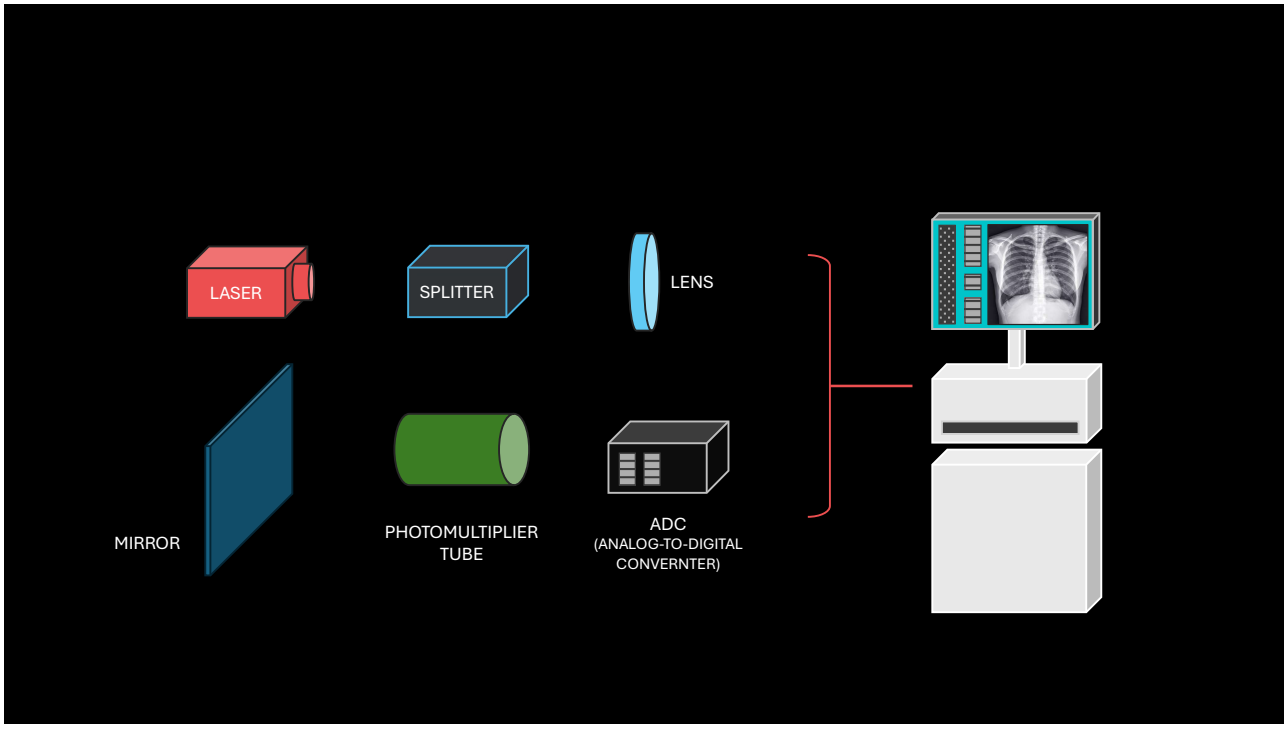
151


REDUCE ELECTROSTATIC
Protective
Photostimulable Phosphor
Conductive (antistatic)
Support (base)
Reflective (light shield)
Protective

152


Protective
Photostimulable Phosphor
Conductive (antistatic)
Support (base)
Reflective (light shield)
Protective
DIRECTS EMITTED LIGHT

153


LASER
SPLITTER
LENS
MIRROR
PHOTOMULTIPLIER TUBE
ADC (ANALOG-TO-DIGITAL CONVERNTER)

154

DIGITAL RADIOGRAPHY

D R

155

CR

COMPUTED RADIOGRAPHY (CR)

- Uses cassettes and cassette readers
- Image processed manually by the user
- Slower process
- Lower quality images

DR

DIGITAL RADIOGRAPHY (DR)

→ DIRECT
→ INDIRECT

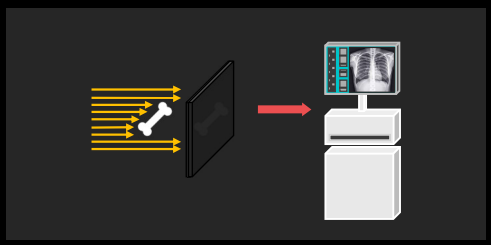
- Does not use cassettes or cassette readers
- Image processed automatically
- Faster process
- Higher quality images

156

CR

COMPUTED RADIOGRAPHY (CR)

- Uses cassettes and cassette readers
- Image processed manually by the user
- Slower process
- Lower quality images



DR

DIGITAL RADIOGRAPHY (DR)

→ DIRECT
→ INDIRECT

- Does not use cassettes or cassette readers
- Image processed automatically
- Faster process
- Higher quality images

157

CR

COMPUTED RADIOGRAPHY (CR)

- Uses cassettes and cassette readers
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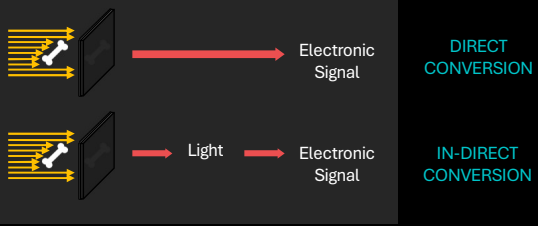
DR

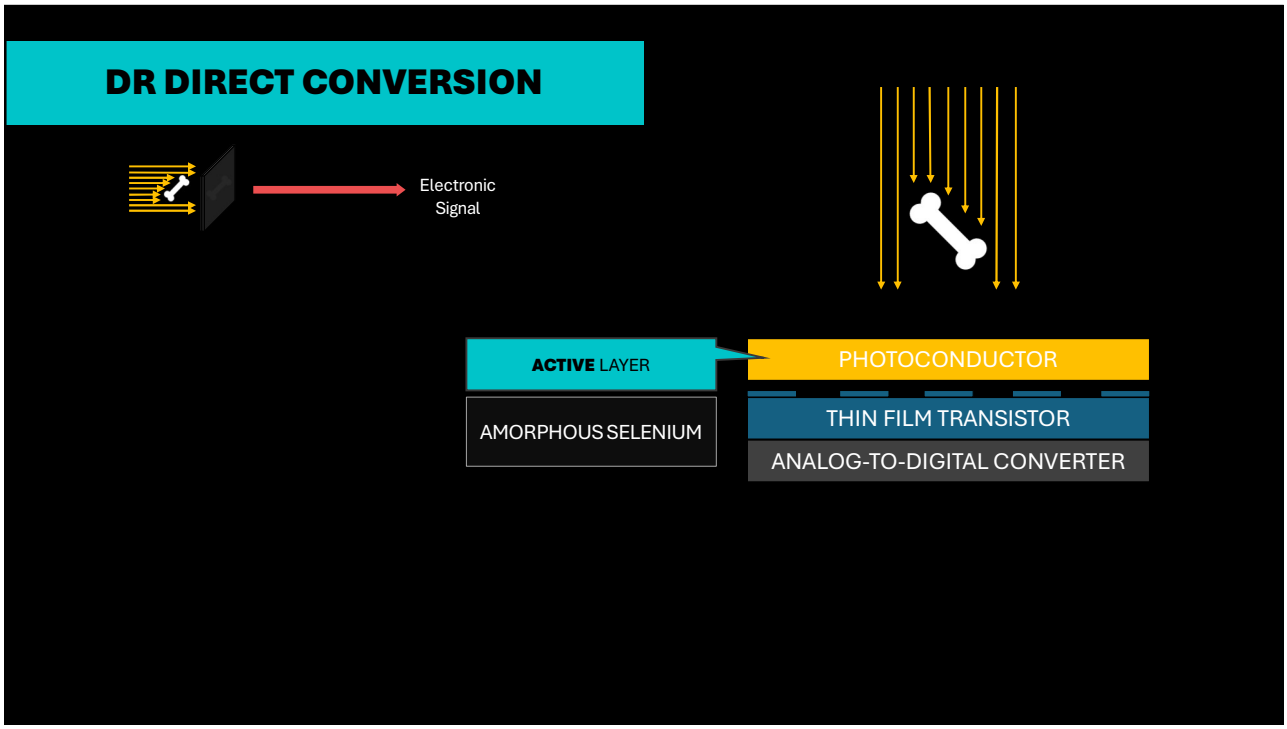
DIGITAL RADIOGRAPHY (DR)

→ DIRECT
→ INDIRECT

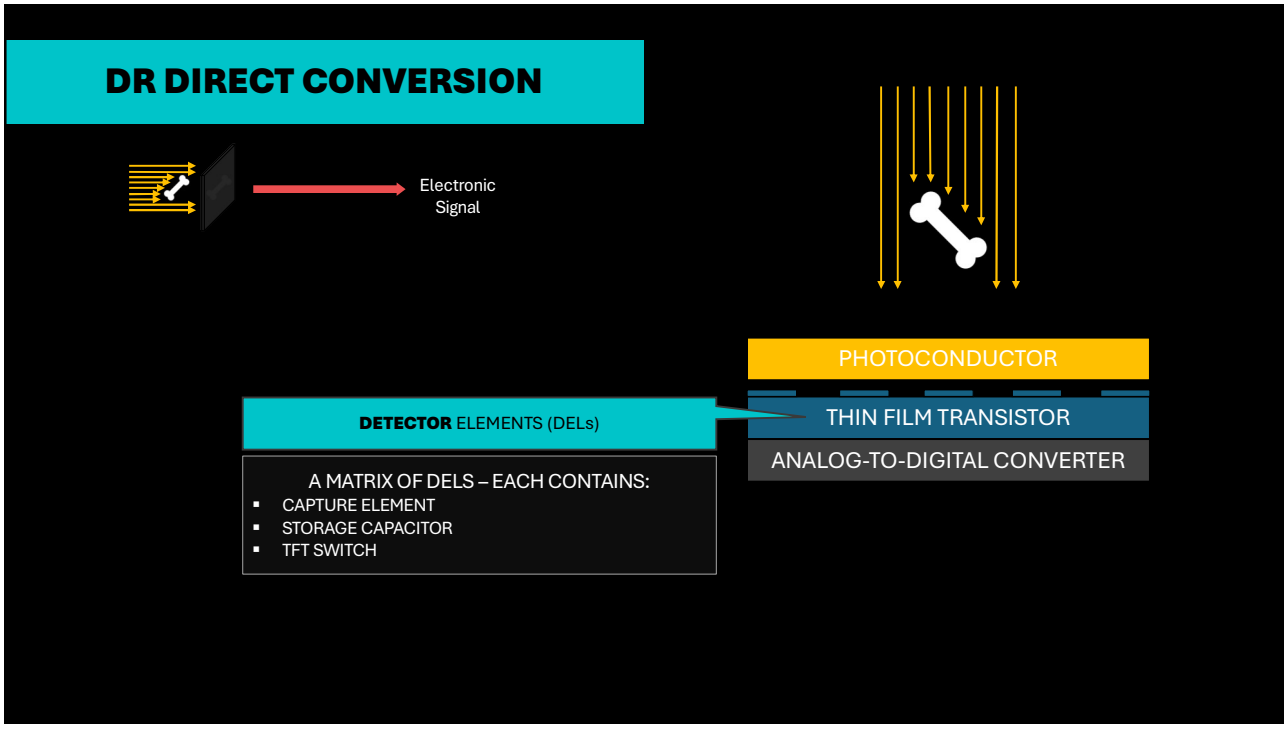
- Does not use cassettes or cassette readers
- Image processed automatically
- Faster process
- Higher quality images



