Cone Beam Radiology

University of Manitoba | Rady Faculty of Health Sciences

Presenter Disclosure

- **Faculty Member:** Dr. Idris Elbakri

- **Relationships with commercial interests:**
  - None to report

Cone Beam CT

Physics

Radiation Dose and Risk

What’s under the cover?

Image Quality

Quality Assurance and Control

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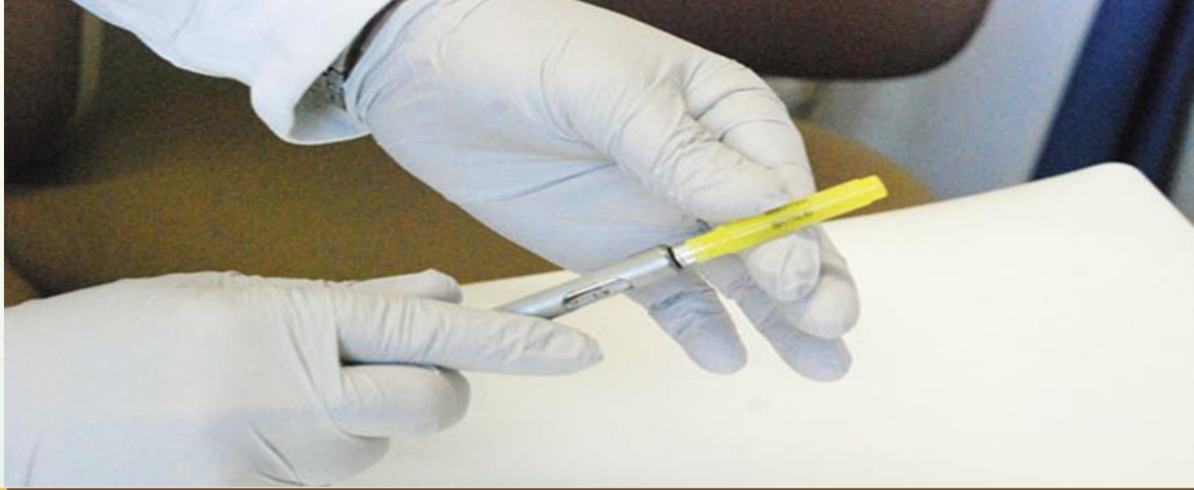

CT Physics

What's under the covers?

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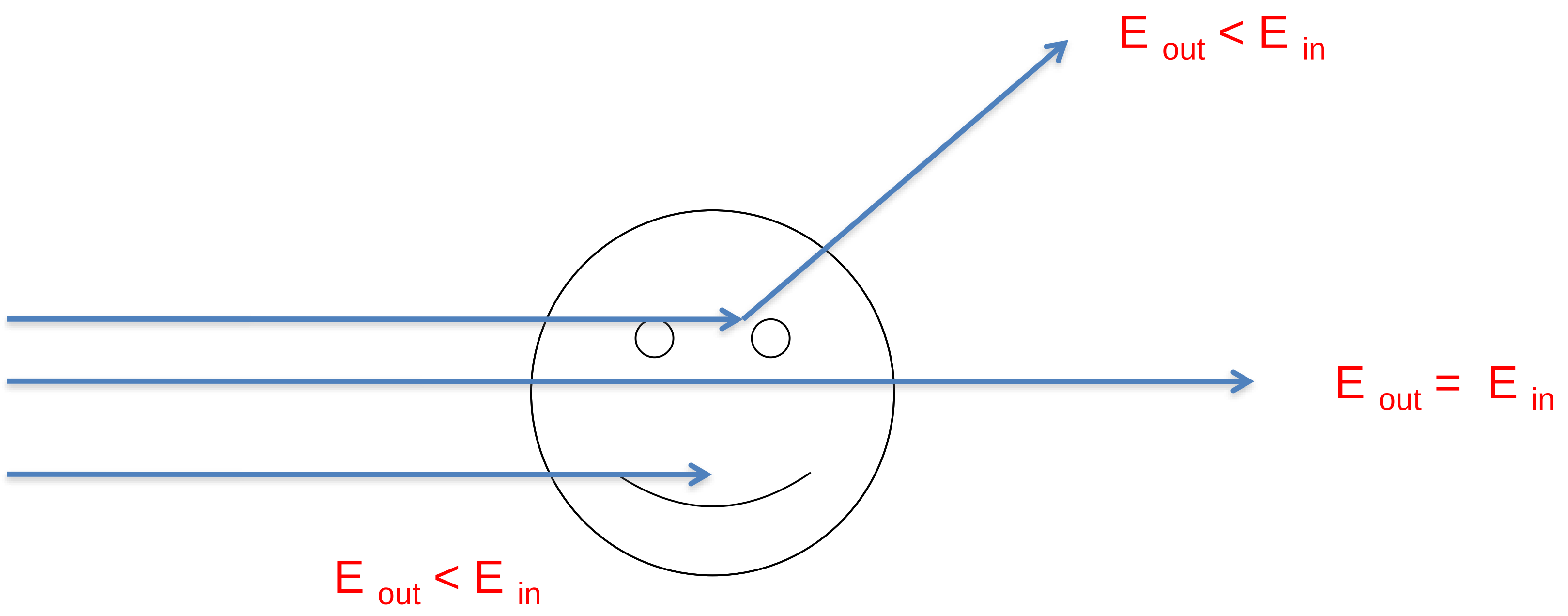
Topics

- Basic physics principles
- CT imaging
- X-ray generation
- X-ray detection
- Image reconstruction
- Acquisition parameters

X-rays and human tissue

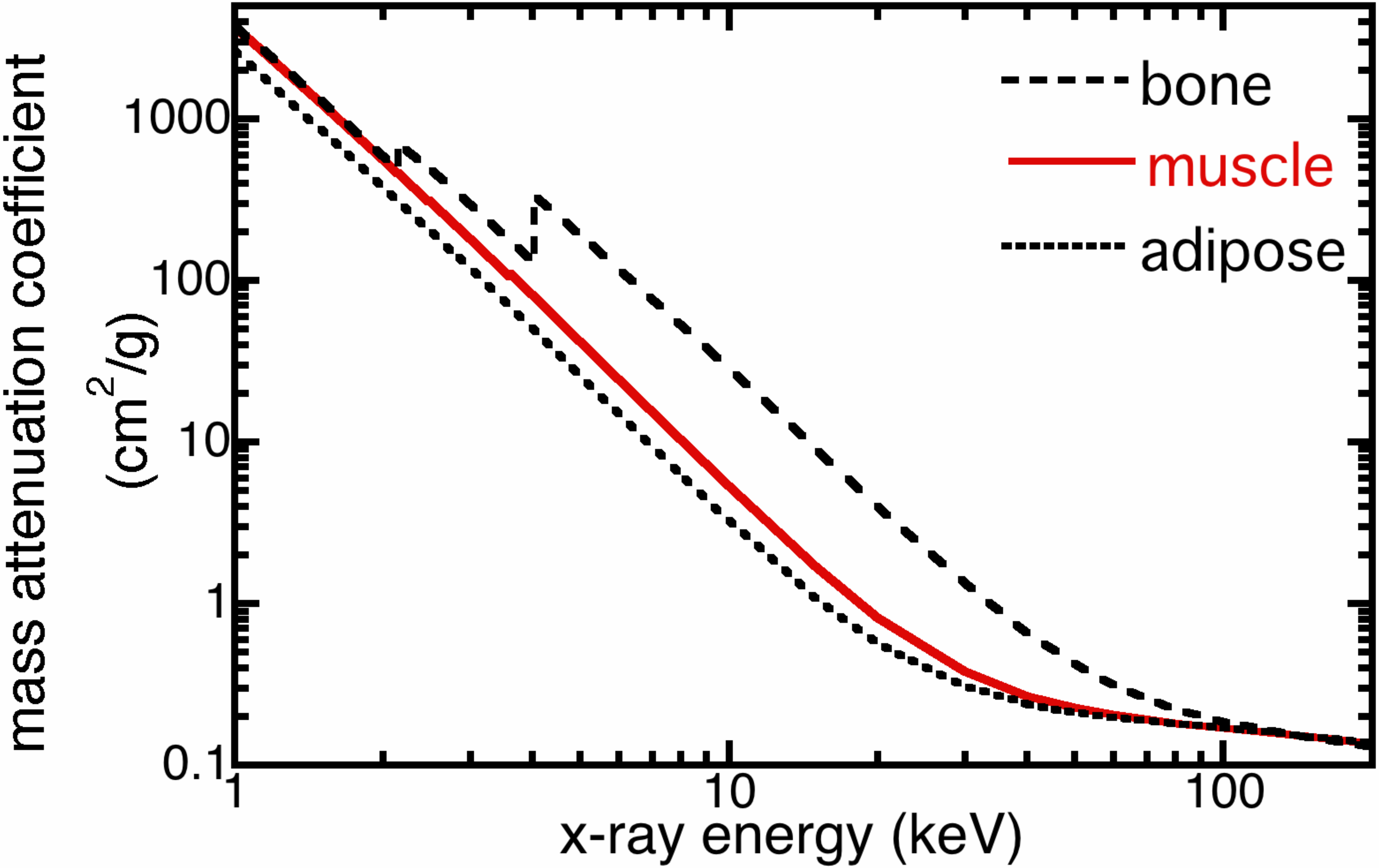
- X-rays propagate through human tissue and undergo several possible interactions:
  - Propagate unchanged…
  - Absorbed
  - Scattered

What happens to a photon?



X-rays and human tissue

- X-rays propagate through human tissue and undergo several possible interactions:
  - Propagate unchanged…
  - Absorbed
  - Scattered
- Attenuation = Absorption + Scatter
- Differential in tissue densities leads to differential in x-ray attenuation

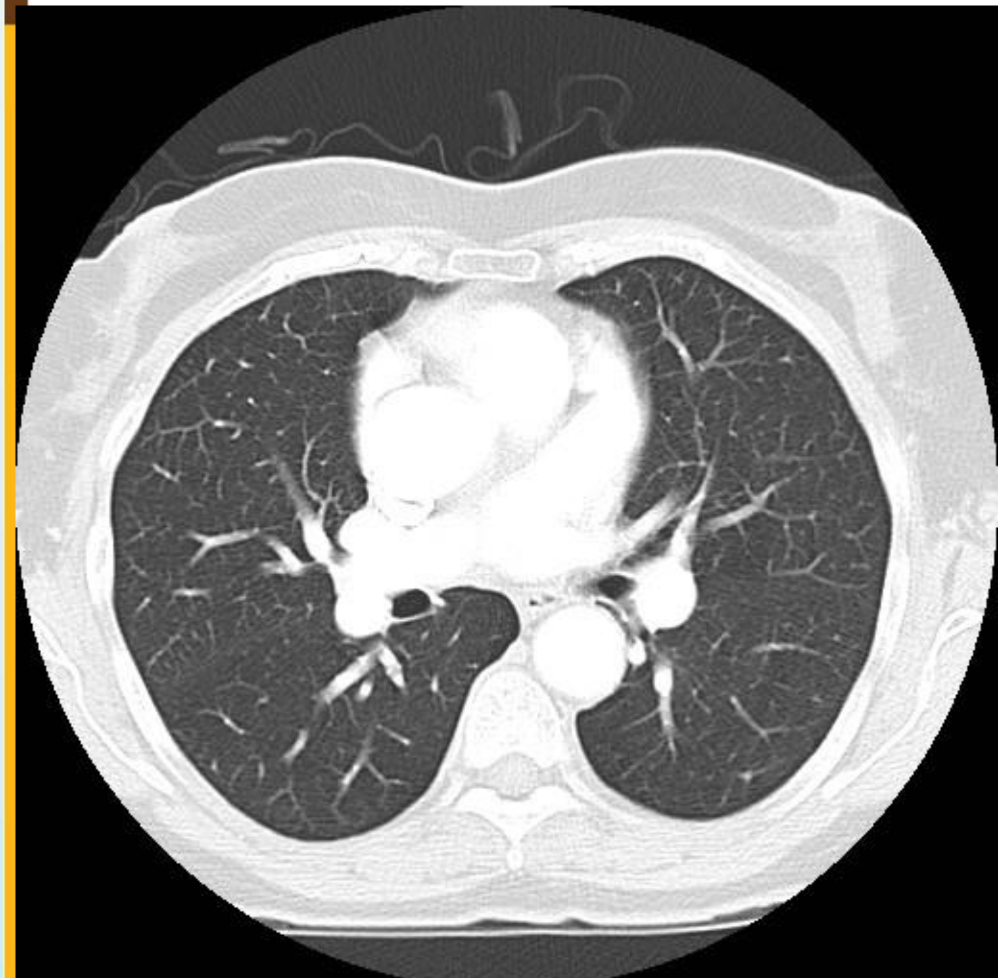

mass attenuation coefficient
(cm^2/g)
1000
100
10
1
0.1
1
10
100
x-ray energy (keV)
bone
muscle
adipose

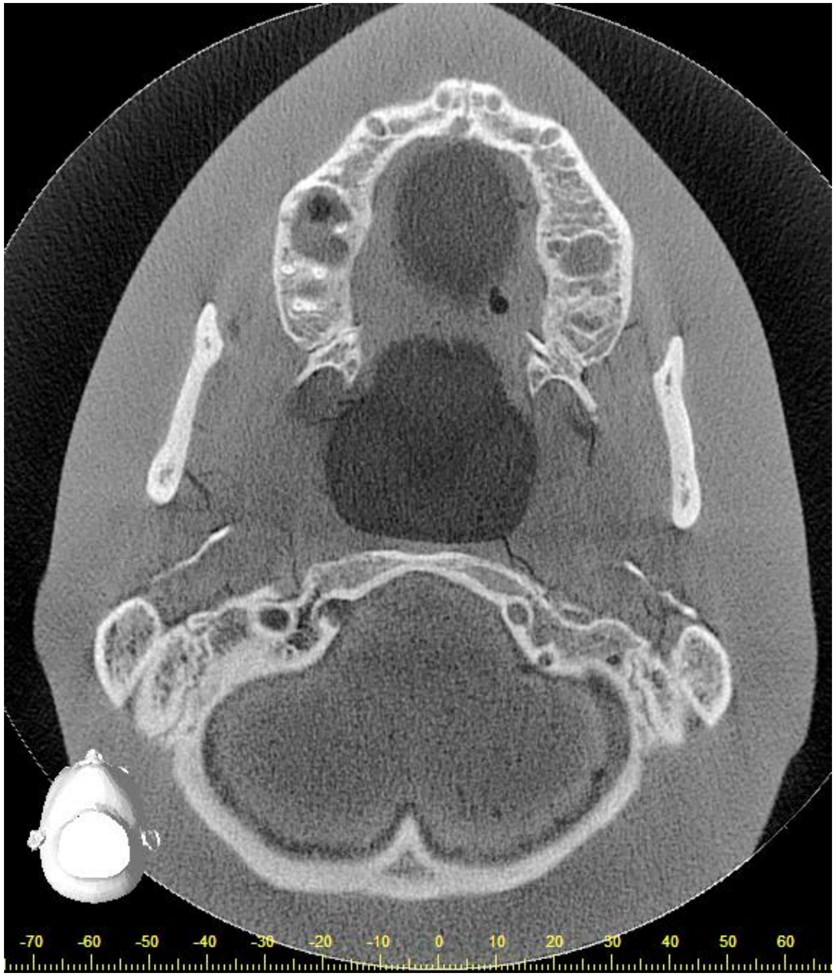

R
L

The "Overlap" Problem

- Solution: computed tomography (CT)!
- Tomography comes from Greek *tomo* which means "to cut"
- CT uses a computer to process information from the passage of x-ray beams, acquired from different angles, through an area of anatomy to generate cross-sectional images.
- CT removes tissue overlap completely

What does CT image?

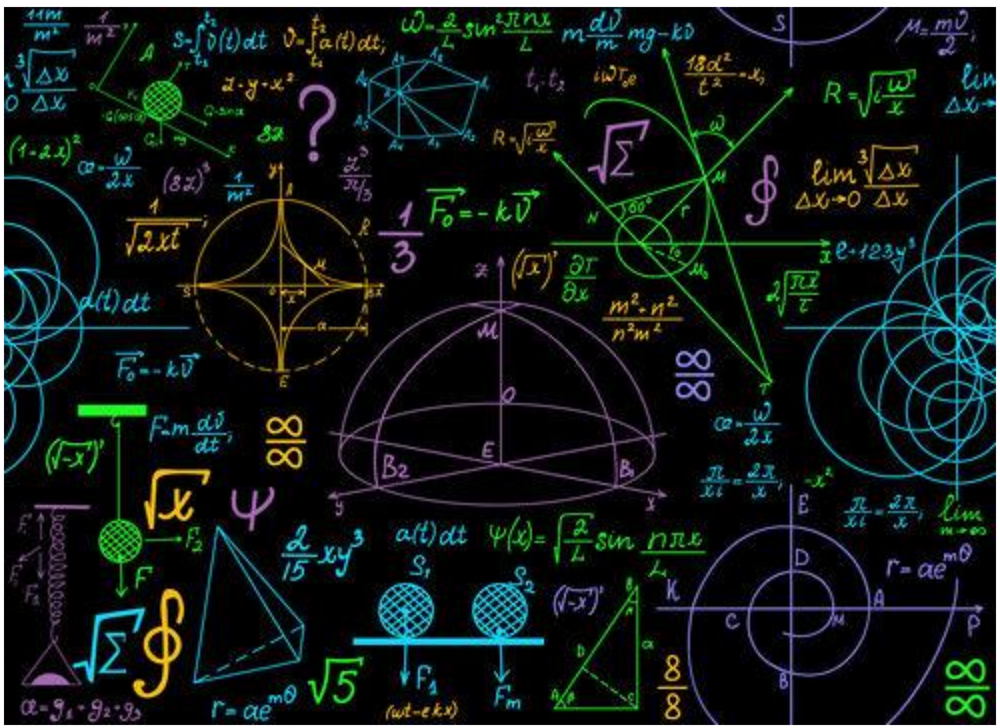




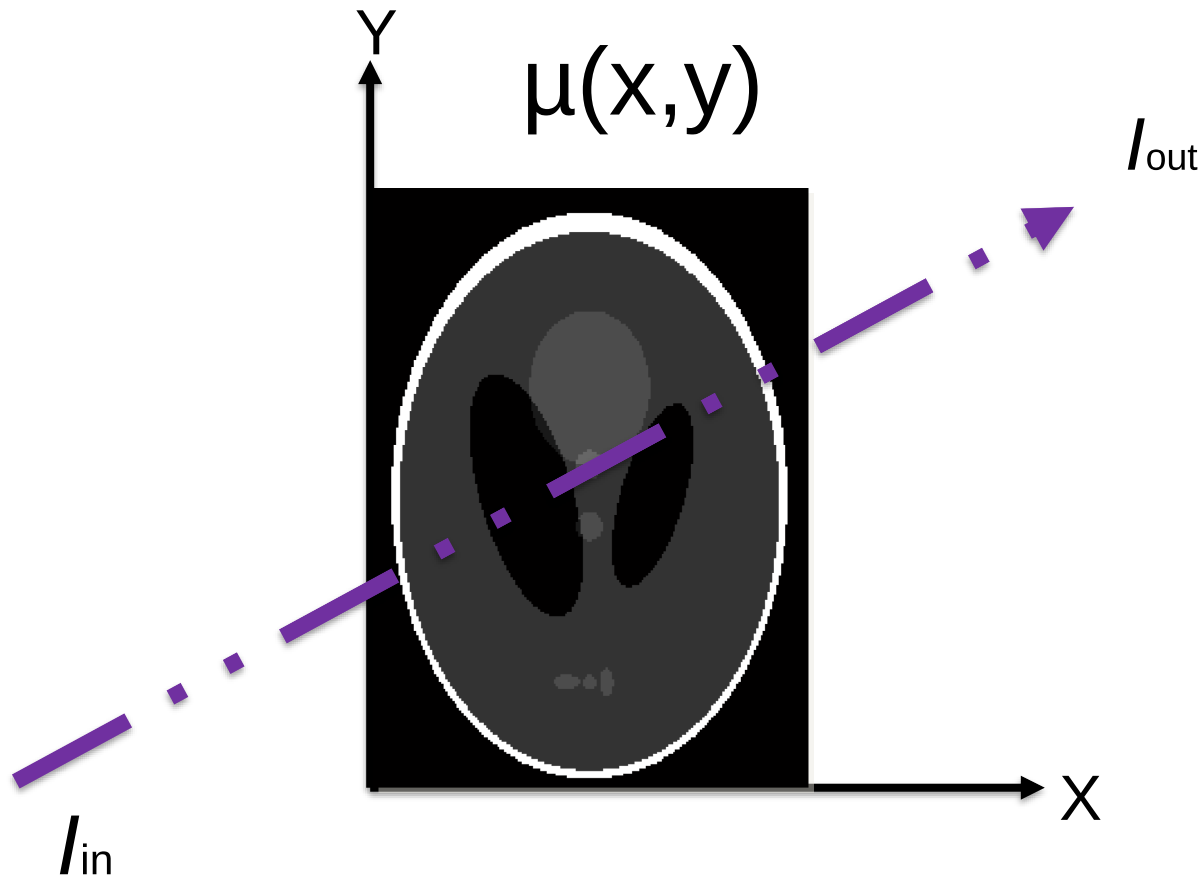
CT makes a map of x-ray attenuation

How do we go from planar to 3D?

- How do we go from planar to cross-sectional or volumetric?



MATHEM
ATICS



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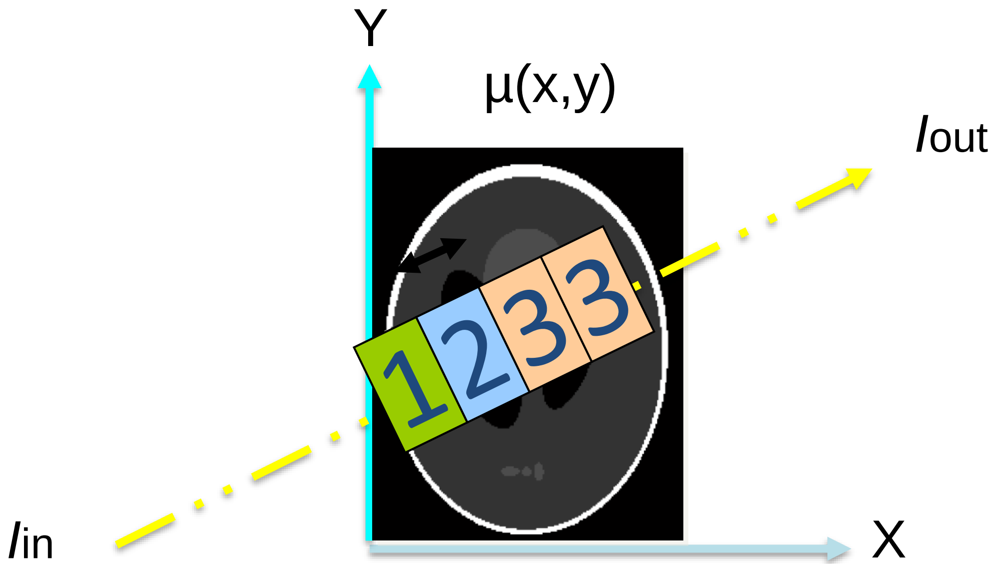


$$I_{out} < I_{in}$$

$$I_{out} = I_{in} \times Transmission$$

$$I_{out} = I_{in} e^{-\int \mu(x,y)dl}$$

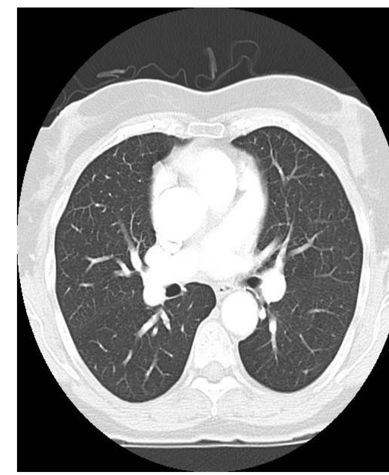
$$I_{out} = I_{in} e^{-(\mu_1 l + \mu_2 l + \mu_3 l + \mu_3 l)}$$

$$-\log \frac{I_{out}}{I_{in}} = \int \mu(x,y)dl$$

$$-\log \frac{I_{out}}{I_{in}} = \int \mu(x, y)\,dl$$

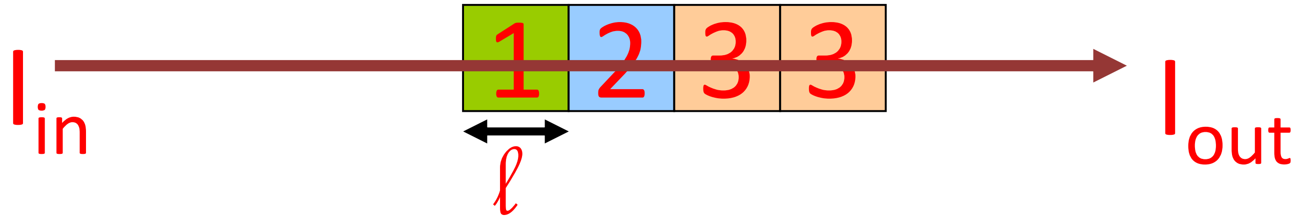
Image Reconstruction Algorithm

$$\mu(x, y)$$



This approach was adapted and generalized from cross-sectional CT to volumetric CBCT

Image Reconstruction

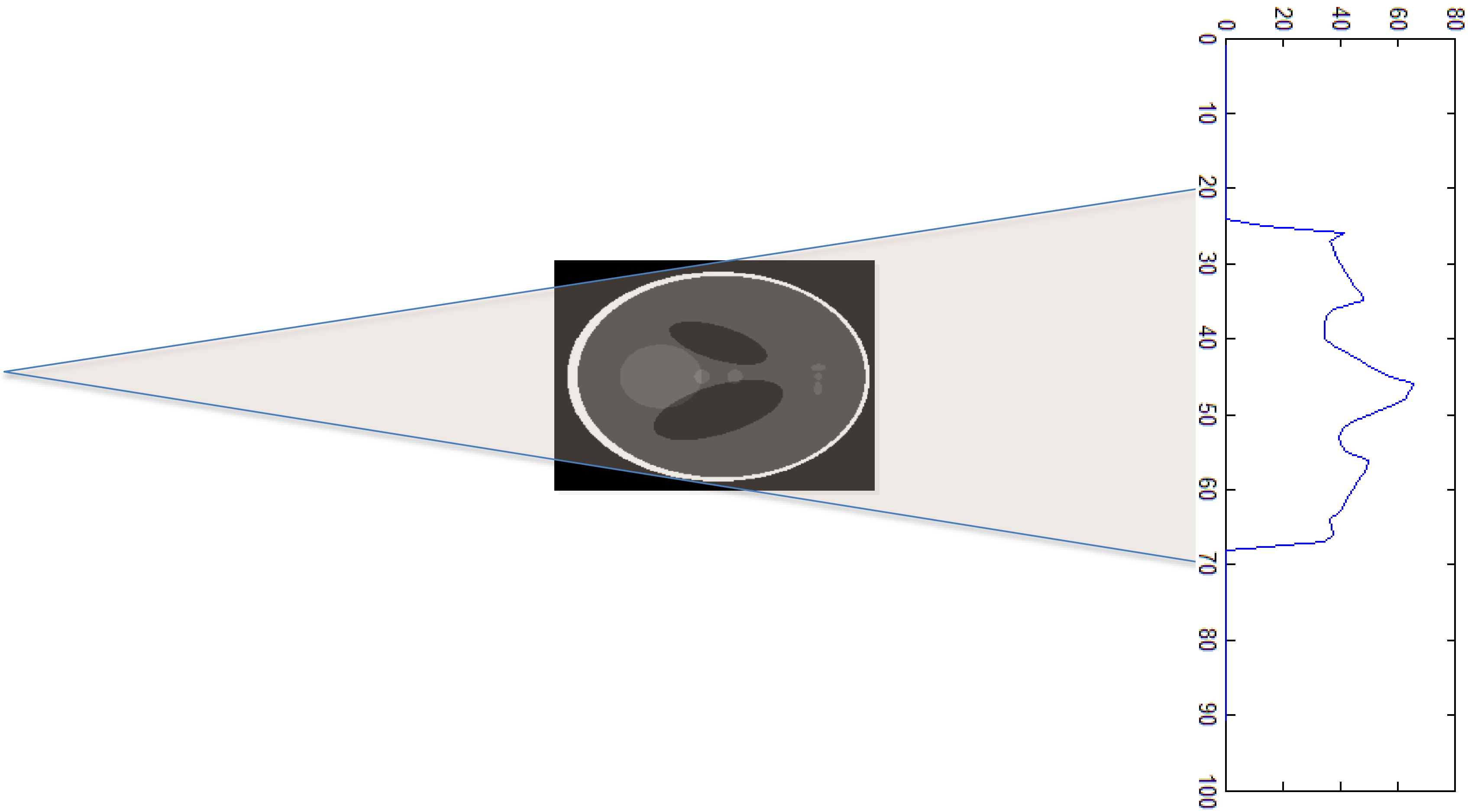


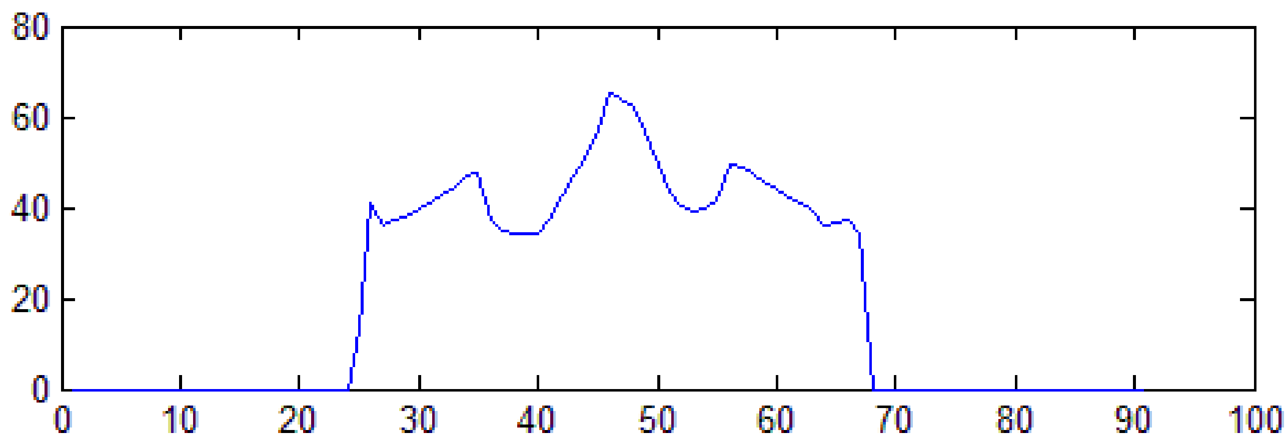
$$I_{out} = I_{in} e^{-(\mu_1 l + \mu_2 l + \mu_3 l + \mu_3 l)}$$

$$P = -\ln\left(\frac{I_{out}}{I_{in}}\right) = \mu_1 l + \mu_2 l + 2 \cdot \mu_3 l$$

$$P = (\mu_1 + \mu_2 + 2 \cdot \mu_3) l$$

The projection is equivalent to a mathematical operation called the ***Radon Transform***