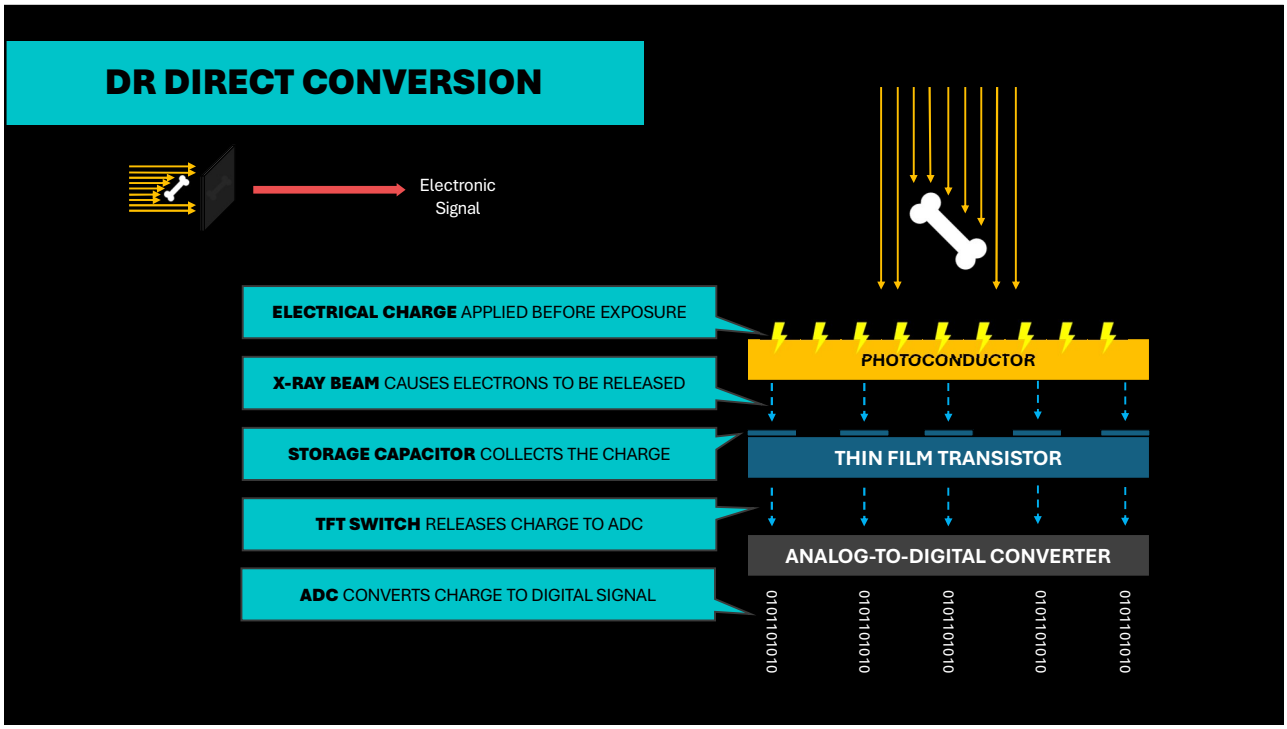
158


DR DIRECT CONVERSION
Electronic Signal
ACTIVE LAYER
AMORPHOUS SELENIUM
PHOTOCONDUCTOR
THIN FILM TRANSISTOR
ANALOG-TO-DIGITAL CONVERTER

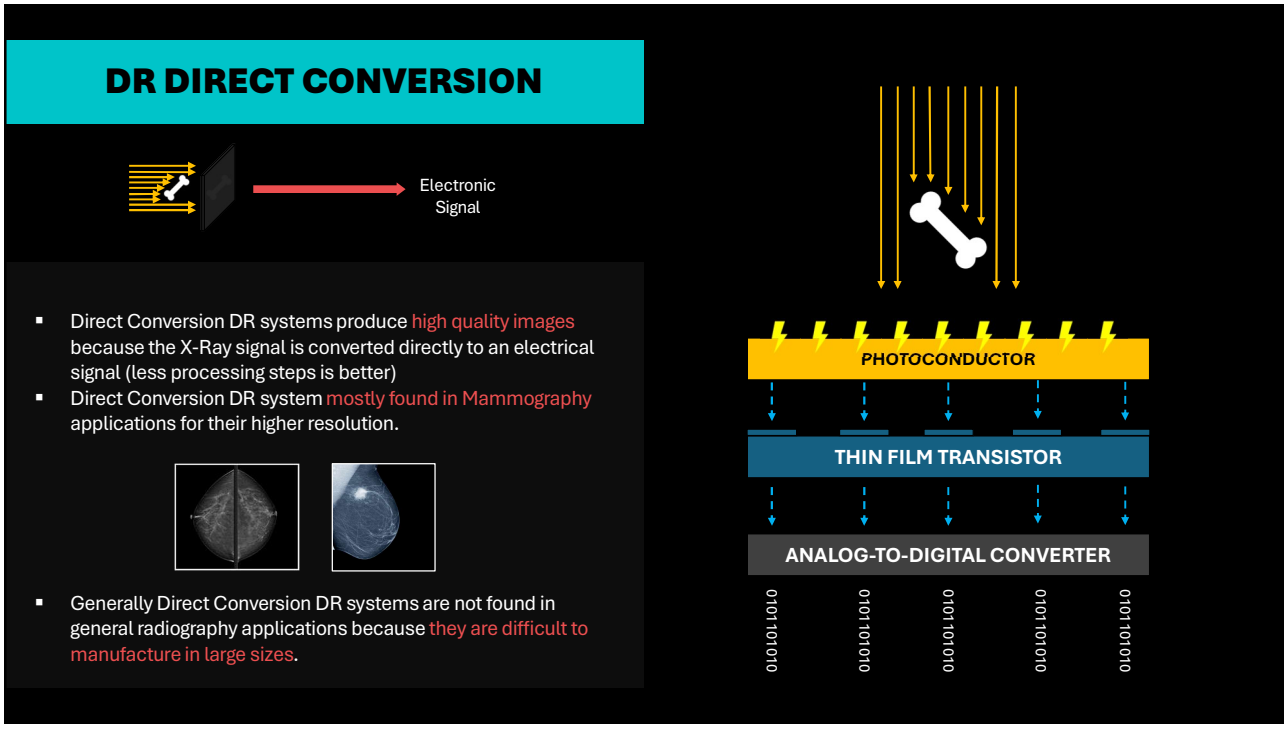
159


DR DIRECT CONVERSION
Electronic Signal
DETECTOR ELEMENTS (DELs)
A MATRIX OF DELS – EACH CONTAINS:
CAPTURE ELEMENT
STORAGE CAPACITOR
TFT SWITCH
PHOTOCONDUCTOR
THIN FILM TRANSISTOR
ANALOG-TO-DIGITAL CONVERTER

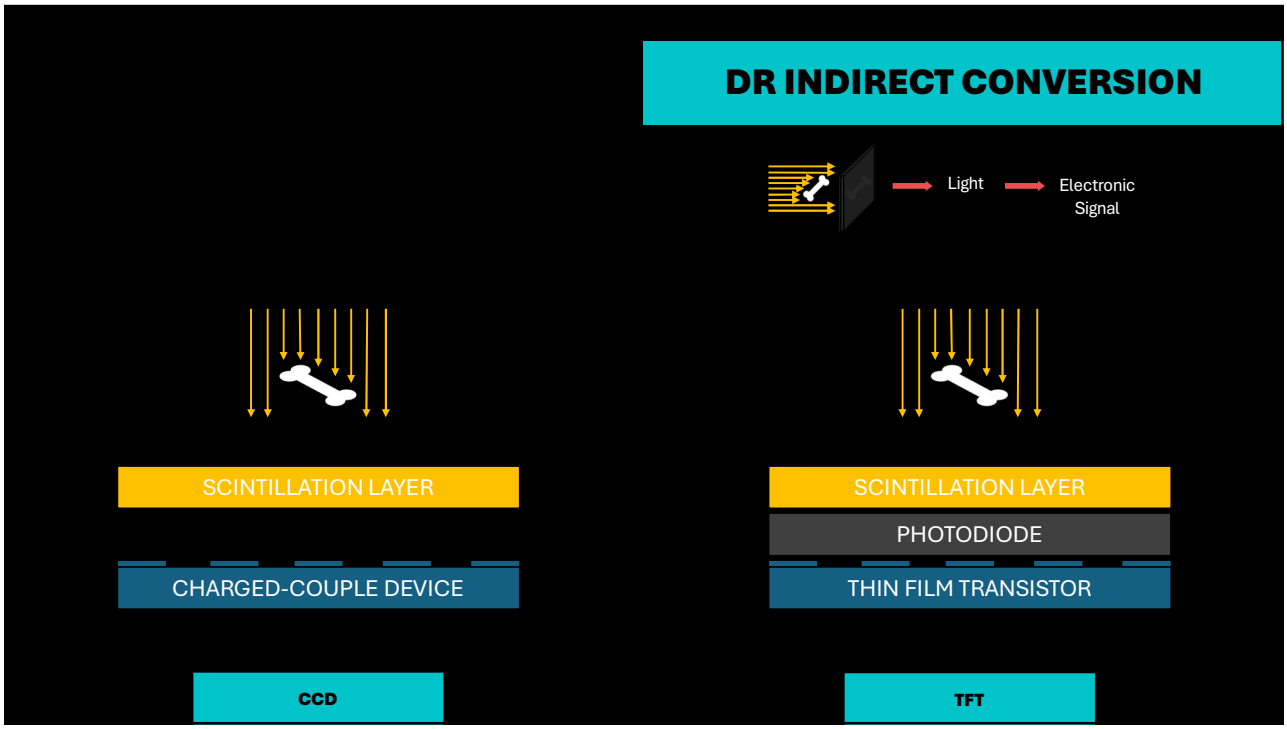
160


DR DIRECT CONVERSION
Electronic Signal
ELECTRICAL CHARGE APPLIED BEFORE EXPOSURE
X-RAY BEAM CAUSES ELECTRONS TO BE RELEASED
STORAGE CAPACITOR COLLECTS THE CHARGE
TFT SWITCH RELEASES CHARGE TO ADC
ADC CONVERTS CHARGE TO DIGITAL SIGNAL
PHOTOCONDUCTOR
THIN FILM TRANSISTOR
ANALOG-TO-DIGITAL CONVERTER
0101101010
0101101010
0101101010
0101101010
0101101010

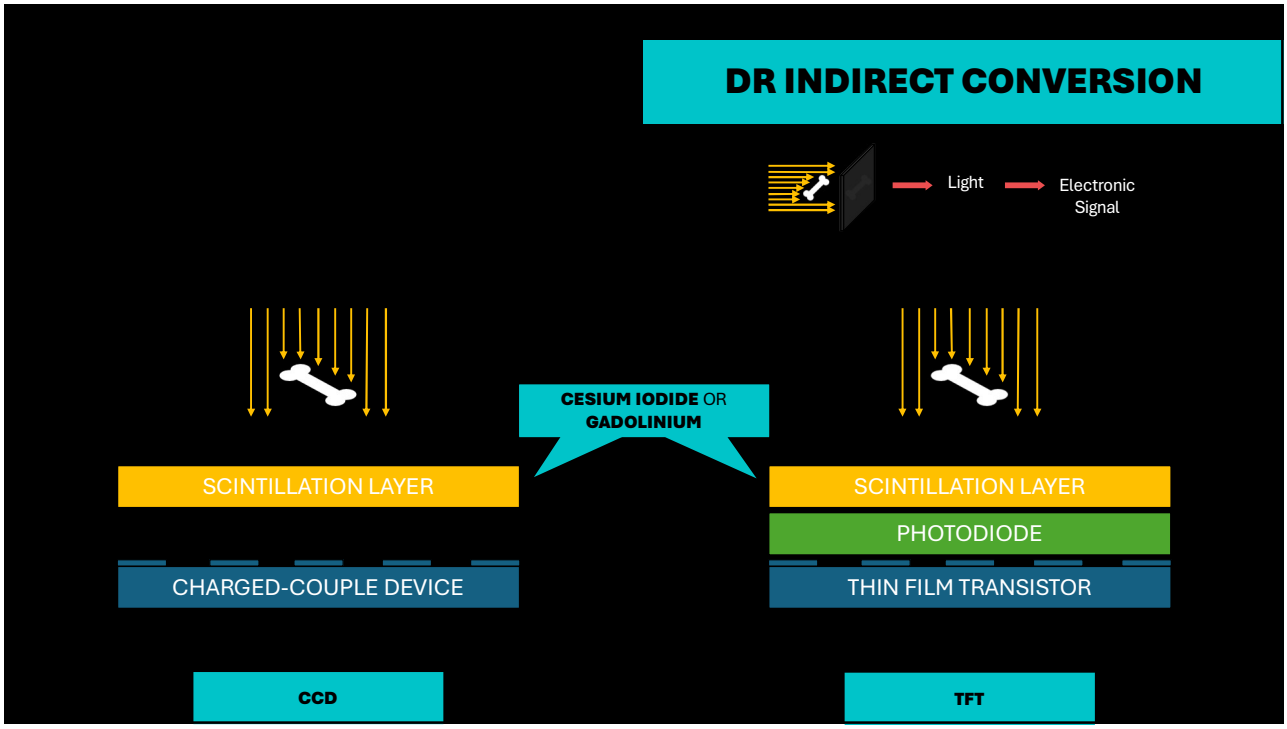
161


DR DIRECT CONVERSION
Electronic Signal
Direct Conversion DR systems produce high quality images because the X-Ray signal is converted directly to an electrical signal (less processing steps is better)
Direct Conversion DR system mostly found in Mammography applications for their higher resolution.
Generally Direct Conversion DR systems are not found in general radiography applications because they are difficult to manufacture in large sizes.
PHOTOCONDUCTOR
THIN FILM TRANSISTOR
ANALOG-TO-DIGITAL CONVERTER
0101101010
0101101010
0101101010
0101101010
0101101010

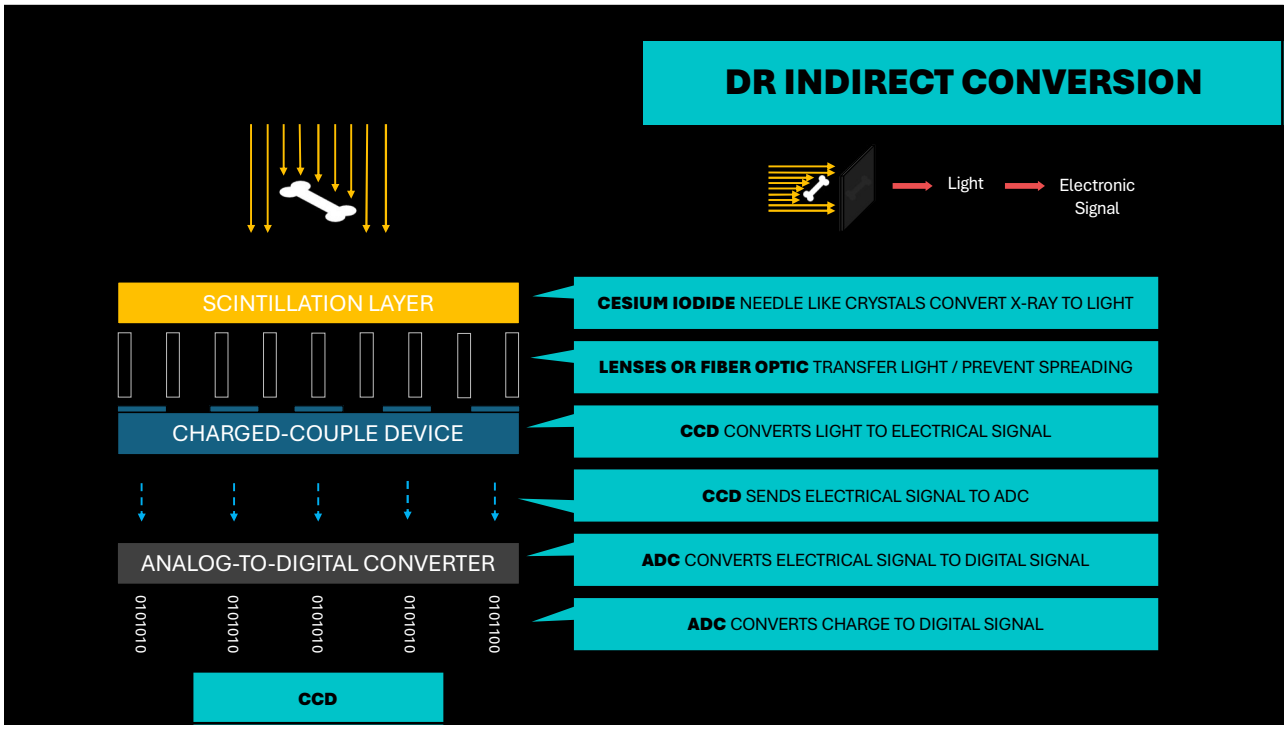
162


DR INDIRECT CONVERSION
Light
Electronic Signal
SCINTILLATION LAYER
CHARGED-COUPLE DEVICE
SCINTILLATION LAYER
PHOTODIODE
THIN FILM TRANSISTOR
CCD
TFT

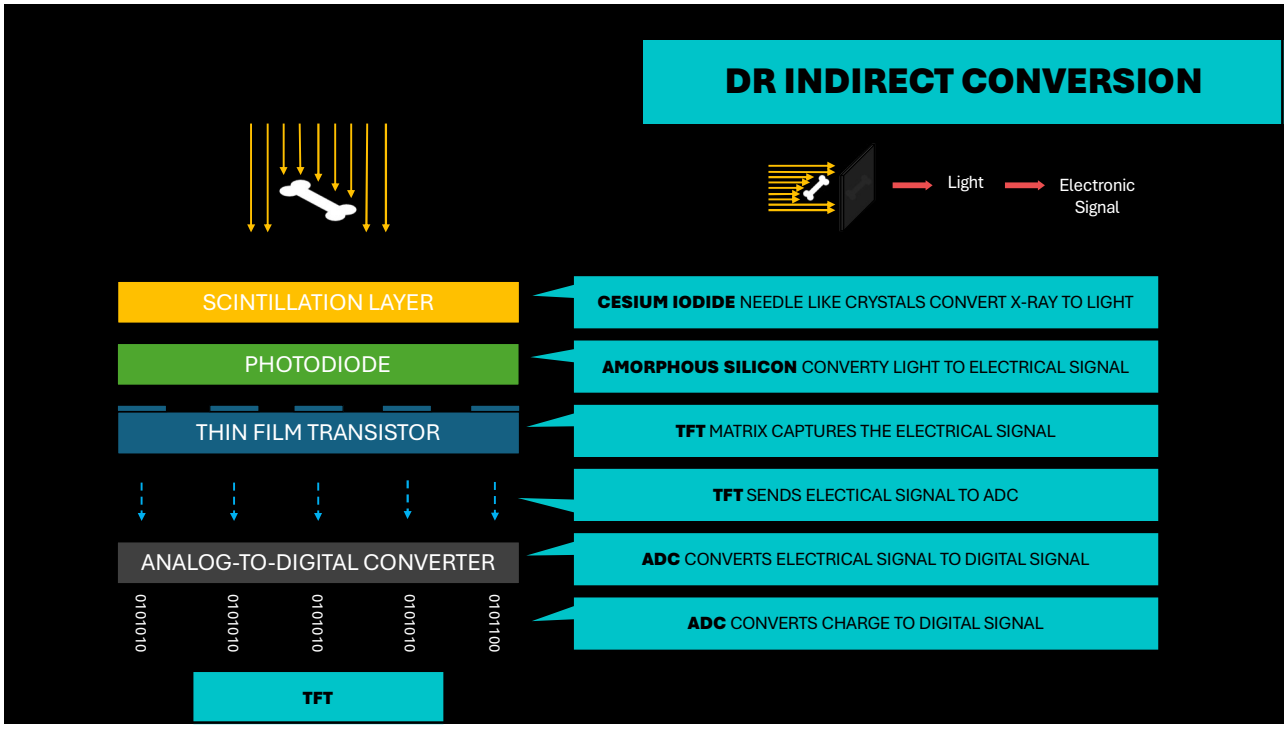
163


DR INDIRECT CONVERSION
Light
Electronic Signal
CESIUM IODIDE OR GADOLINIUM
SCINTILLATION LAYER
CHARGED-COUPLE DEVICE
SCINTILLATION LAYER
PHOTODIODE
THIN FILM TRANSISTOR
CCD
TFT

164

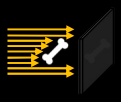

DR INDIRECT CONVERSION
Light
Electronic Signal
SCINTILLATION LAYER
CHARGED-COUPLE DEVICE
ANALOG-TO-DIGITAL CONVERTER
0101010
0101010
0101010
0101010
0101100
CCD
CESIUM IODIDE NEEDLE LIKE CRYSTALS CONVERT X-RAY TO LIGHT
LENSES OR FIBER OPTIC TRANSFER LIGHT / PREVENT SPREADING
CCD CONVERTS LIGHT TO ELECTRICAL SIGNAL
CCD SENDS ELECTRICAL SIGNAL TO ADC
ADC CONVERTS ELECTRICAL SIGNAL TO DIGITAL SIGNAL
ADC CONVERTS CHARGE TO DIGITAL SIGNAL

165


DR INDIRECT CONVERSION
Light
Electronic Signal
SCINTILLATION LAYER
PHOTODIODE
THIN FILM TRANSISTOR
ANALOG-TO-DIGITAL CONVERTER
0101010
0101010
0101010
0101010
0101100
TFT
CESIUM IODIDE NEEDLE LIKE CRYSTALS CONVERT X-RAY TO LIGHT
AMORPHOUS SILICON CONVERTY LIGHT TO ELECTRICAL SIGNAL
TFT MATRIX CAPTURES THE ELECTRICAL SIGNAL
TFT SENDS ELECTICAL SIGNAL TO ADC
ADC CONVERTS ELECTRICAL SIGNAL TO DIGITAL SIGNAL
ADC CONVERTS CHARGE TO DIGITAL SIGNAL

166

DR INDIRECT CONVERSION



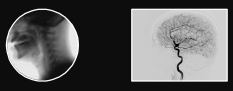
Light → Electronic Signal

CCD

TFT

- Both indirect conversion DR systems (CCD and TFT) are used in general radiography applications.

- Typically, TFT systems are used in fluoroscopy and angiography.



- Both indirect conversion DR systems (CCD and TFT) cost less than direct conversion DR.
- Both easier to repair than direct conversion DR.
- Due to the extra conversion step (X-Ray to light signal to electrical signal), both indirect DR systems produce lower spatial resolution images compares to direct DR.