0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80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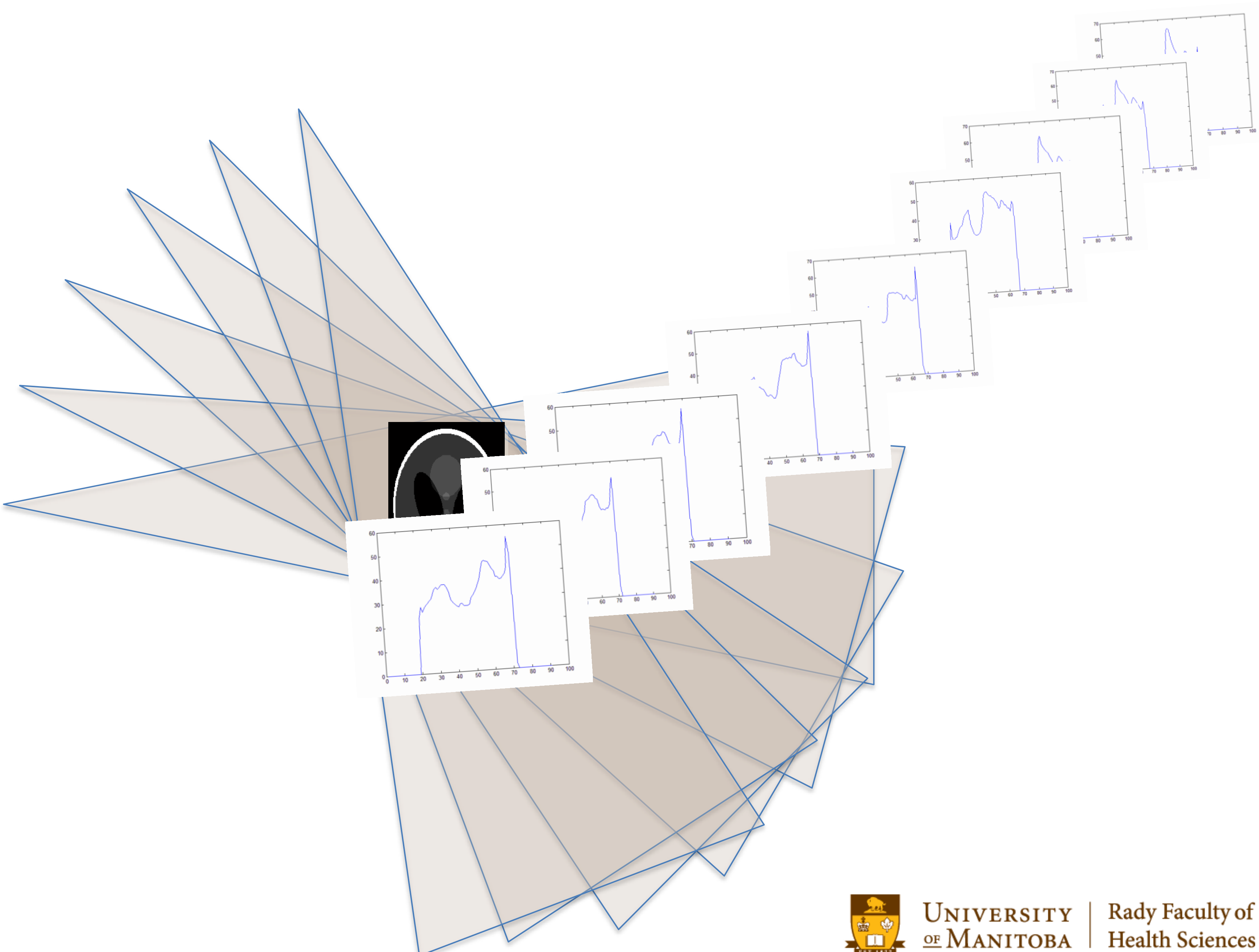
80
90
100


60
50
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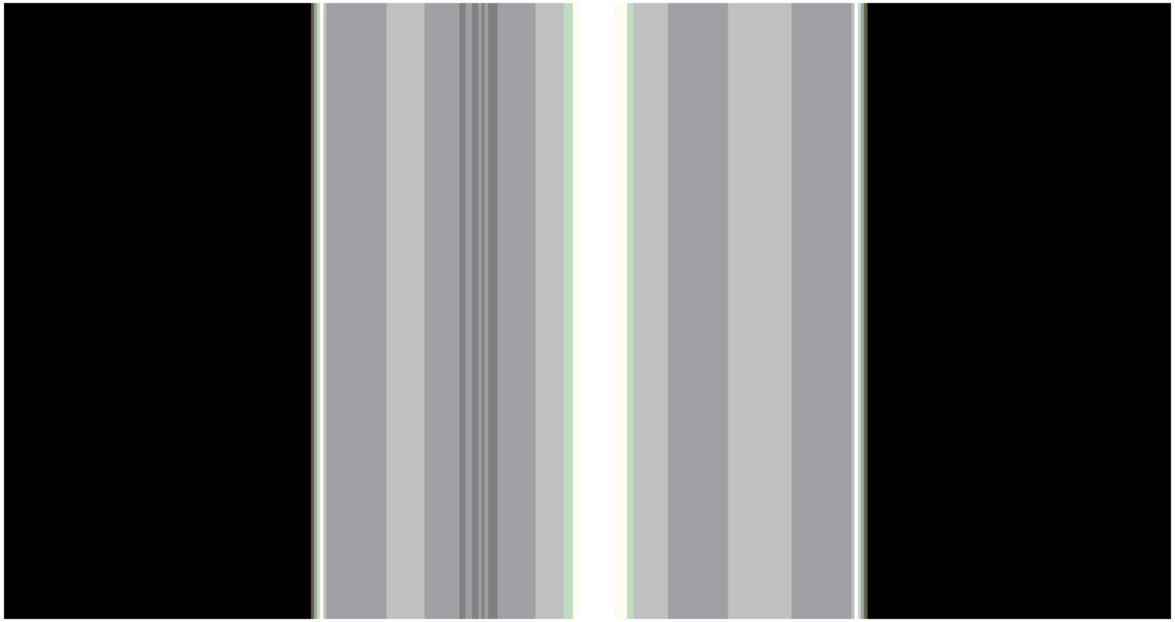
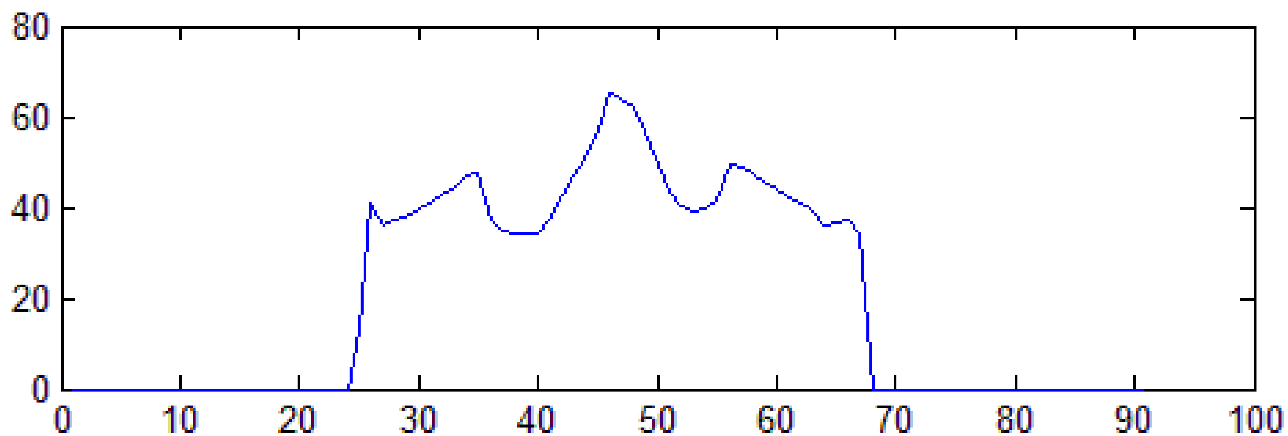
0
0 10 20 30 40 50 60 70 80 90 100




80
60
40
20
0
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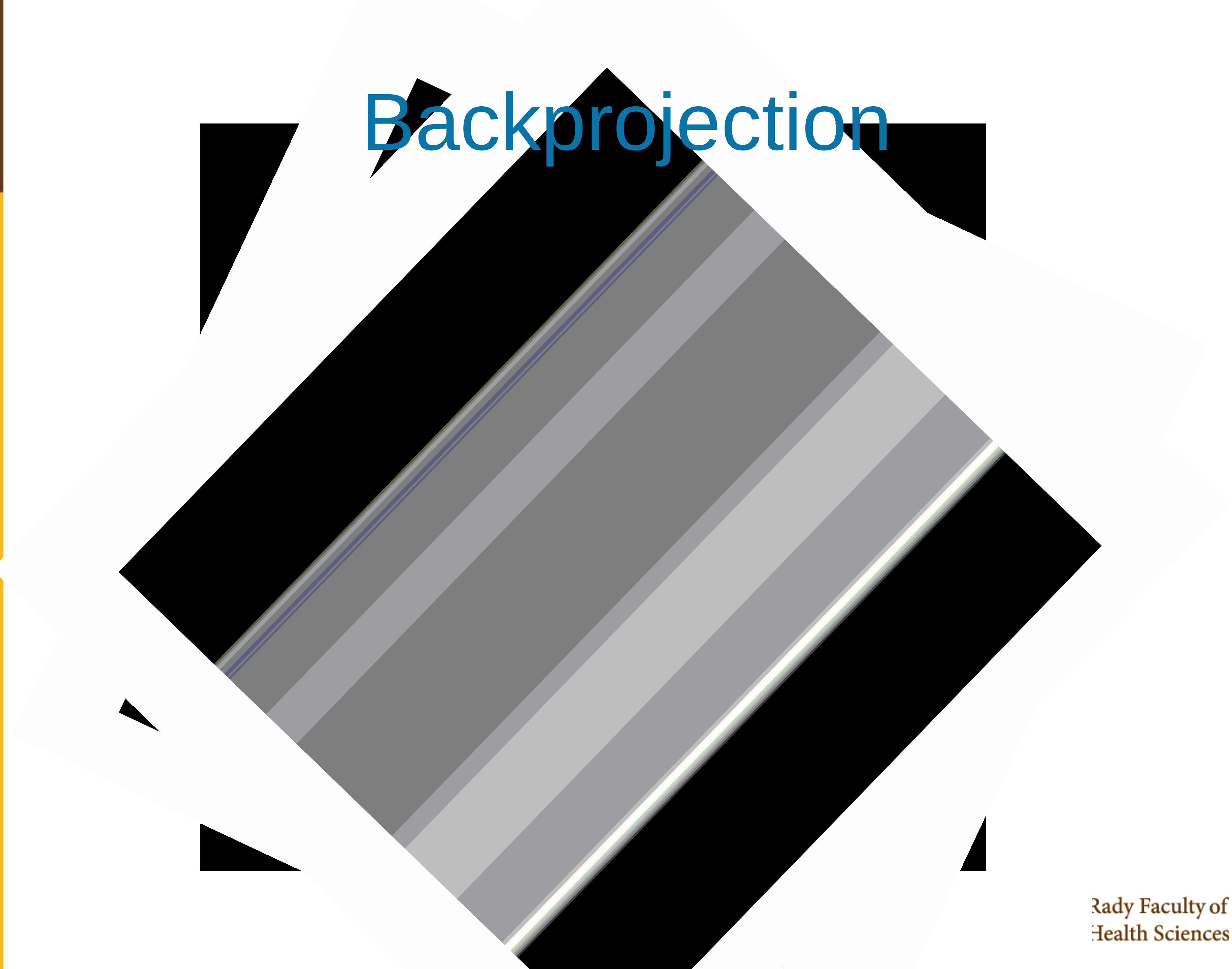
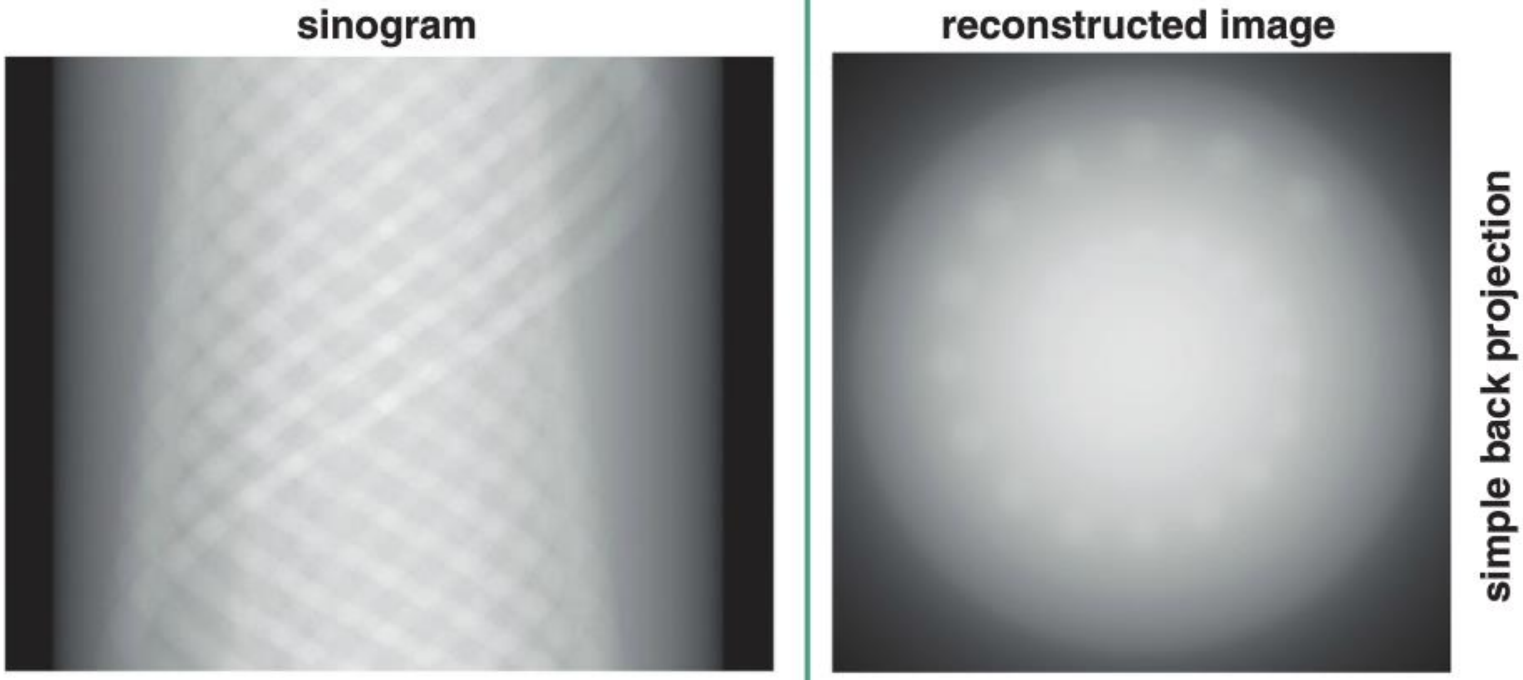
10
20
30
40
50
60
70
80
90
100

Backprojection



Filtered Backprojection



of
es

Bushberg et al. Essential Physics of Medical Imaging. 3rd edition, Fig 10-52

CBCT Image Reconstruction

- Filtered back projection (FBP) is based on the Radon Transform. The math was developed way before the invention of CT.
- Cone-beam CT requires a generalization of FBP to allow for the volumetric geometry.
- The generalization is called the Feldkamp algorithm.