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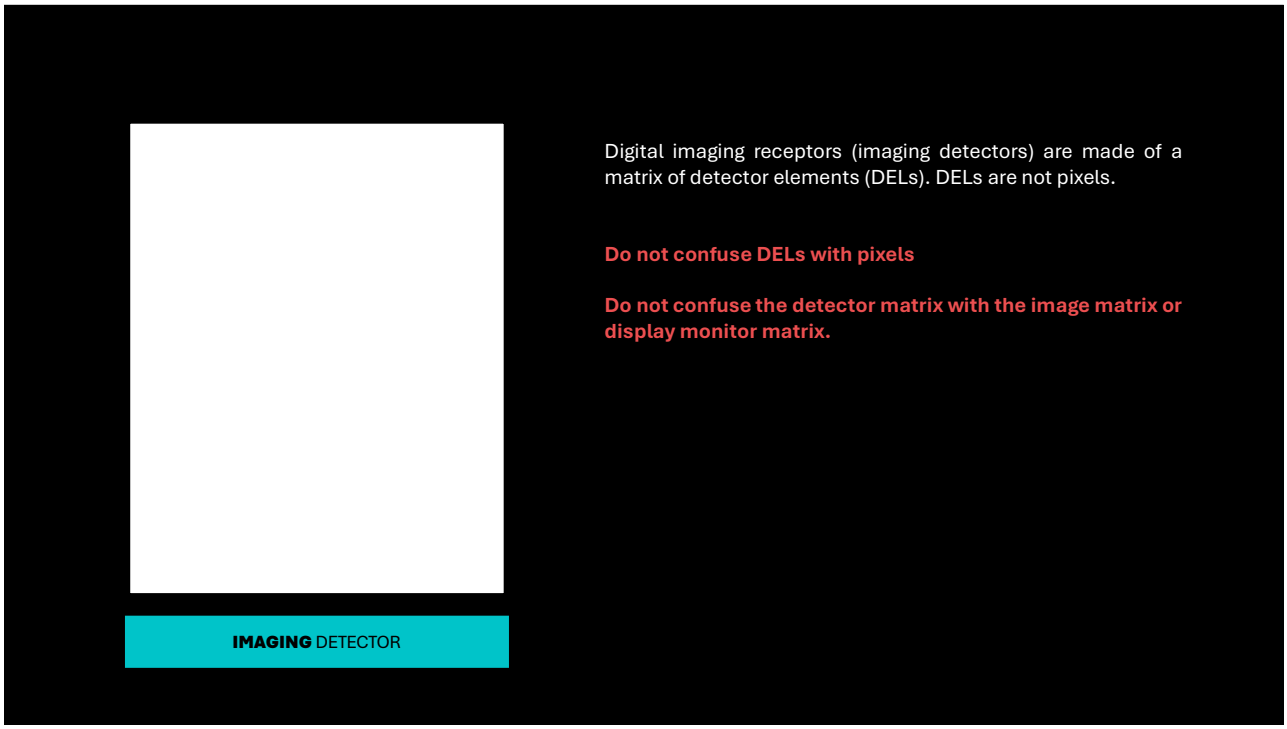
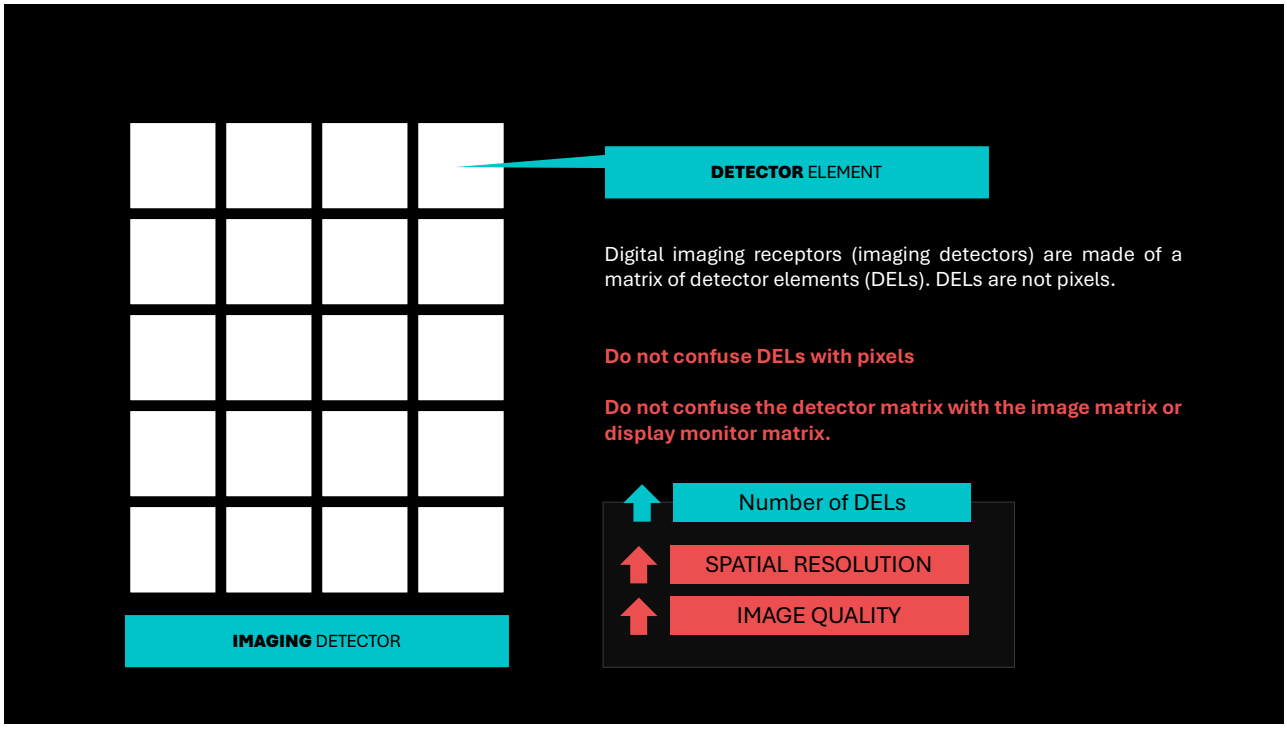
IMAGE RECEPTORS

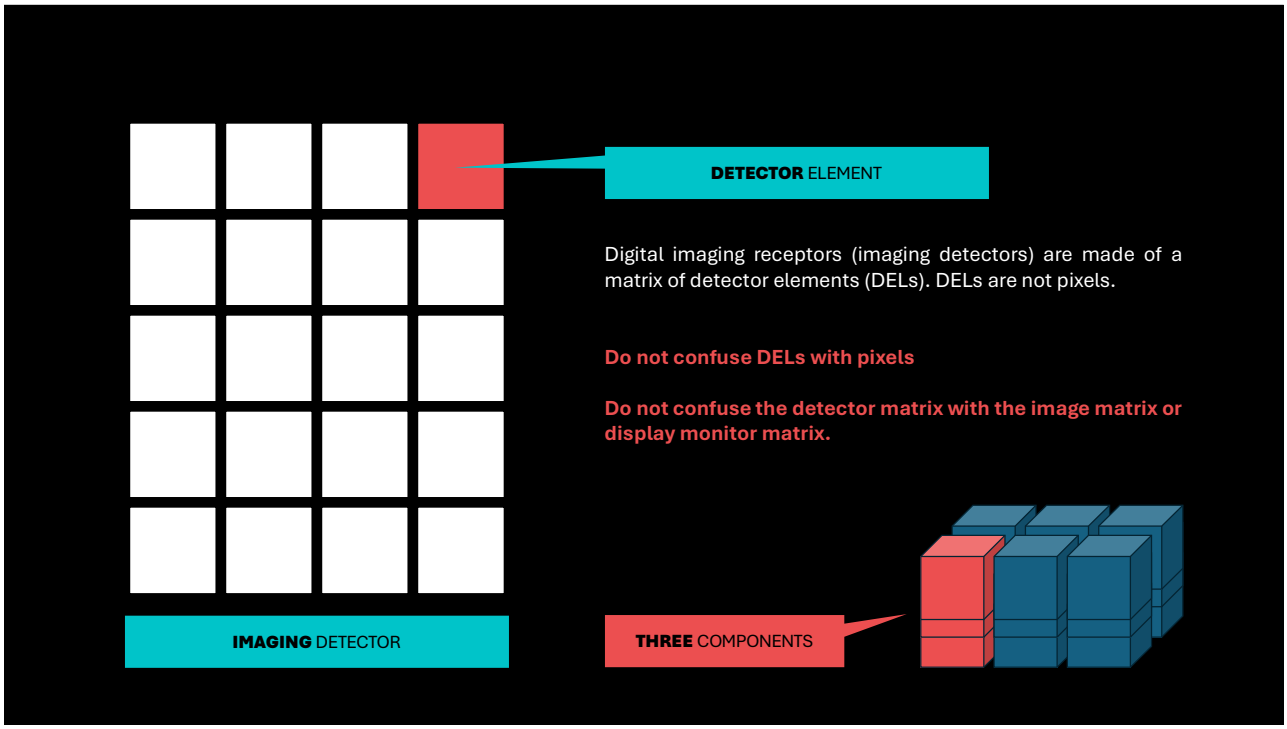
168


IMAGING DETECTOR
Digital imaging receptors (imaging detectors) are made of a matrix of detector elements (DELs). DELs are not pixels.
Do not confuse DELs with pixels
Do not confuse the detector matrix with the image matrix or display monitor matrix.

169


DETECTOR ELEMENT
IMAGING DETECTOR
Digital imaging receptors (imaging detectors) are made of a matrix of detector elements (DELs). DELs are not pixels.
Do not confuse DELs with pixels
Do not confuse the detector matrix with the image matrix or display monitor matrix.
Number of DELs
SPATIAL RESOLUTION
IMAGE QUALITY