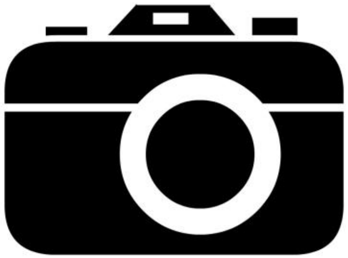
Questions

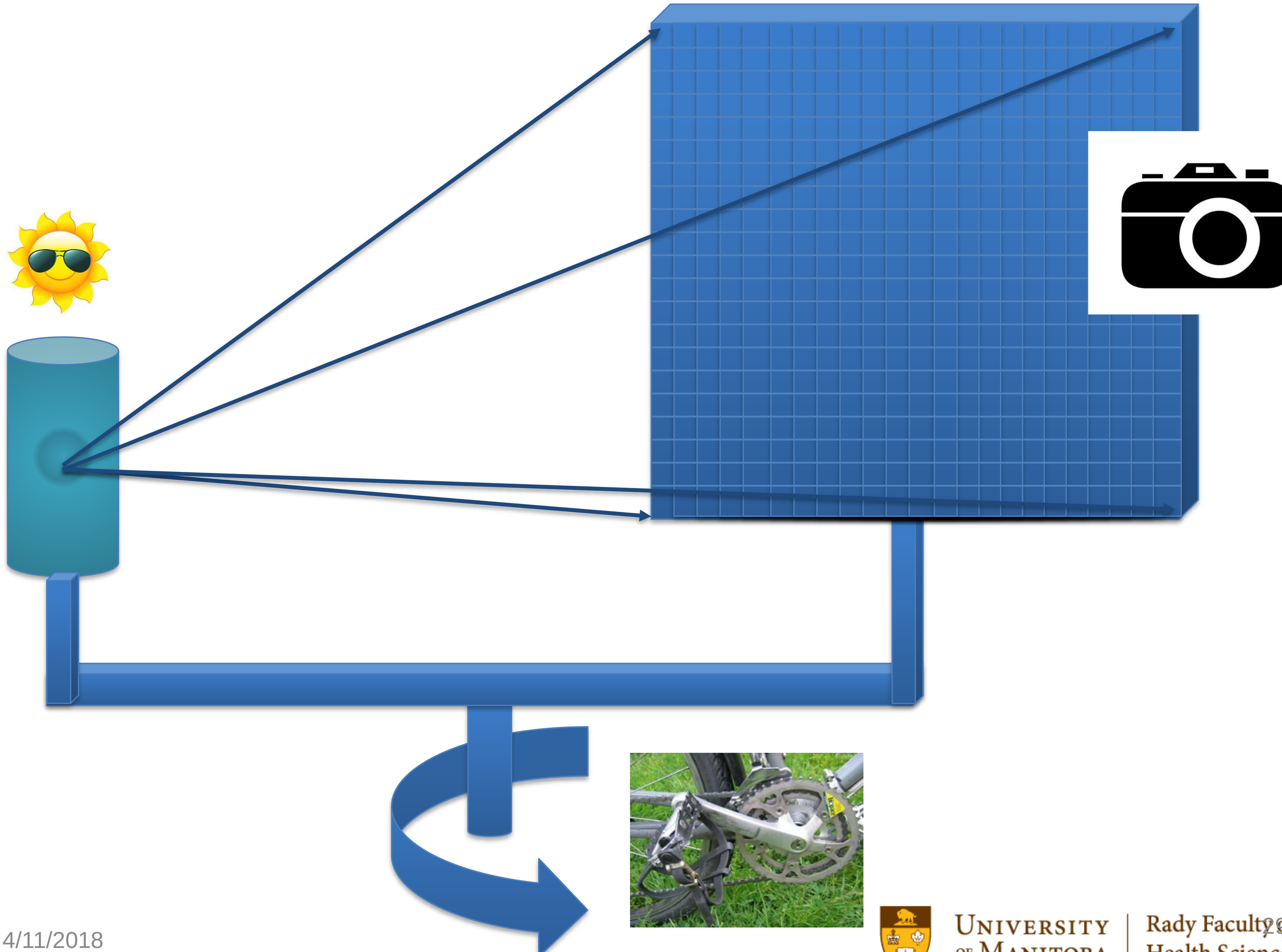
- The fundamental measurement made by a CT scanner is the:
  a) Sorting of CT numbers
  b) Determination of gray scale
  c) Pixel density
  d) X-ray attenuation
  e) Voxel atomic number

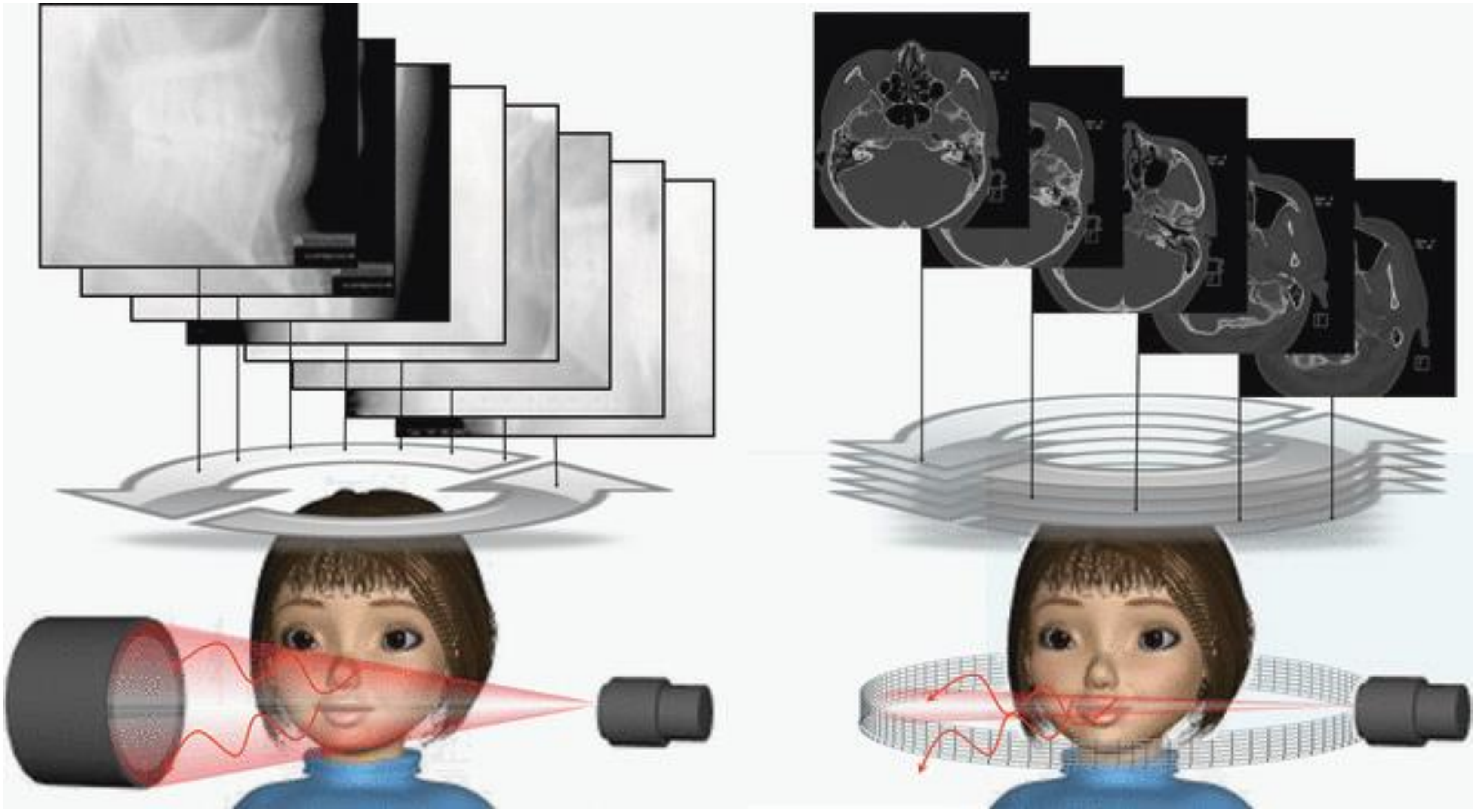
- The measured x-ray transmissions from a single angle through the patient is called a:

a) Panoramic image
b) Tomographic slice
c) Primary beam
d) Projection

To take a photo, you need…

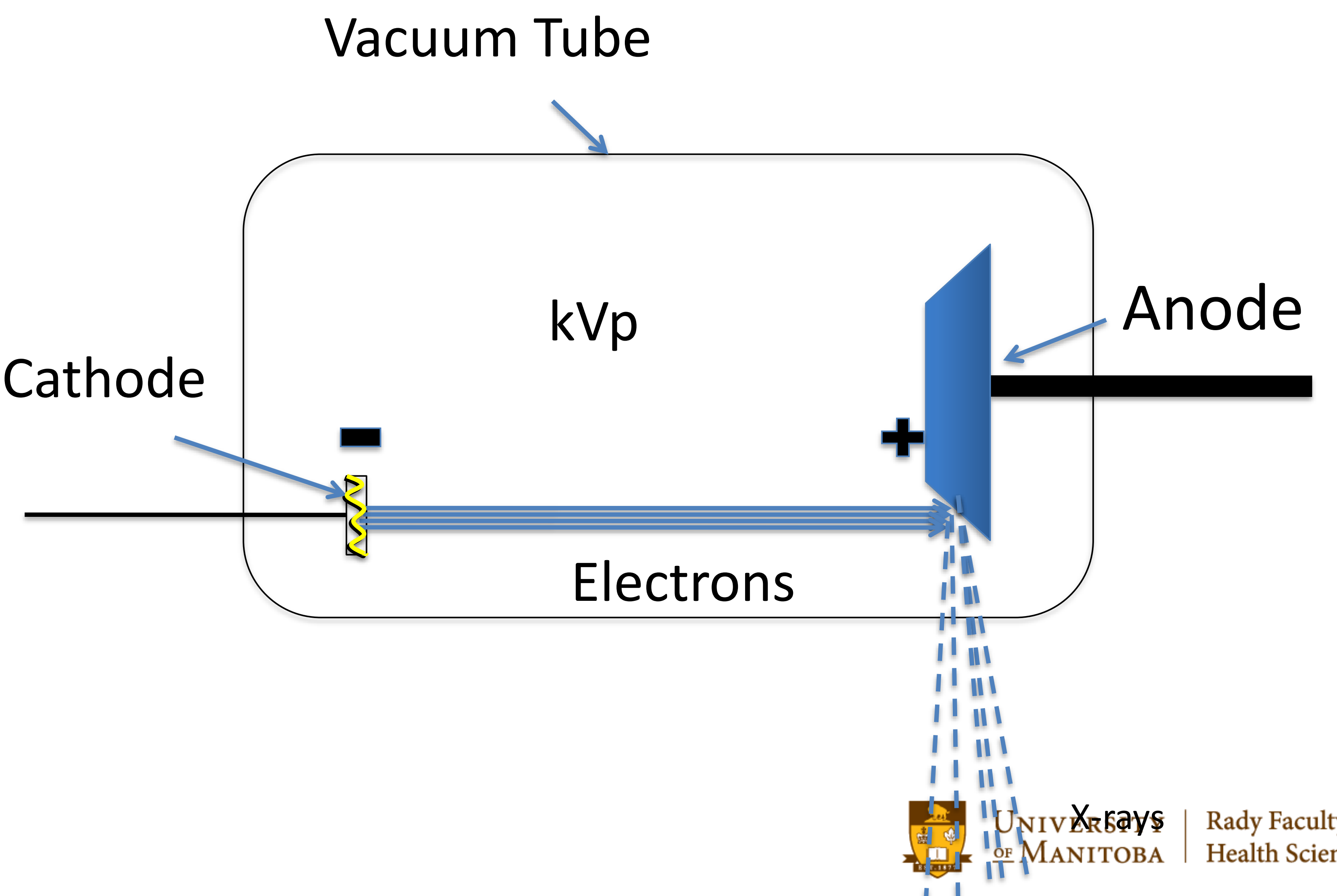


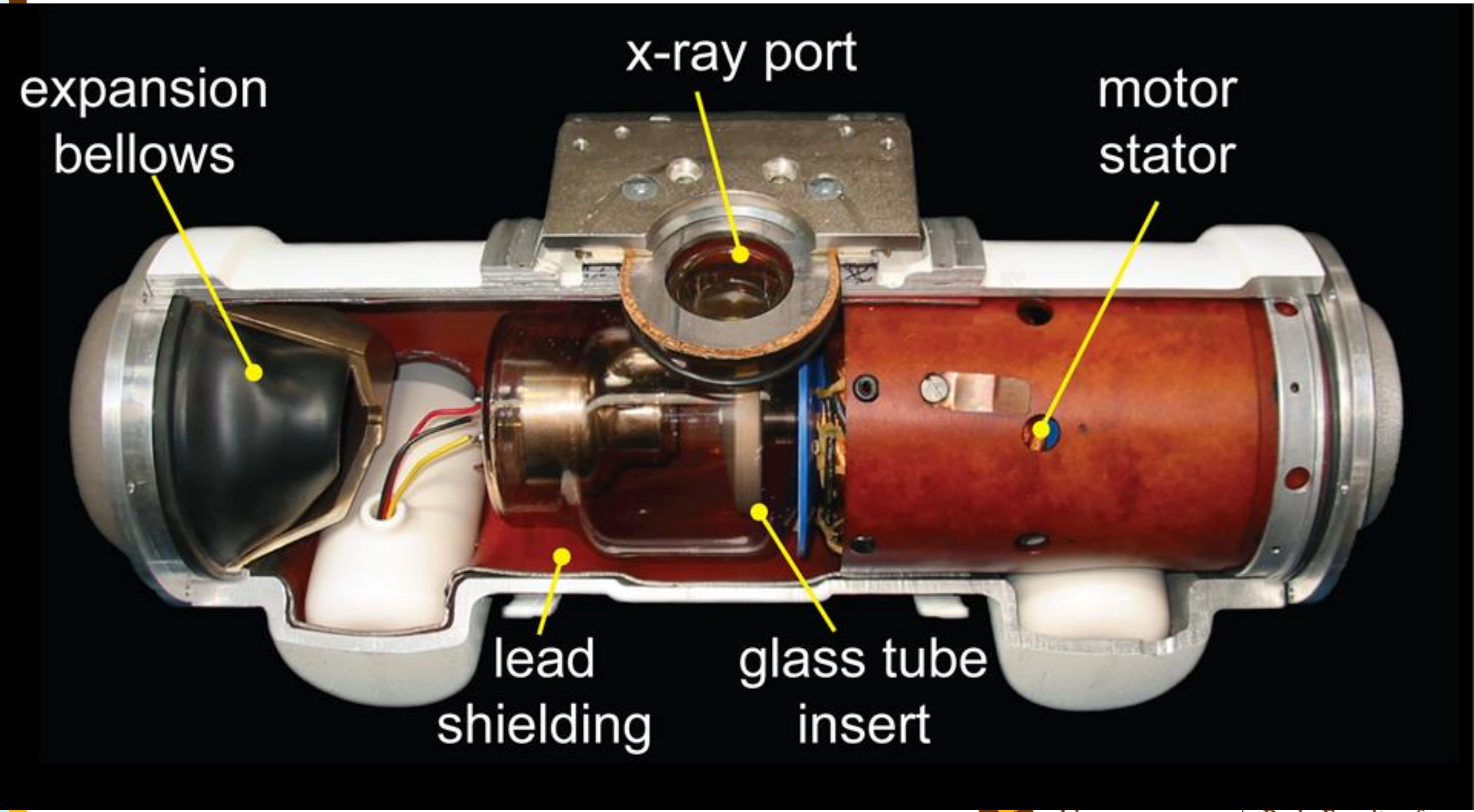




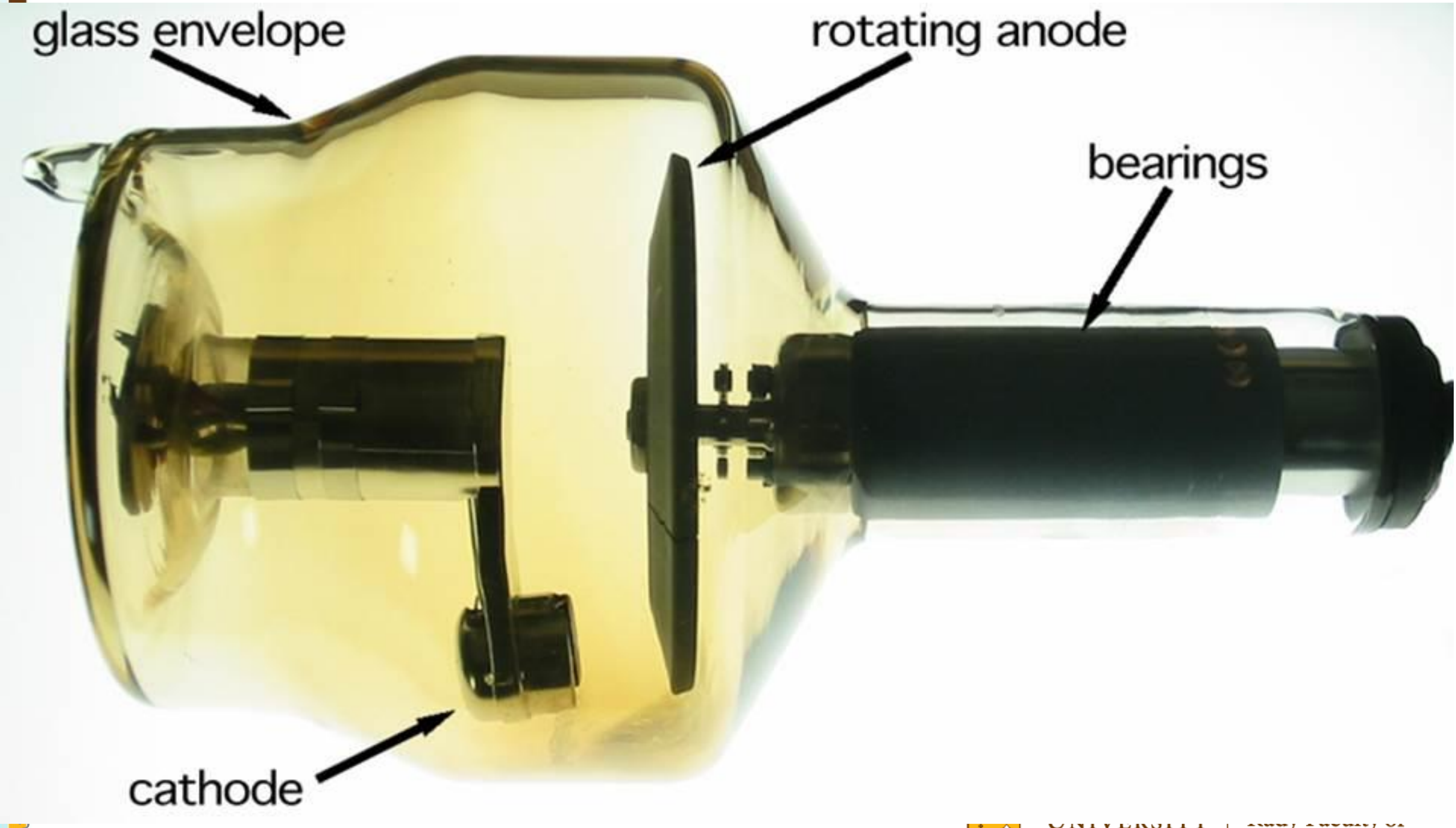
Australian Dental Journal
pages 46-60, 29 FEB 2012 DOI: 10.1111/j.1834-7819.2011.01657.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1834-7819.2011.01657.x/full#f1

X-ray Tube

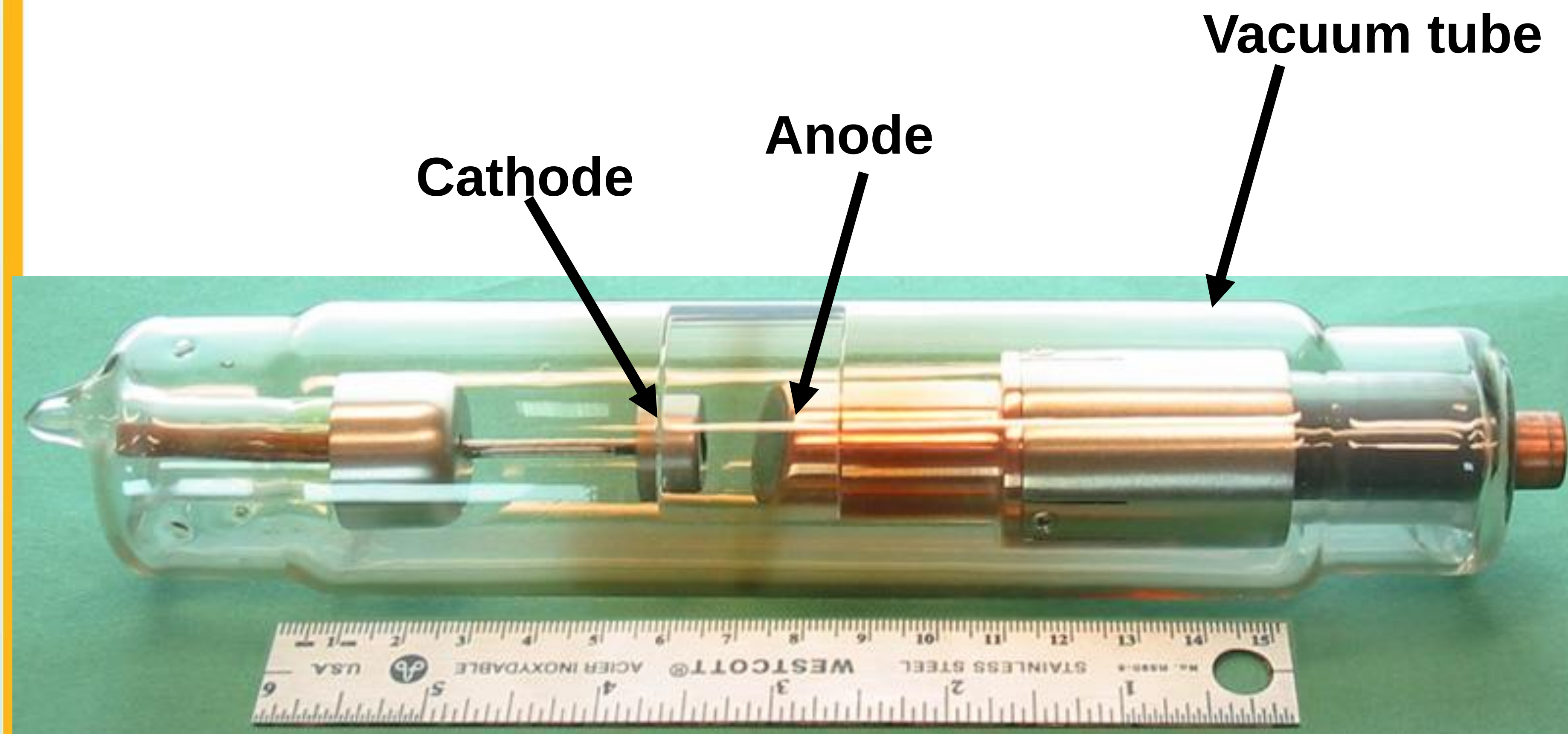



expansion bellows
x-ray port
motor stator
lead shielding
glass tube insert

Rotating Anode X-ray Tube



Fixed Anode X-ray Tube



X-Ray Tube Filament (Cathode)

hot filament

X-ray Detector

- Interacts with x-rays that penetrate tissue
- Absorbs x-ray energy
- Converts x-ray energy to electronic signal
- Reads, amplifies and digitizes
- Two main technologies used in CBCT
  - Image Intensifiers
  - Digital flat panels

The Image Intensifier (II)

- II converts x-rays into optical image:
  - Evacuated enclosure (glass, Al)
  - Input phosphor to convert the x-ray signal to light
  - Photocathode to covert light to electrons
  - Electronic lens to focus the electrons
  - Output phosphor to convert the electrons to visible light
  - Fibre-optic coupling of light to CCD camera

Image Intensifiers

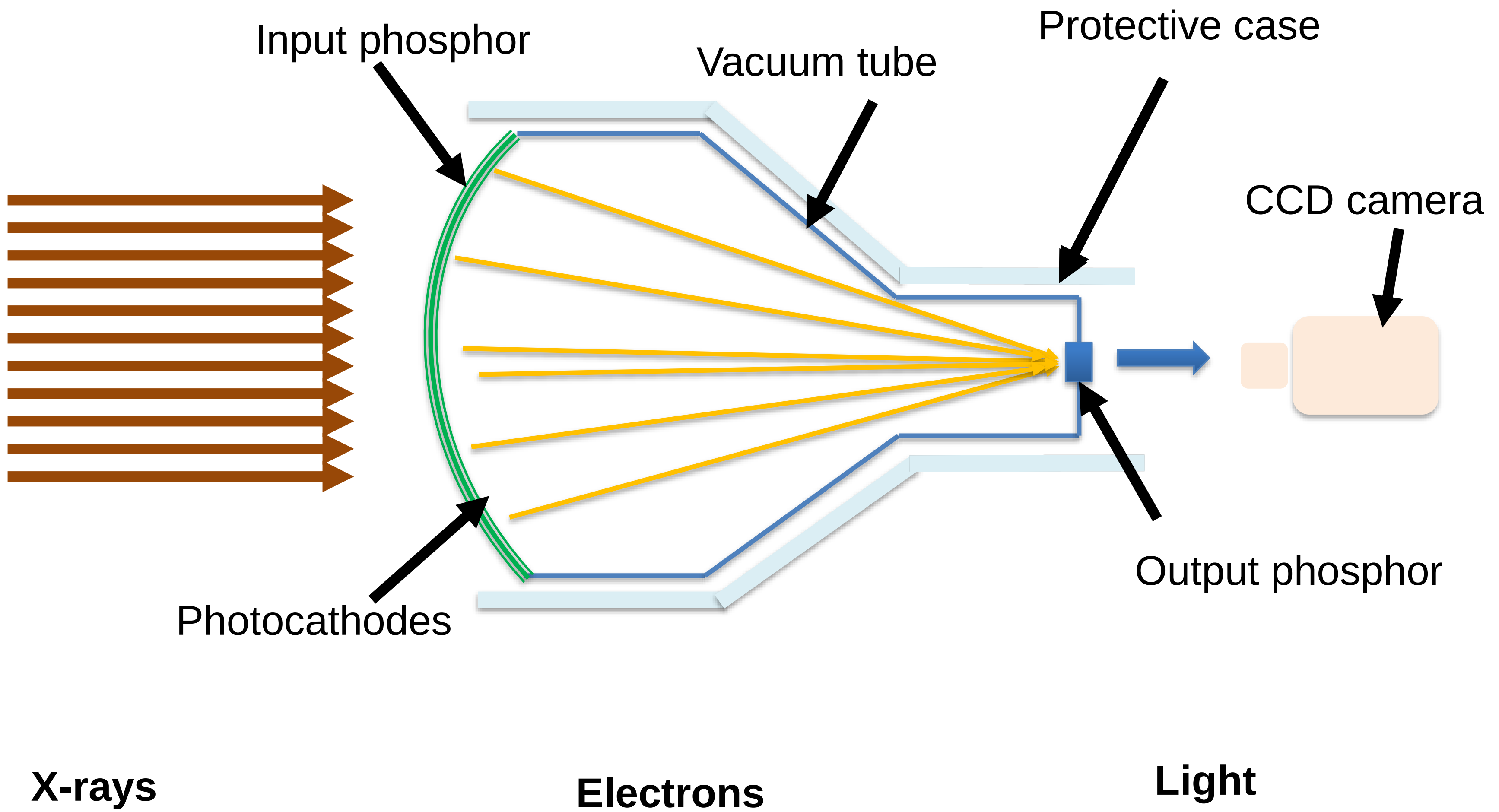
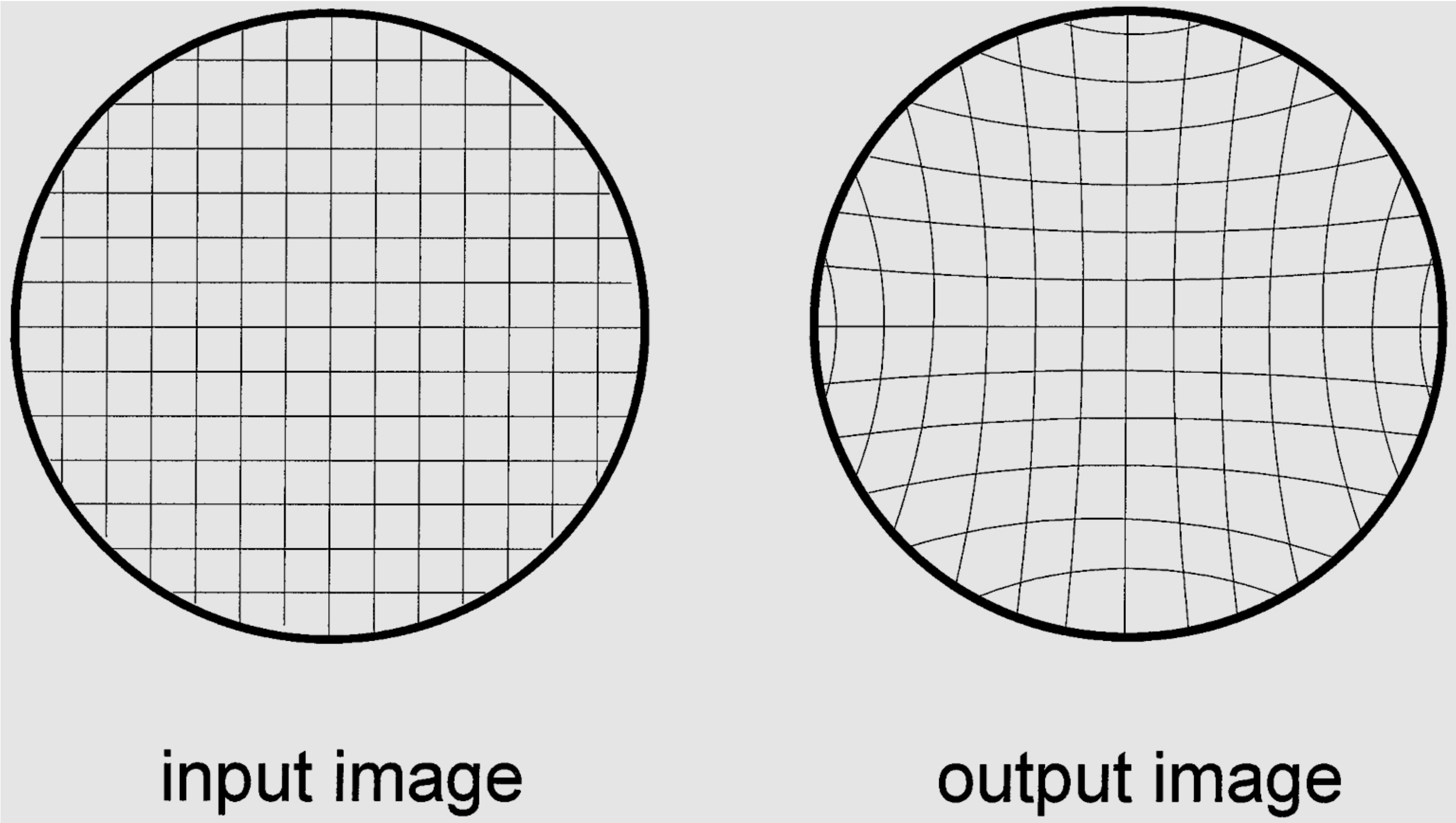


Image Intensifiers

- X-ray signal is *"intensified"* through an electric field and then converted to optical image
- Image distortion is a problem
- Detector system bulky

Electronic Focusing

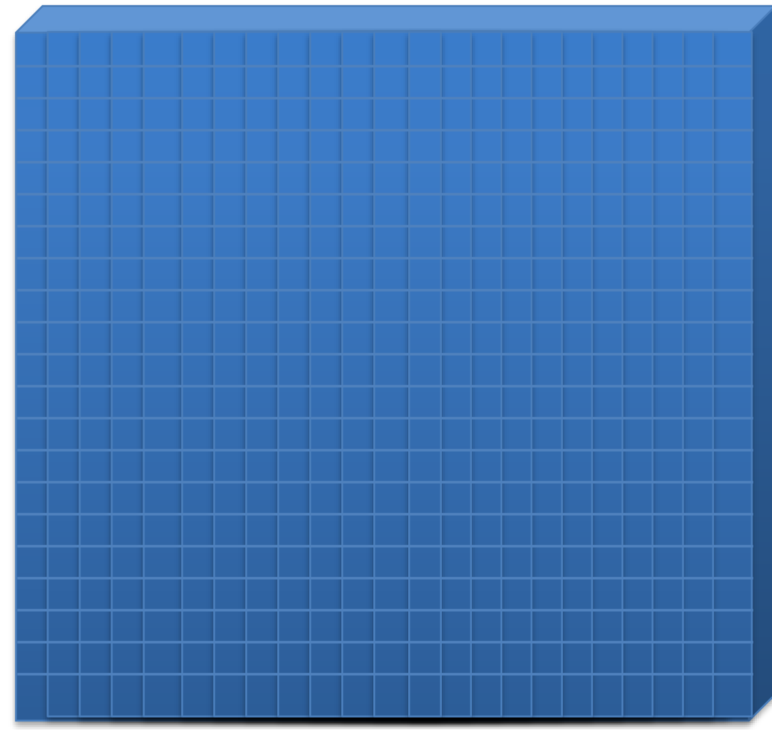


c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed., p. 235.

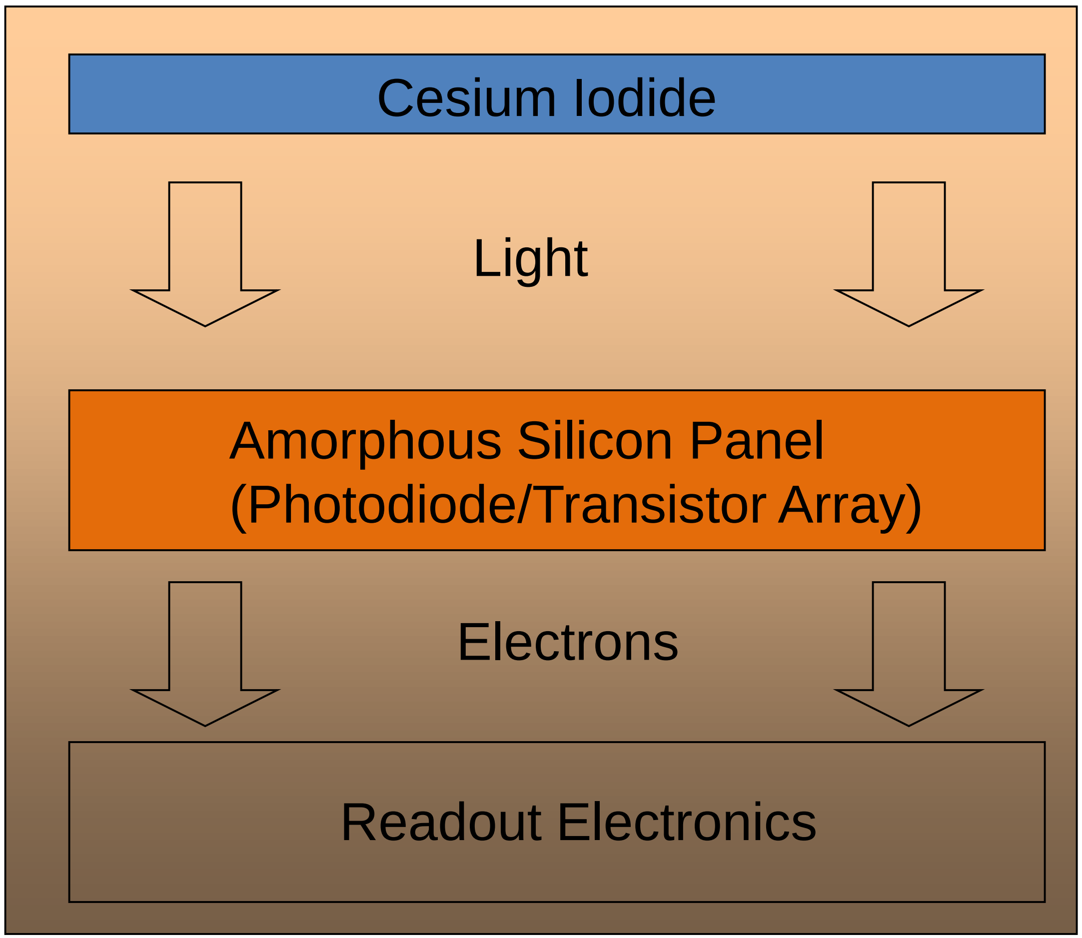
Source: www.sirona.com

Indirect Detection Flat Panel

- Large-area amorphous silicon TFT plate
- Phosphor layer converts x-rays to light.
- Array of small light-sensitive photodiodes converts light to electric charge
- Electric charge transmitted through complex electronics