170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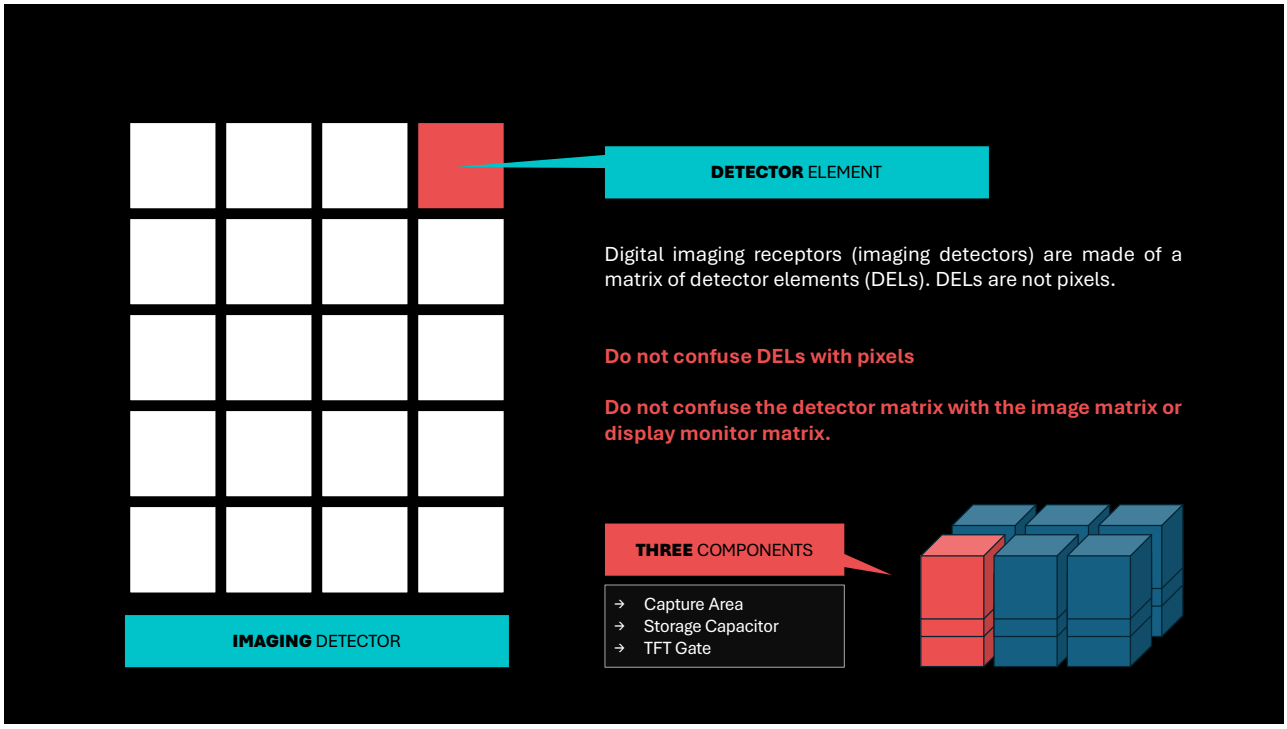
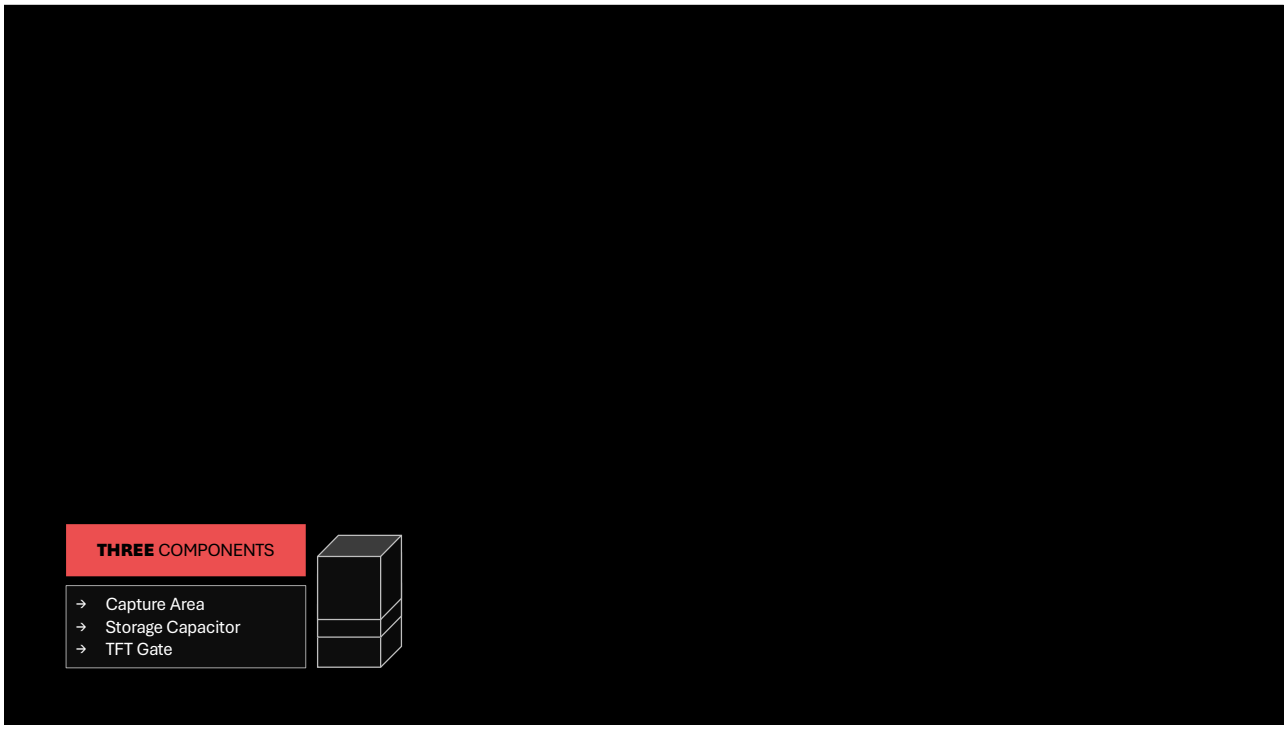
IMAGING DETECTOR
THREE COMPONENTS

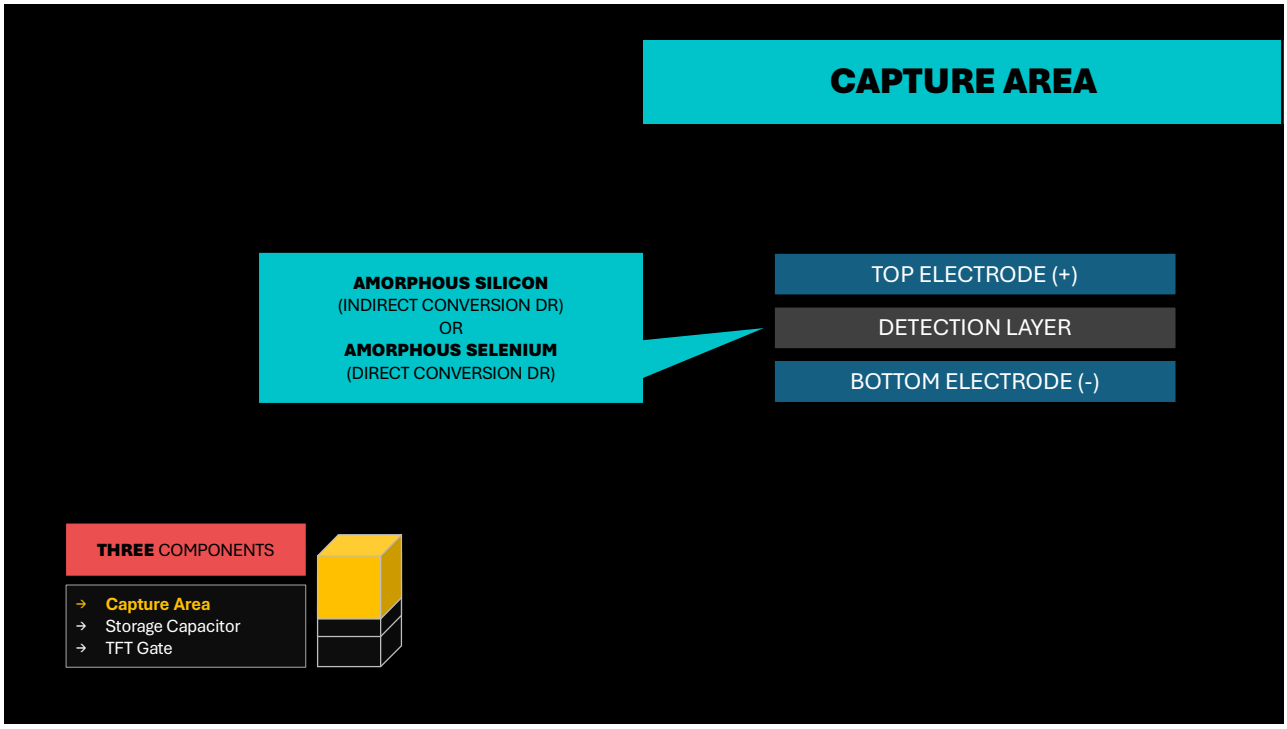
171


DETECTOR ELEMENT
Digital imaging receptors (imaging detectors) are made of a matrix of detector elements (DELs). DELs are not pixels.
Do not confuse DELs with pixels
Do not confuse the detector matrix with the image matrix or display monitor matrix.
IMAGING DETECTOR
THREE COMPONENTS
Capture Area
Storage Capacitor
TFT Gate

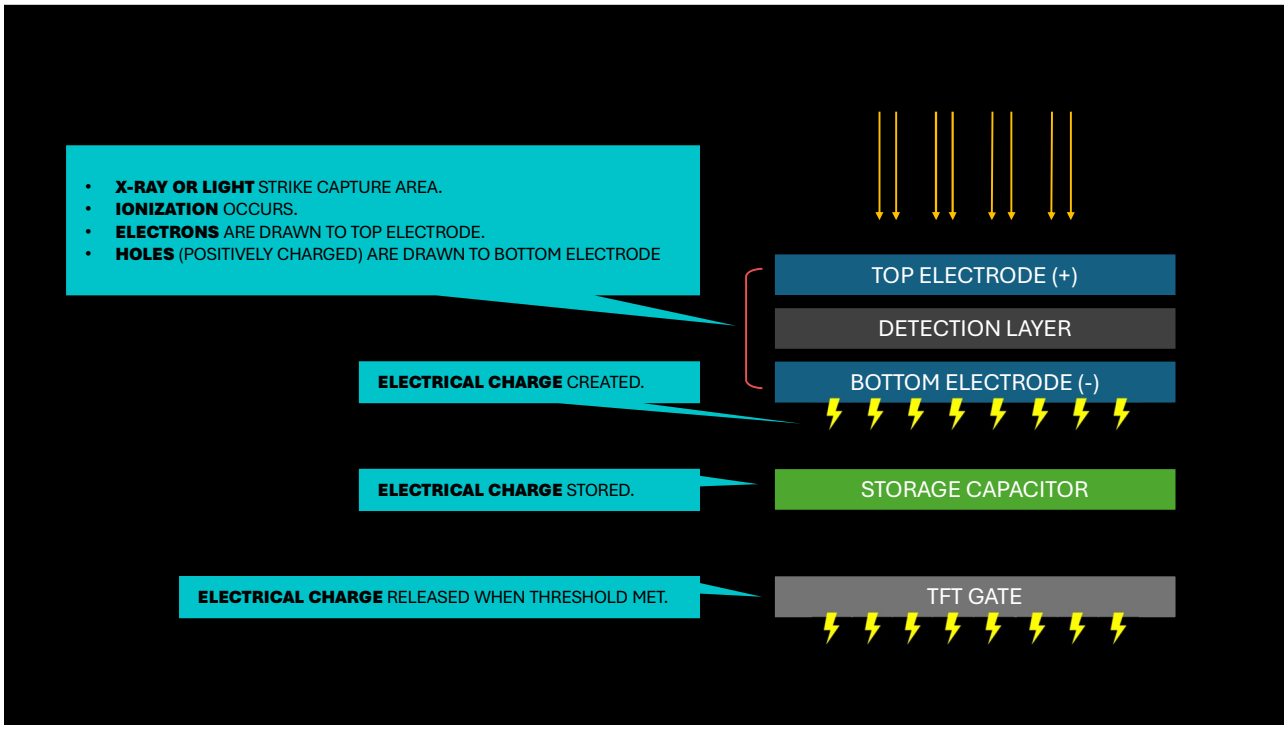
172


THREE COMPONENTS
→ Capture Area
→ Storage Capacitor
→ TFT Gate

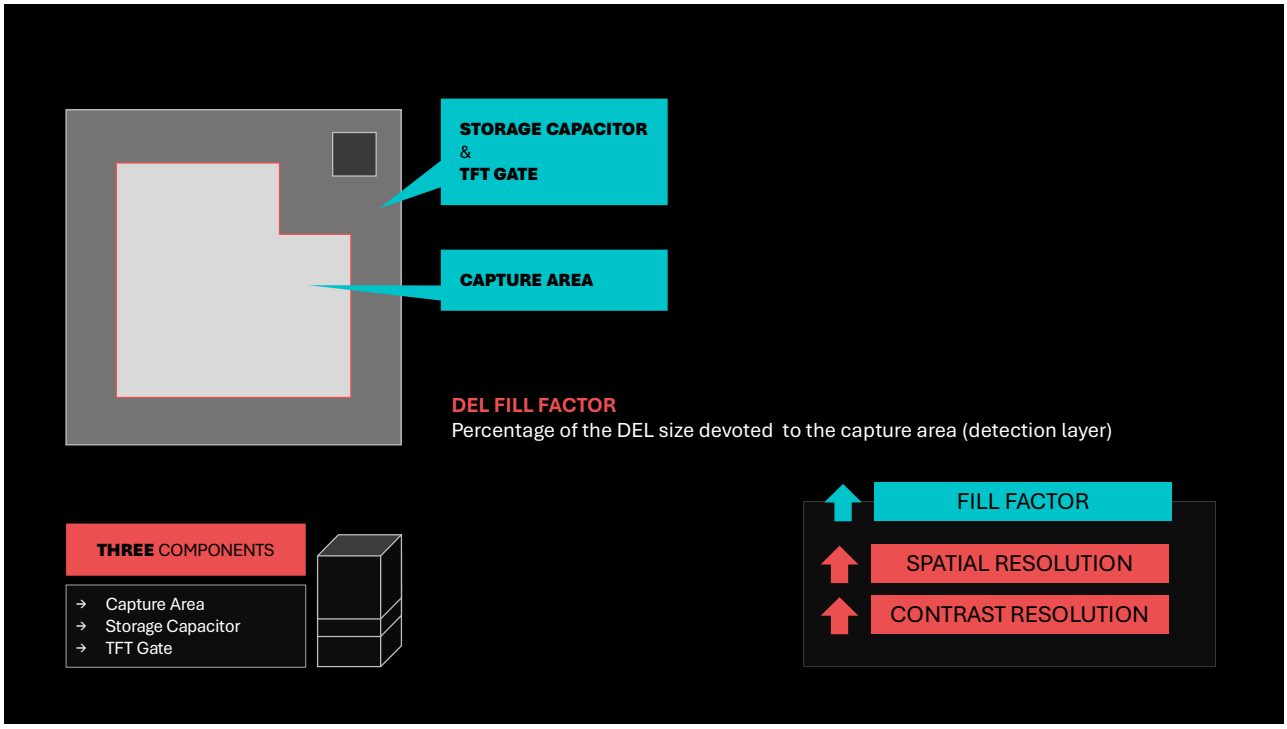
173


CAPTURE AREA
AMORPHOUS SILICON
(INDIRECT CONVERSION DR)
OR
AMORPHOUS SELENIUM
(DIRECT CONVERSION DR)
TOP ELECTRODE (+)
DETECTION LAYER
BOTTOM ELECTRODE (-)
THREE COMPONENTS
→ Capture Area
→ Storage Capacitor
→ TFT Gate