Indirect Detection Flat Panel

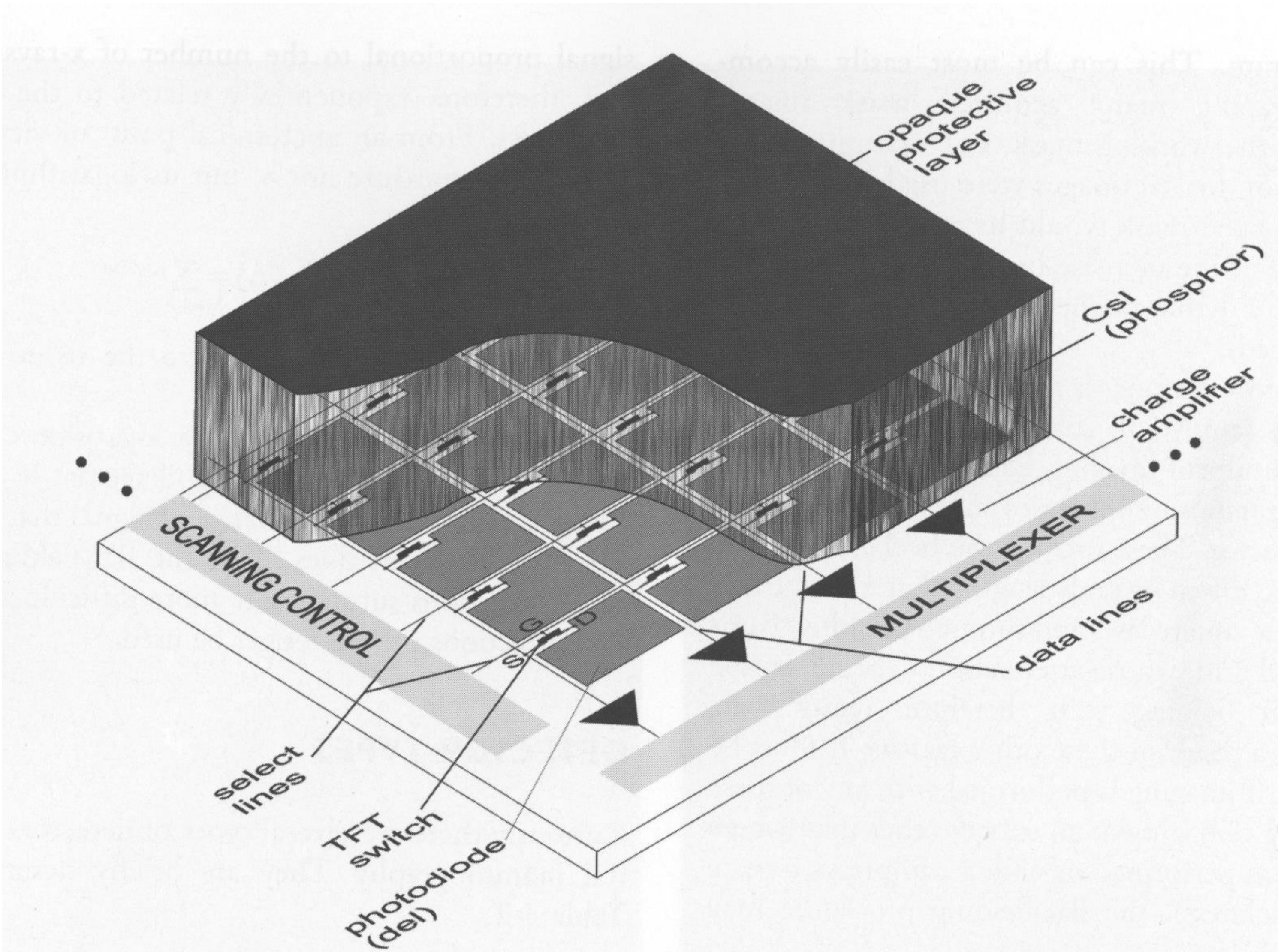


CsI scintillator absorbs X-rays and converts them to light

Photodiode array absorbs light and converts it into electrons

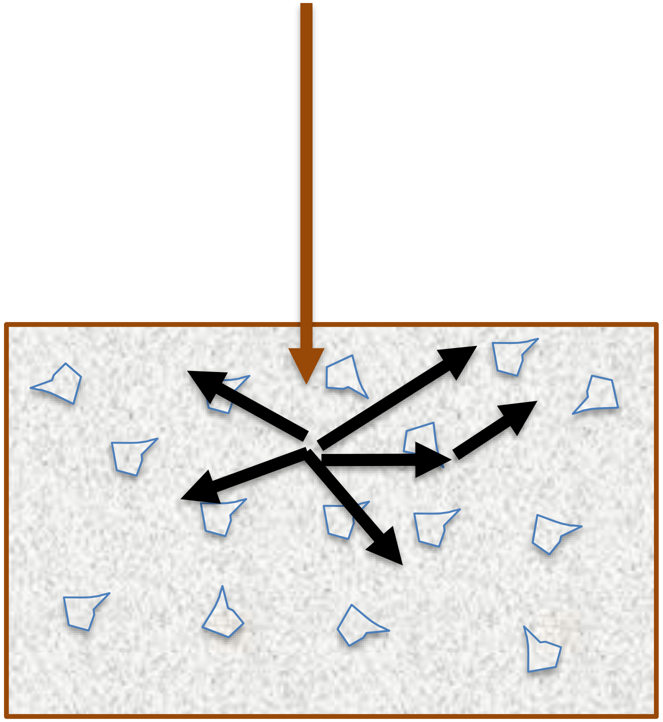
Electronic read out

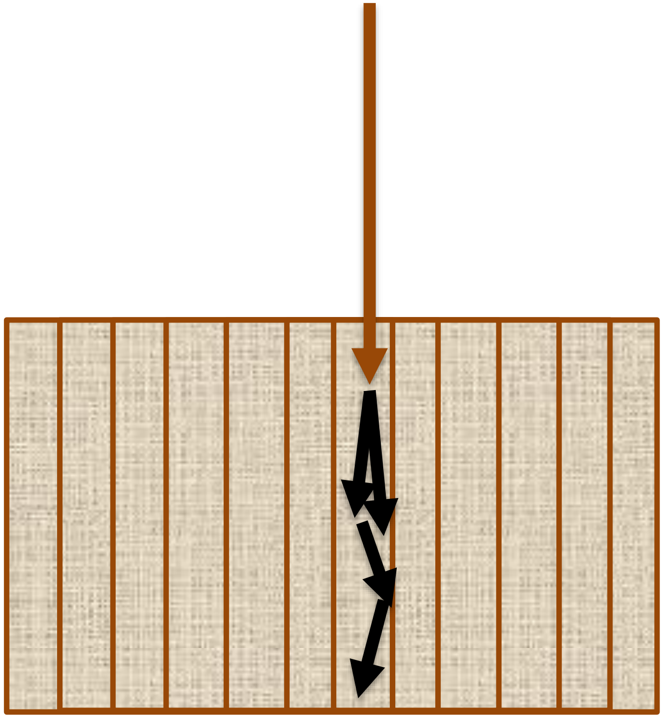
Amorphous Silicon Flat Panel



Digital Mammography, Pisano, Yaffe and Kuzmiak, LW&W 2004

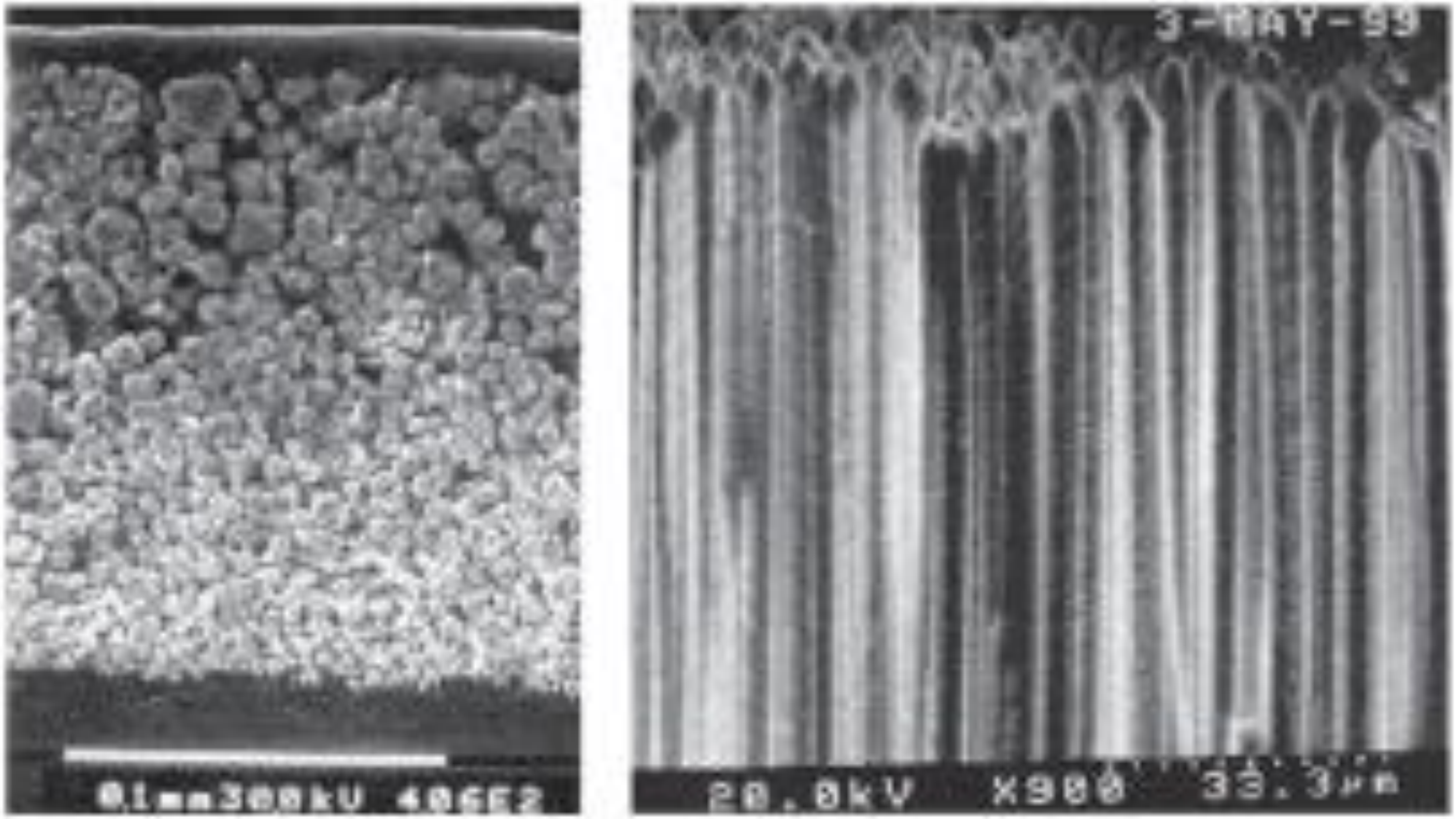
Scintillators





Gadox
Lower cost, higher dose, lower resolution

CsI
Higer cost, lower dose, higher resolution



Yorkston, Advanced in Digital Radiography, RSNA 2003

Flat Panel Detectors

- No geometric distortion
- Less prone to artifacts
- Compact packaging
- More sensitive to x-rays than II’s
- More expensive than II’s

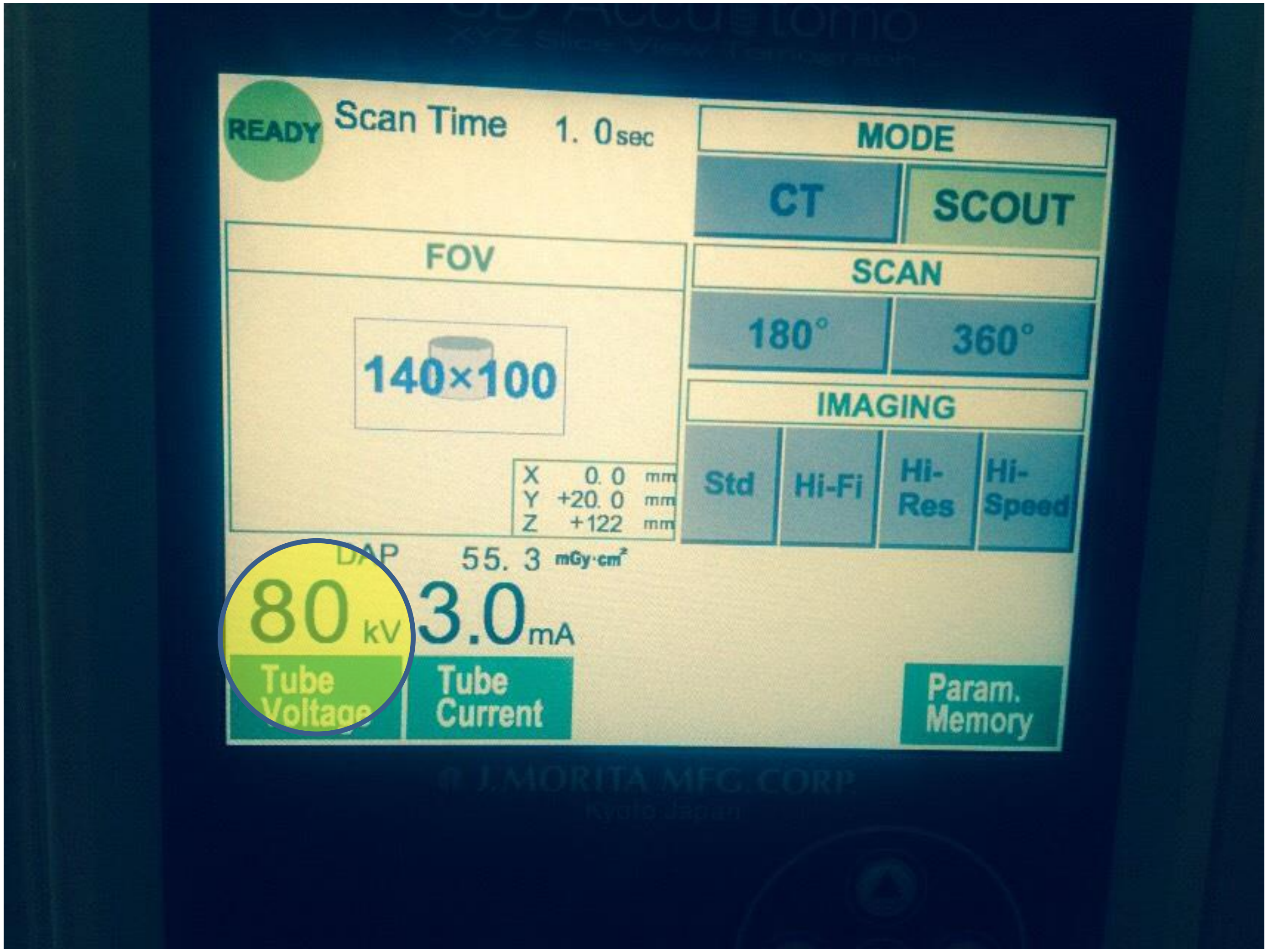
CT Image Formation Steps

- X-ray tube generates x-rays which traverse the patient and are absorbed in the detector.
- The detector and the digital acquisition system converts x-rays to electronic signal.
- X-ray tube and detector assembly rotate around the patient, repeating the process over 360 degrees.

CT Image Formation

- The projection data acquired over 360 degrees is processed mathematically to generate cross sectional images.
- The image is a matrix of pixels/voxels with gray levels representing the attenuation coefficient
- The image is displayed by converting the pixel values to brightness on the monitor.

Acquisition Parameters



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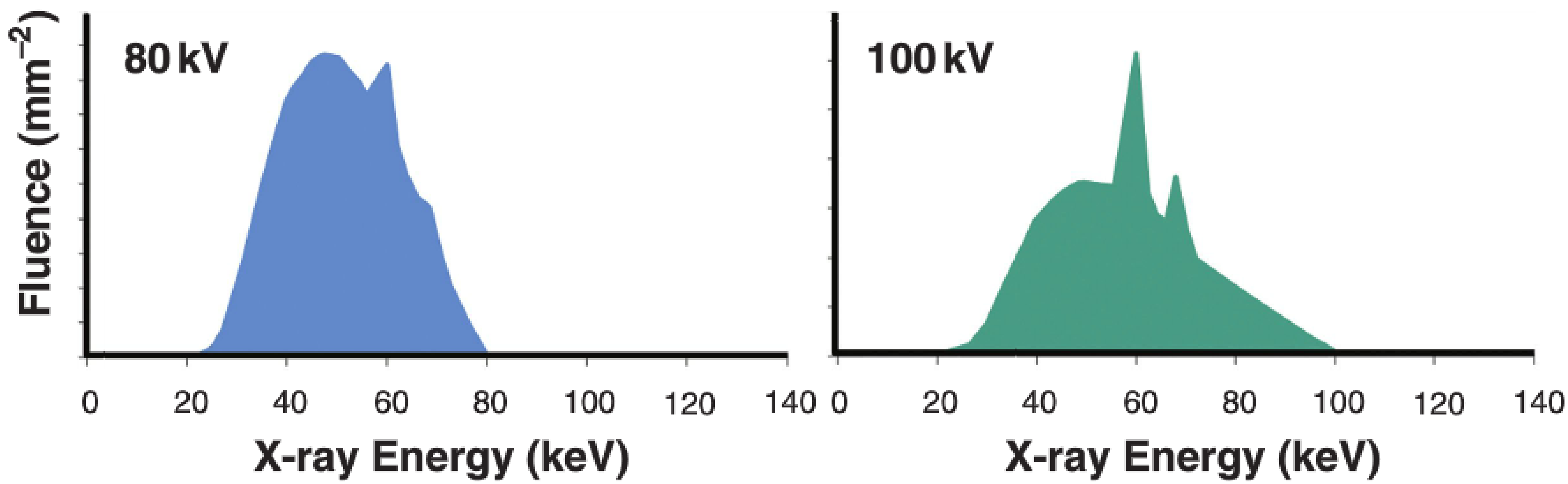
Tube Voltage

- Tube voltage, tube potential, kVp (kilo volts peak)
- The voltage applied in the x-ray tube between the anode and cathode
- Typically 70,000 to 90,000 V
- kVp determines the x-ray energy distribution

kVp and x-ray spectra



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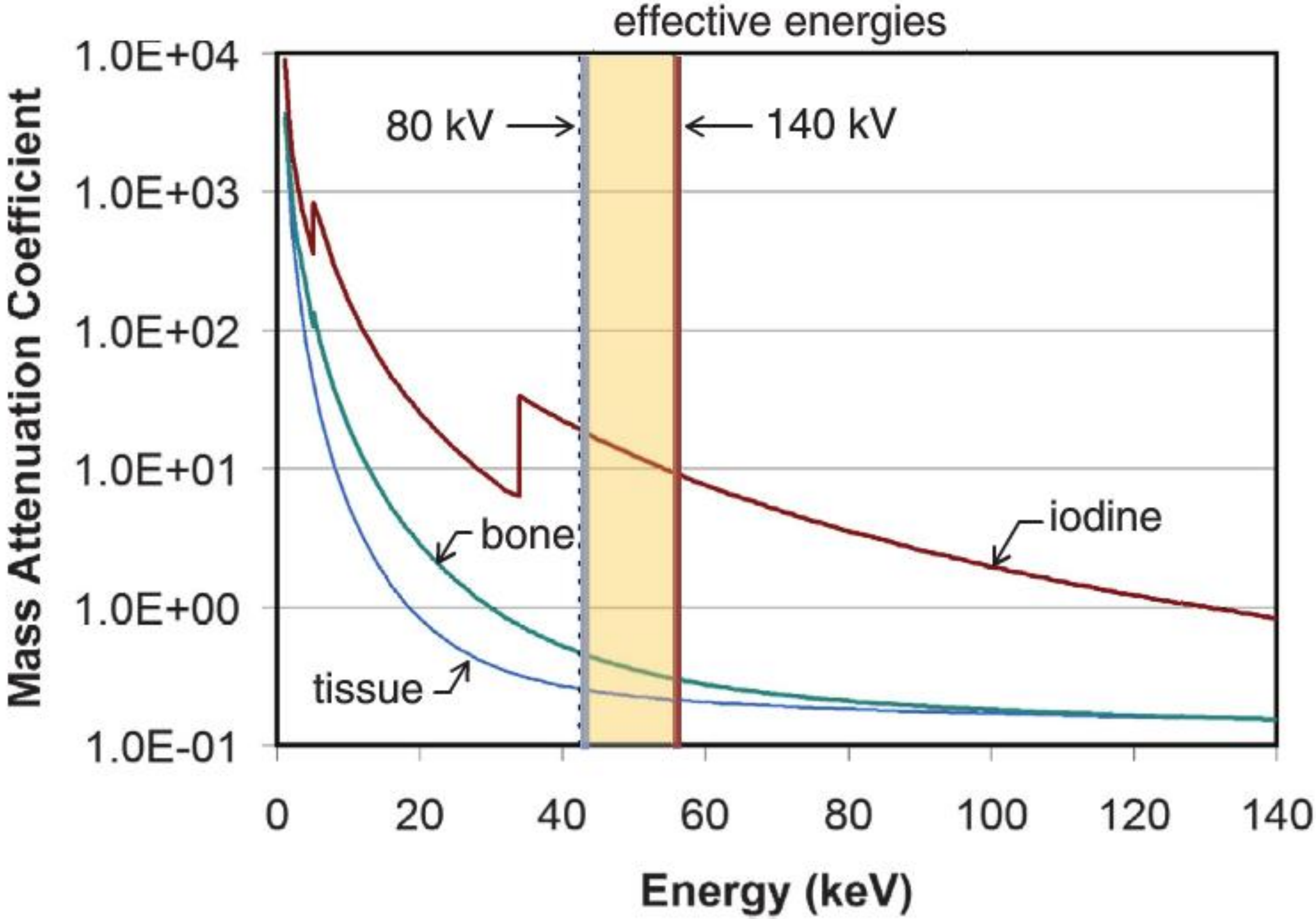
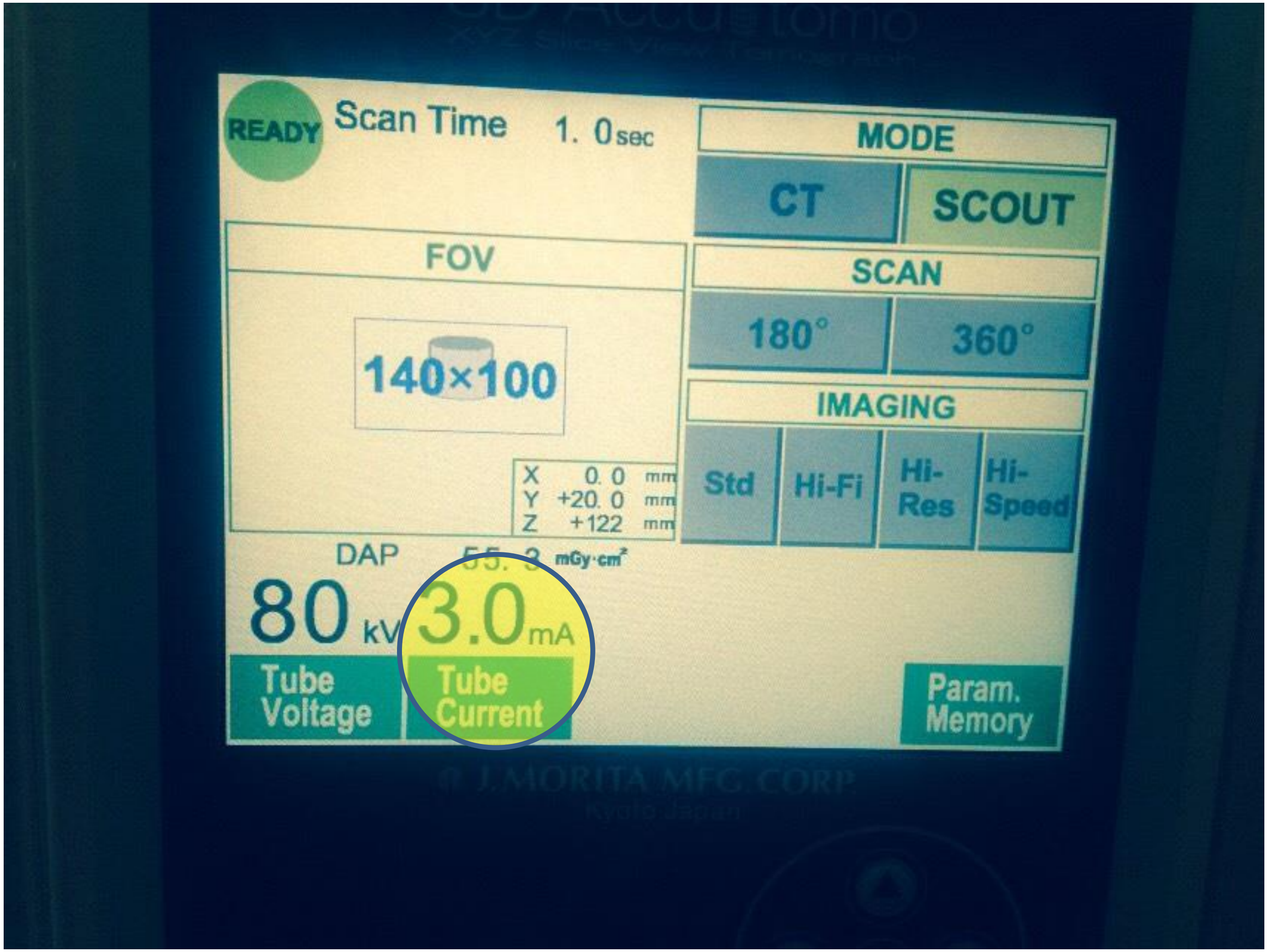