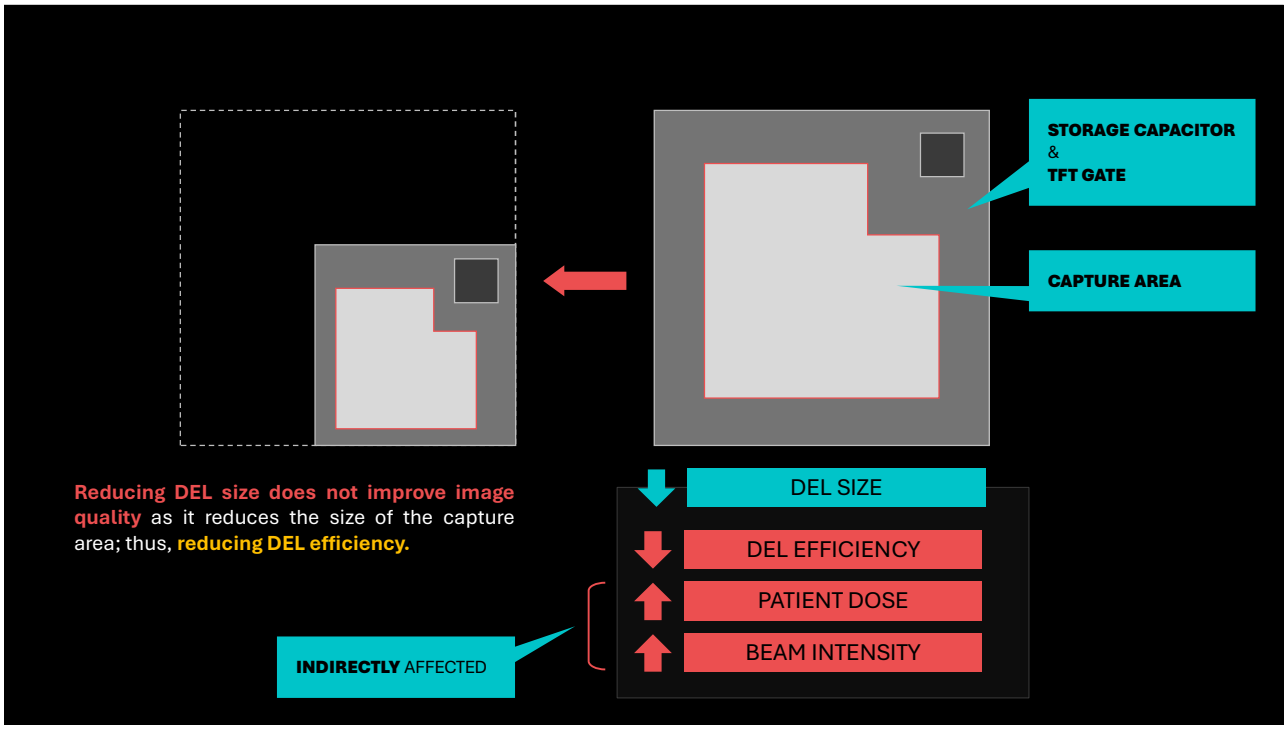
174


• X-RAY OR LIGHT STRIKE CAPTURE AREA.
• IONIZATION OCCURS.
• ELECTRONS ARE DRAWN TO TOP ELECTRODE.
• HOLES (POSITIVELY CHARGED) ARE DRAWN TO BOTTOM ELECTRODE
TOP ELECTRODE (+)
DETECTION LAYER
BOTTOM ELECTRODE (-)
ELECTRICAL CHARGE CREATED.
ELECTRICAL CHARGE STORED.
STORAGE CAPACITOR
ELECTRICAL CHARGE RELEASED WHEN THRESHOLD MET.
TFT GATE

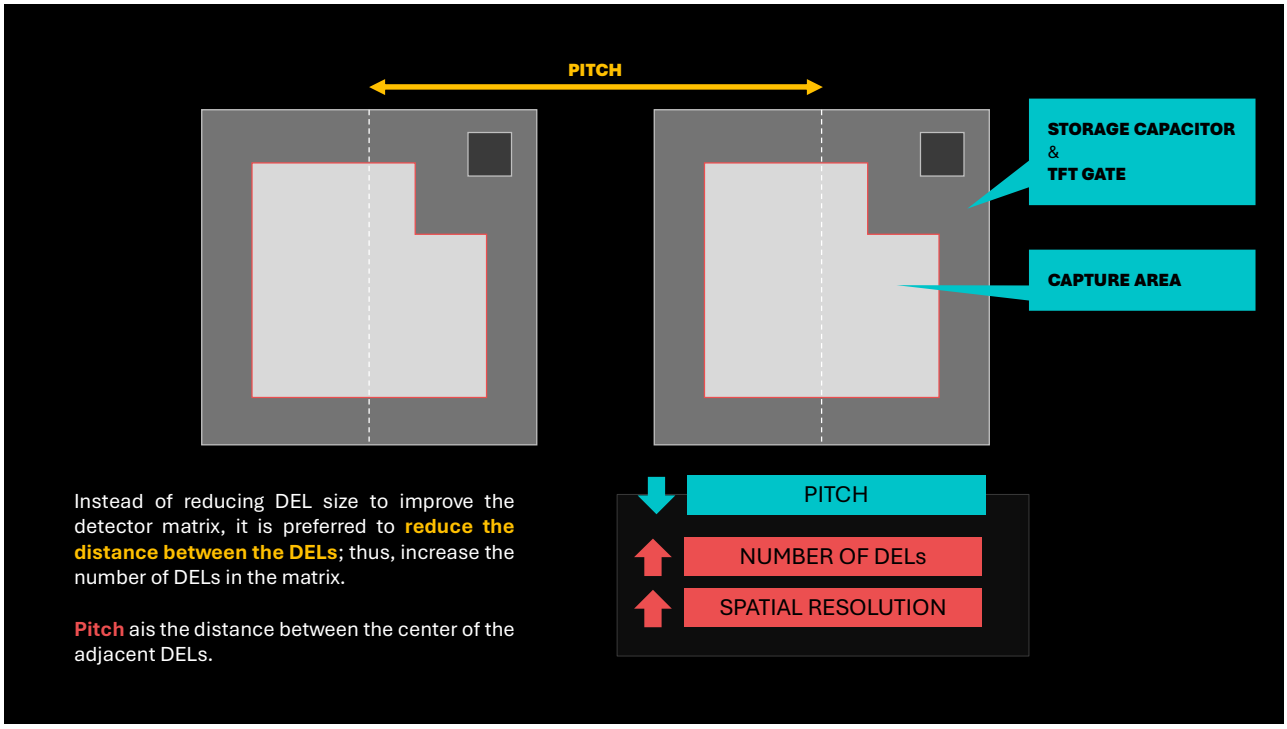
175


STORAGE CAPACITOR
&
TFT GATE
CAPTURE AREA
DEL FILL FACTOR
Percentage of the DEL size devoted to the capture area (detection layer)
FILL FACTOR
SPATIAL RESOLUTION
CONTRAST RESOLUTION
THREE COMPONENTS
→ Capture Area
→ Storage Capacitor
→ TFT Gate

176


STORAGE CAPACITOR
&
TFT GATE
CAPTURE AREA
Reducing DEL size does not improve image quality as it reduces the size of the capture area; thus, reducing DEL efficiency.
DEL SIZE
DEL EFFICIENCY
PATIENT DOSE
BEAM INTENSITY
INDIRECTLY AFFECTED

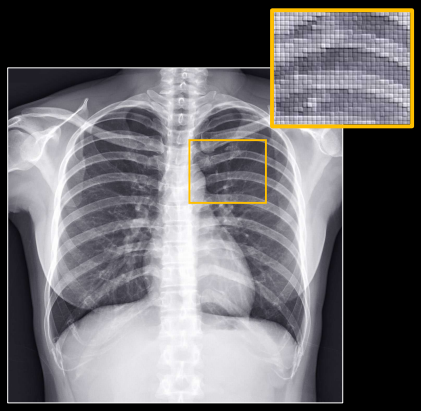
177


PITCH
STORAGE CAPACITOR
&
TFT GATE
CAPTURE AREA
Instead of reducing DEL size to improve the detector matrix, it is preferred to reduce the distance between the DELs; thus, increase the number of DELs in the matrix.
Pitch ais the distance between the center of the adjacent DELs.
PITCH
NUMBER OF DELs
SPATIAL RESOLUTION

178

PIXELS & MATRIX

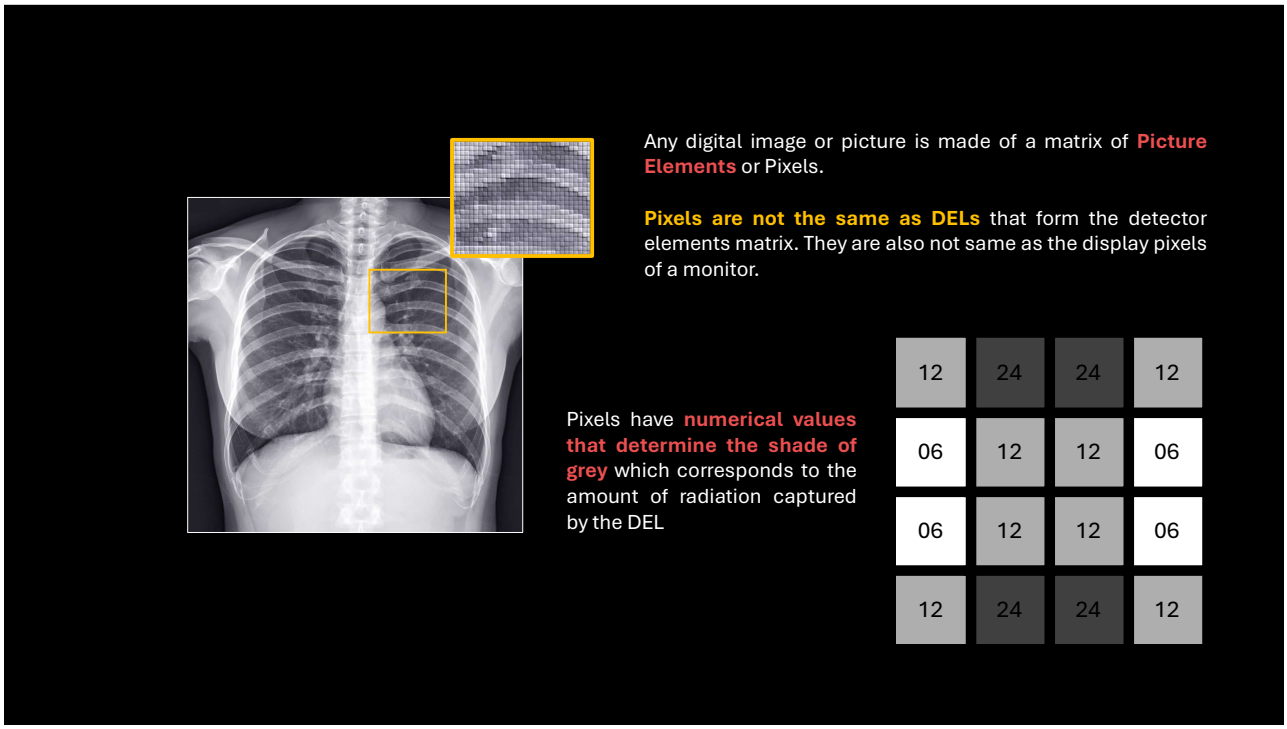
179



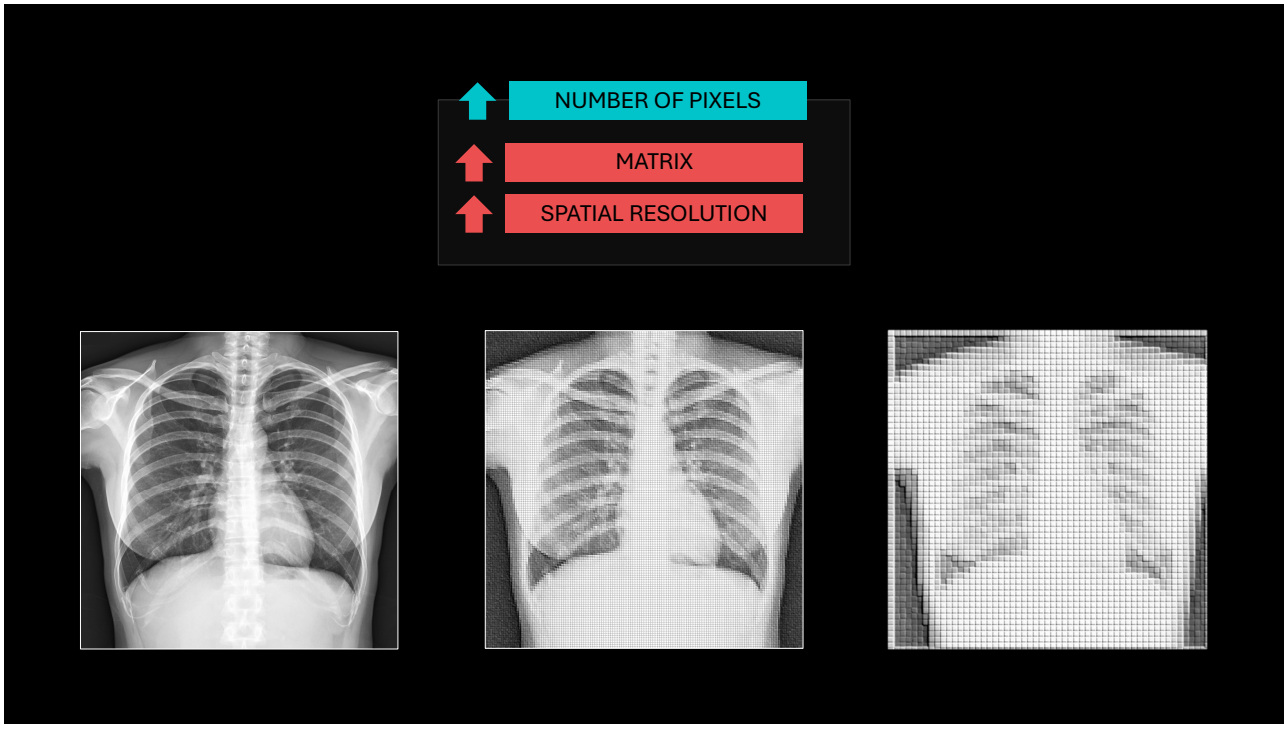
Any digital image or picture is made of a matrix of **Picture Elements** or Pixels.

Pixels are not the same as DELs that form the detector elements matrix. They are also not same as the display pixels of a monitor.

180


Any digital image or picture is made of a matrix of Picture Elements or Pixels.
Pixels are not the same as DELs that form the detector elements matrix. They are also not same as the display pixels of a monitor.
Pixels have numerical values that determine the shade of grey which corresponds to the amount of radiation captured by the DEL
12 24 24 12
06 12 12 06
06 12 12 06
12 24 24 12

181


NUMBER OF PIXELS
MATRIX
SPATIAL RESOLUTION

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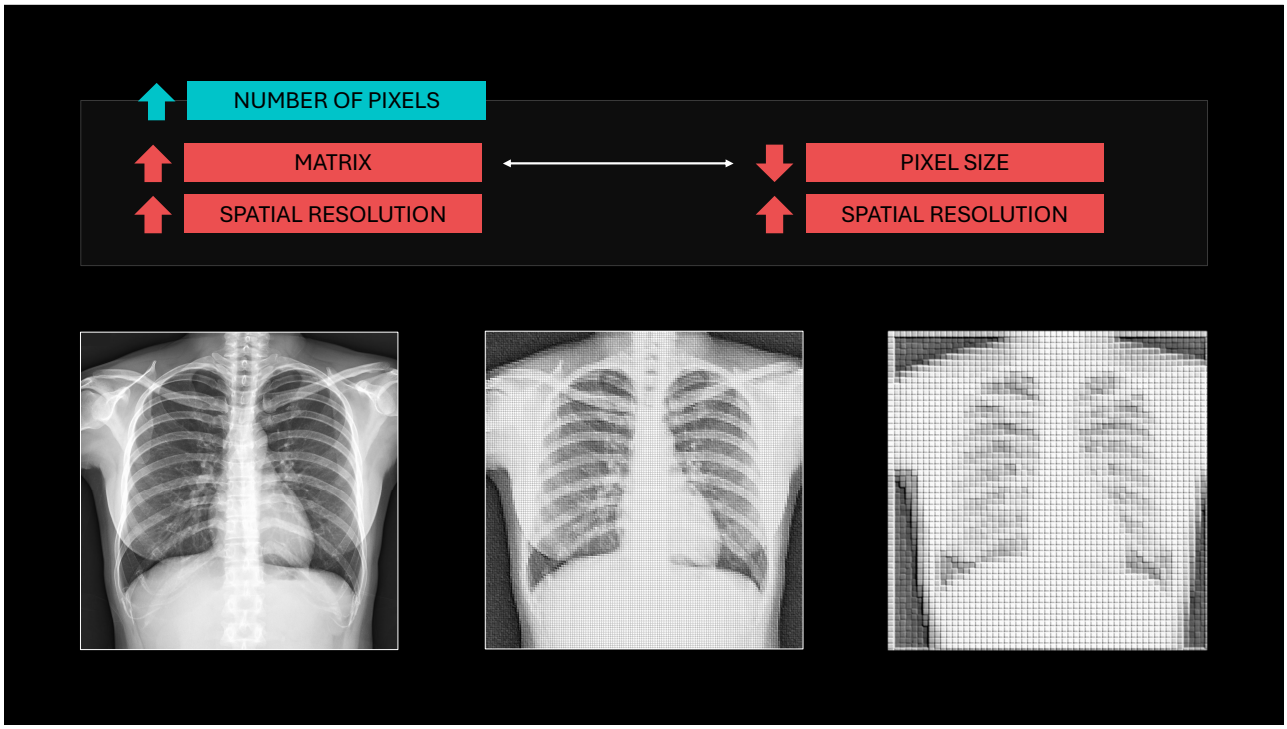
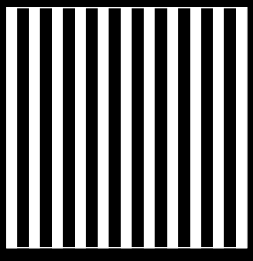


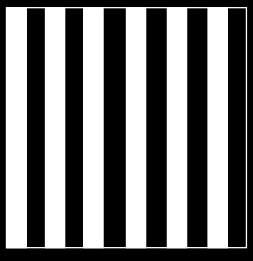
183

SPATIAL FREQUENCY

Number of line pairs (line + space) in a given length. It is measured in line-pairs per millimeter (lp/mm). **It describes the number of detail that be fit into a given space**.



HIGH SPATIAL FREQUENCY



LOW SPATIAL FREQUENCY

How many lines + gaps can be fit in the same area size? **Higher spatial frequency means more lines + spaces can be fitted**. Therefore, higher spatial resolution and better image quality.

184

CALCULATING SPATIAL FREQUENCY

PIXEL SIZE = **FIELD** OF VIEW / **MATRIX** SIZE

= **30** CM / **1024** MATRIX

= **0.029** CM

Or **0.29mm**

FIELF OF VIEW = 30cm
MATRIX = 1024 x 1024

185

CALCULATING SPATIAL FREQUENCY

PIXEL SIZE = **FIELD** OF VIEW / **MATRIX** SIZE

= **30** CM / **1024** MATRIX

= **0.029** CM

Or **0.29mm**

SPATIAL FREQUENCY = **1** / **2X** PIXEL SIZE

= **1** / **2X** 0.29

= **1.72** lp/mm

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BIT DEPTH & QUANTIZATION

187

BIT DEPTH
Number of brightness levels (or shades of grey) the digital system can produce.

HIGH BIT DEPTH

LOW BIT DEPTH

188

BIT DEPTH
Number of brightness levels (or shades of gray) the digital system can produce.

LOW BIT DEPTH

HIGH BIT DEPTH

1 bit
(2^1) = 2 shades of gray

2 bit
(2^2) = 4 shades of gray

3 bit
(2^3) = 8 shades of gray

8 bit
(2^8) = 256 shades of gray

12 bit
(2^{12}) = 4,096 shades of gray

16 bit
(2^{16}) = 65,536 shades of gray

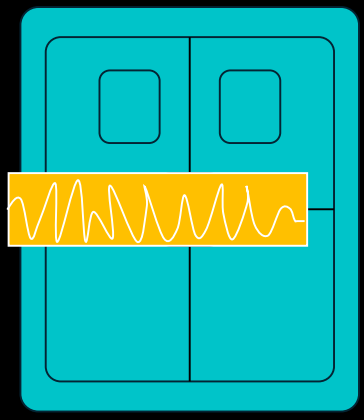
189

QUANTIZATION
The process of converting high-precision, continuous signal into a smaller finite set of lower-precision values. In other others converting the electrical signal into a digital signal by sampling it at set-interval and assigning a digital value to it. The higher the bit depth the more digital values available to assign.

LOW BIT DEPTH

0100101010001010100 10

Analog-to-Digital Converter (ADC)

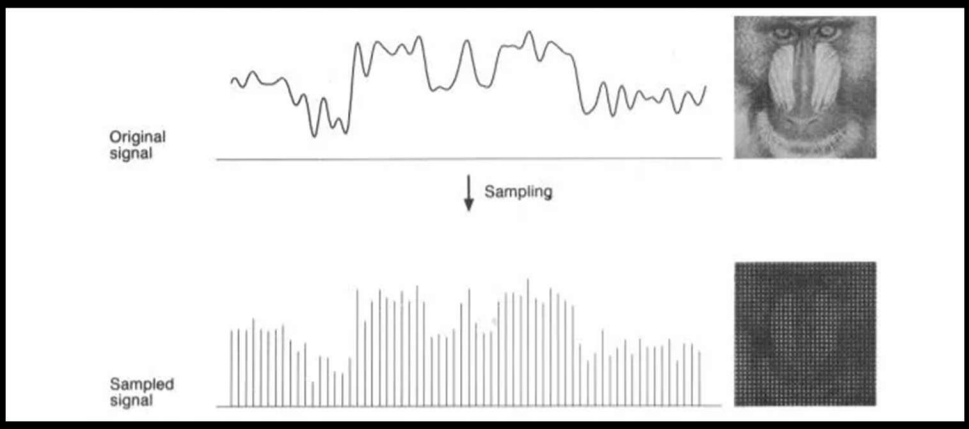


HIGH BIT DEPTH

190

QUANTIZATION

The process of converting high-precision, continuous signal into a smaller finite set of lower-precision values. In other others converting the electrical signal into a digital signal by sampling it at set-interval and assigning a digital value to it. The higher the bit depth the more digital values available to assign.



BIT DEPTH → BRIGHTNESS LEVELS → CONTRAST RESOLUTION

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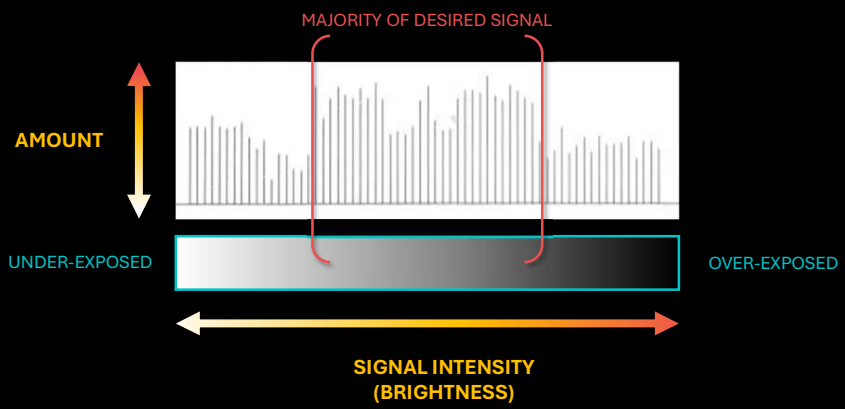
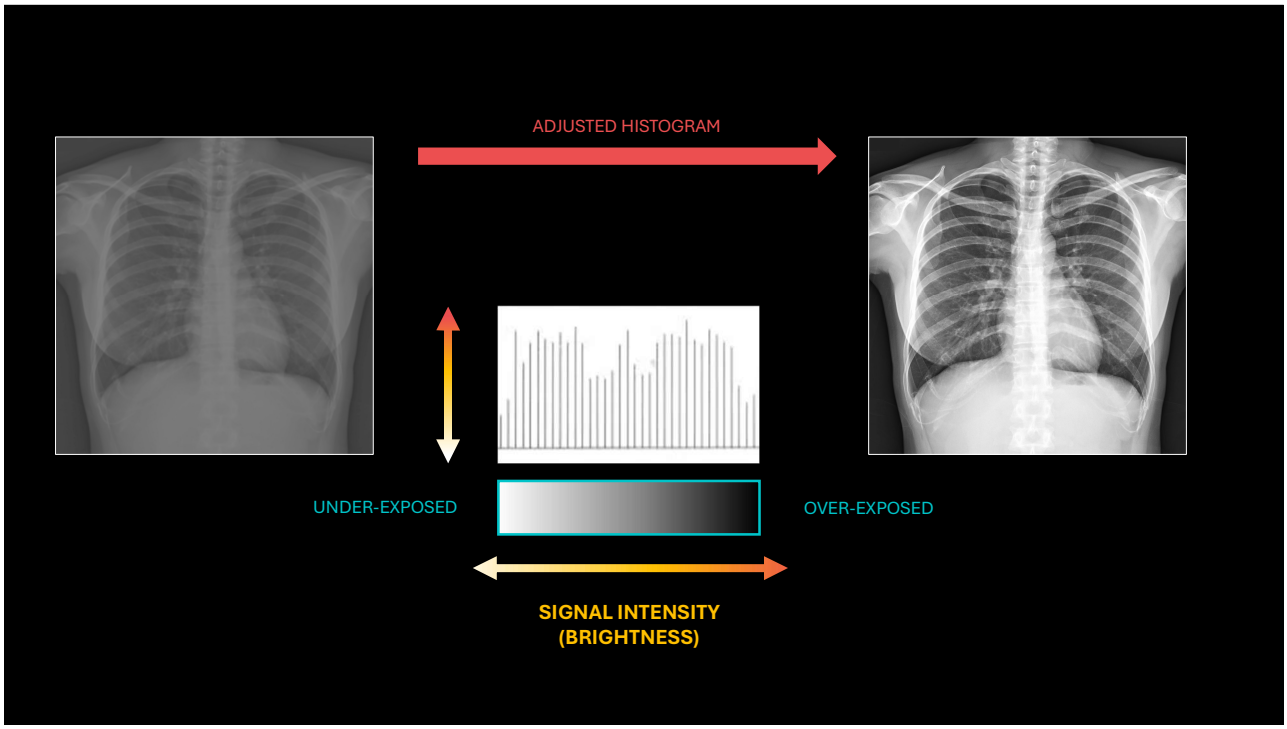
HISTOGRAM

A graph representing the range of exposure values recorded by the image receptor and the amount of signal recorded at different ranges.



192



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MODULATION TRANSFER FUNCTION

M T F

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MTF

A score that measures the accuracy of the image compared to the actual object. It is simply the imaging system's ability to transfer the object information into the image. The higher the accuracy the better.

MTF SCORE	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
IMAGE ACCYRACY	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%

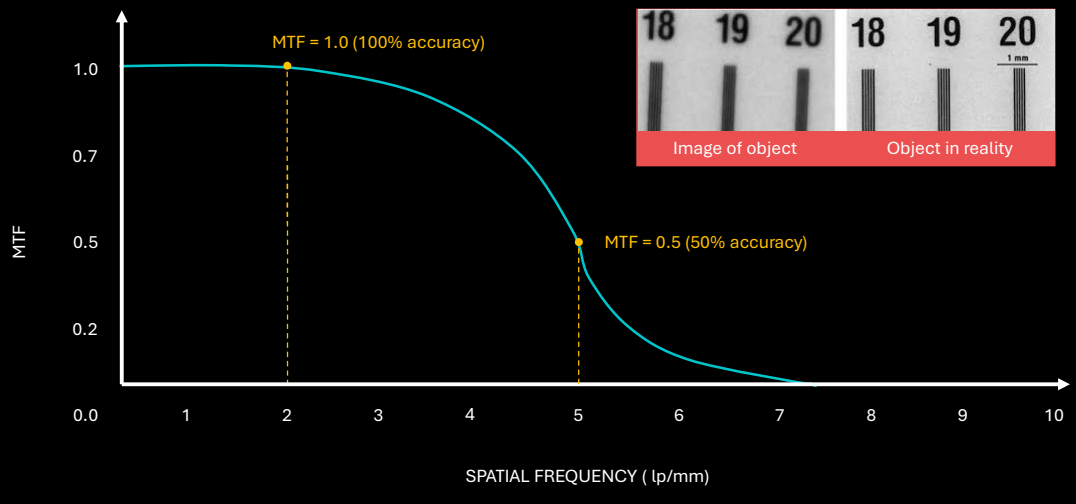
PERFECT SCORE: Image matches object in spatial resolution and contrast

WORST SCORE: Image does not match object. Object not even visible on the image

195

MTF

A score that measures the accuracy of the image compared to the actual object. It is simply the imaging system's ability to transfer the object information into the image. The higher the accuracy the better.



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SIGNAL-TO-NOISE RATIO

S N R

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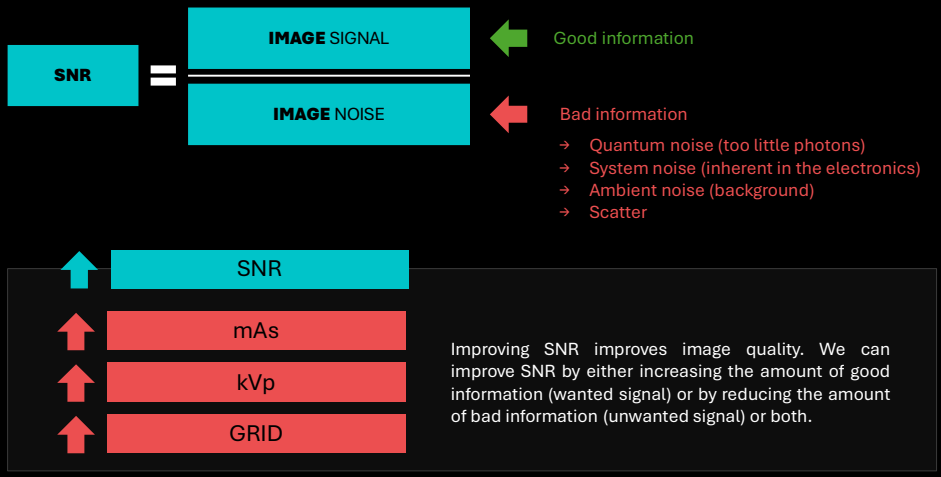
SNR

Compares the amount of signal (wanted information) to the amount of noise (unwanted information).
The higher the SNR, the better the image quality. Low SNR produce bad image quality.



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DETECTIVE QUANTUM EFFICIENCY

D Q E

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DQE

A Score that describes the ability of the imaging system to convert signal (remnant X-Ray beam) into a high-quality image. The higher the DQE, the higher the system's imaging efficiency and the better are the images produced with lesser amounts of signal.

$$DQE = \frac{(\text{SNR output})^2}{(\text{SNR input})^2}$$

Different detector types perform differently (CR vs Direct DR vs InDirect DR). One way to compare detectors is their efficiency or DQE. The higher the DQE the more efficient is the detector.

DQE is affected strongly by kVp. **The higher the kVp the lower the DQE**. This is due to the fact that at high kVp values the wanted signal (X-Ray photons) will penetrate not only the patient, but also the detector and will not interact with the detector; thus, less detection or less detector efficiency.

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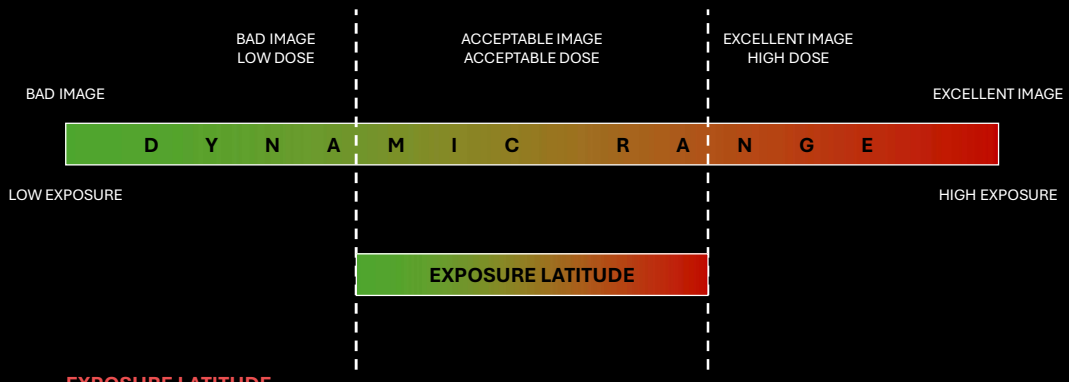
DYNAMIC RANGE & EXPOSURE LATITUDE

201

DYNAMIC RANGE
Range of exposures that can be captured by the image receptor



EXPOSURE LATITUDE
Range of exposures that can produce acceptable images at acceptable patient dose levels.

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TOPICS
X-RAY TUBE
X-RAY BEAM
EXPOSURE FACTORS
DIGITAL RADIOGRAPHY
IMAGE QUALITY
IMAGE EVALUATION
KBR PART ONE PHYSICS SYLLABUS
PROJECTION IMAGING

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