effective energies
80 kV
140 kV
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
Mass Attenuation Coefficient
iodine
bone
tissue
0
20
40
60
80
100
120
140
Energy (keV)

Increase Tube Voltage (kVp)

- Beam energy and penetration:
  - **Increases**. Lower relative beam absorption.
- Dose:
  - **Increases** if all other factors unchanged.
- Image Contrast:
  - **Decreases** because attenuation differential smaller
- Image Noise:
  - **Decreases** if all other factors unchanged.
- Lower dose may be achieved if kVp is increased (less absorption) and mAs decreased (lower tube output).

Acquisition Parameters



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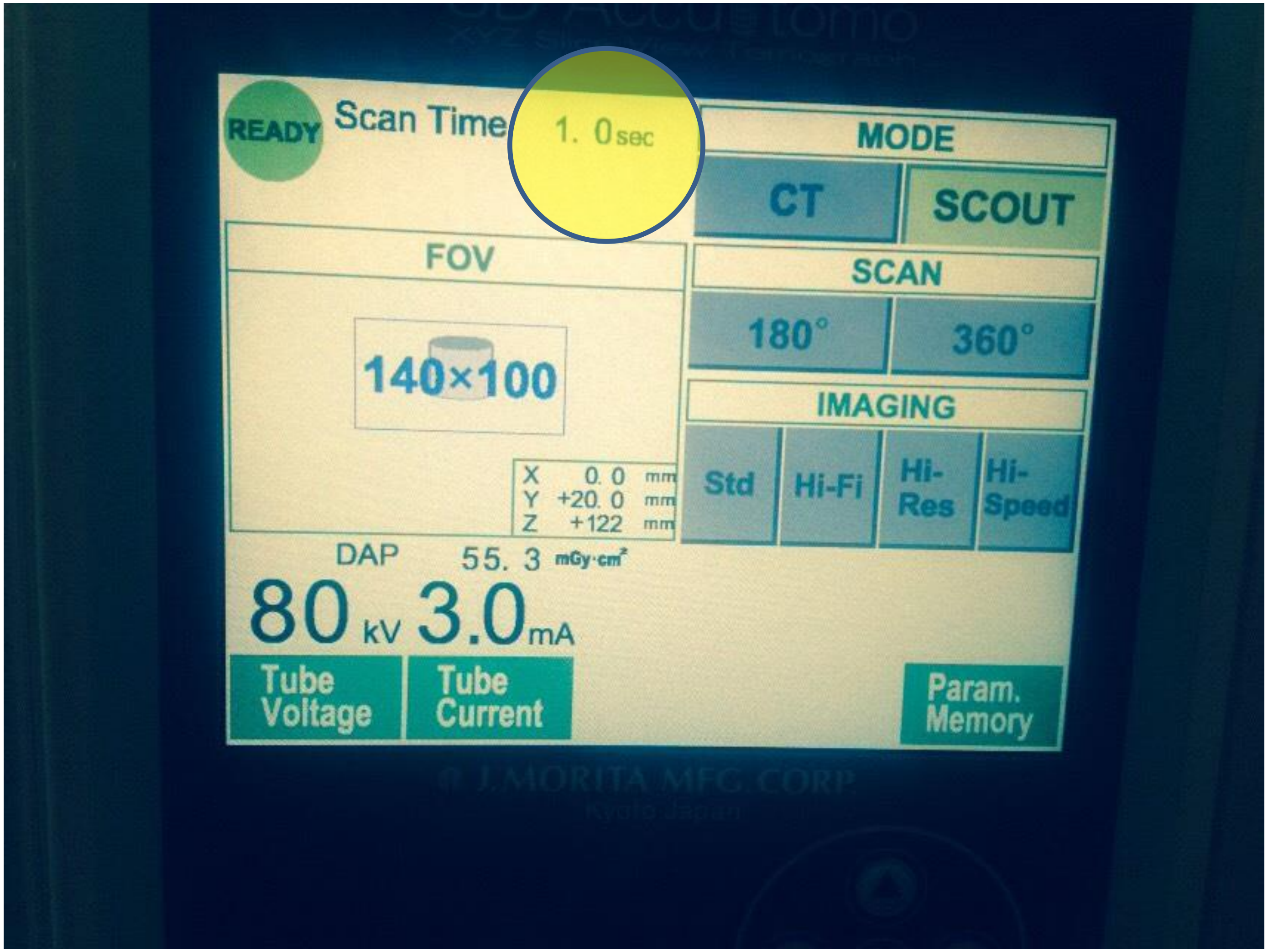
Tube Current (mA)

- kVp affects quality (energy) and quantity (intensity) of the beam.
- Tube current (mA) is the current that flows in the x-ray tube between anode and cathode.
- It determines how many electrons hit the anode target and cause emission of radiation.
- It controls the intensity of radiation.
- Dose is linearly proportional to mA

Tube current

- Higher mA has no effect on beam absorption
- Higher mA increases dose.
- Higher mA improves image quality because image noise is decreased.

Acquisition Parameters



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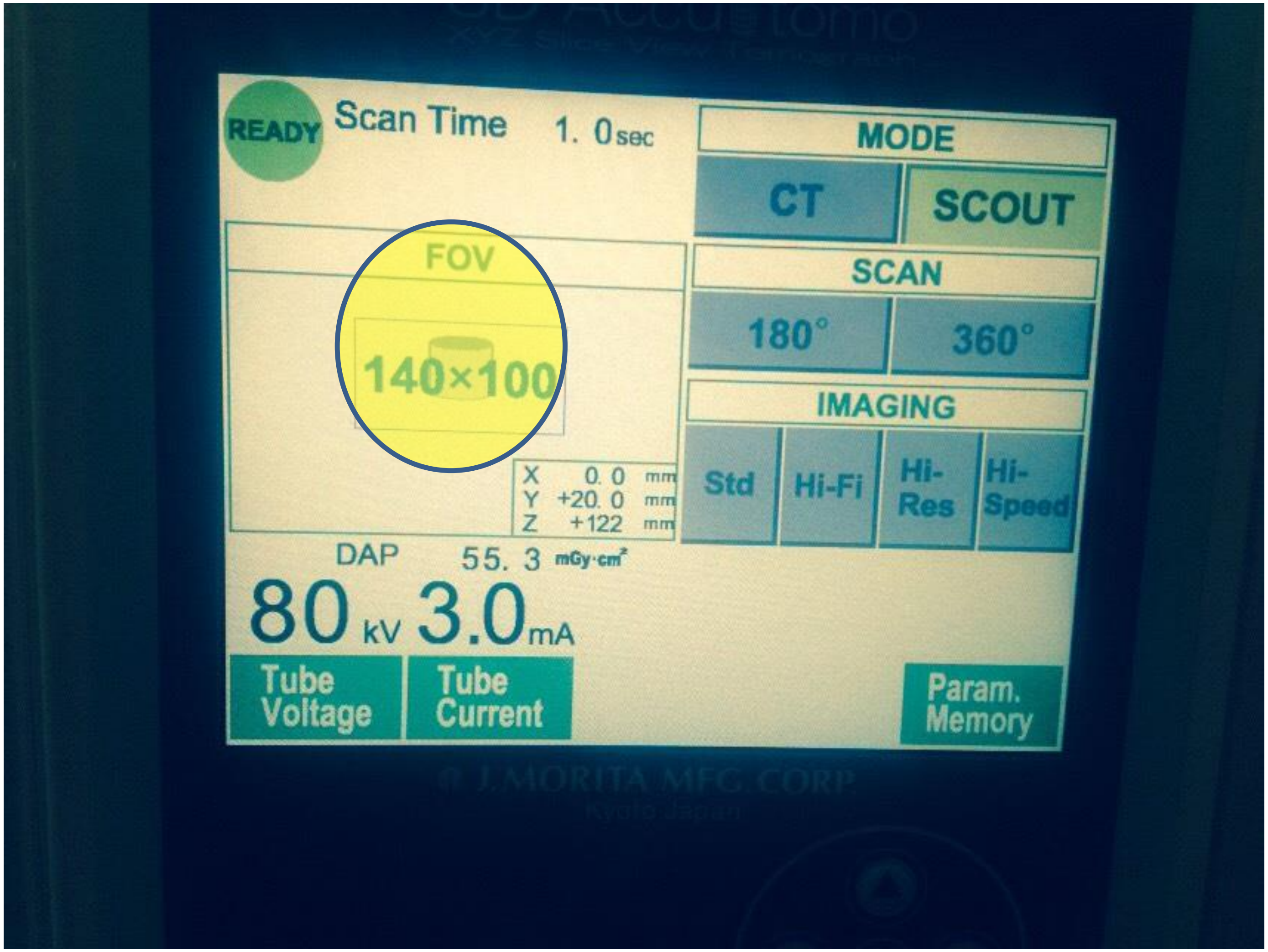
Acquisition Time

- CBCT scan times are much slower than clinical CT (per rotation) (~ 10 sec vs < 1 sec).
- Patient motion during the scan can induce artifacts.
- Longer times increase dose and possibility of artifacts.
- Shorter times increase image noise (because dose is lower).

Acquisition Parameters



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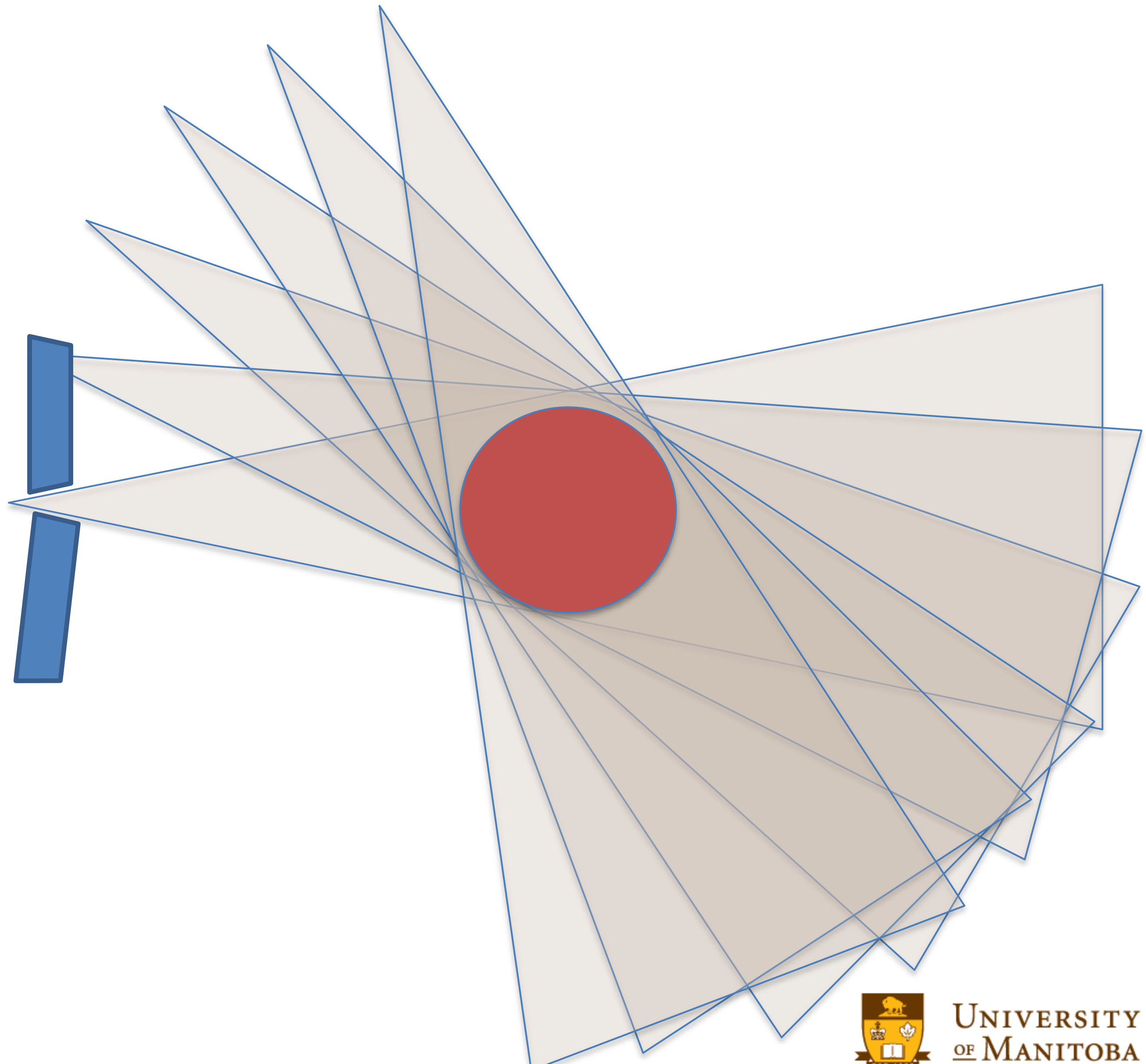
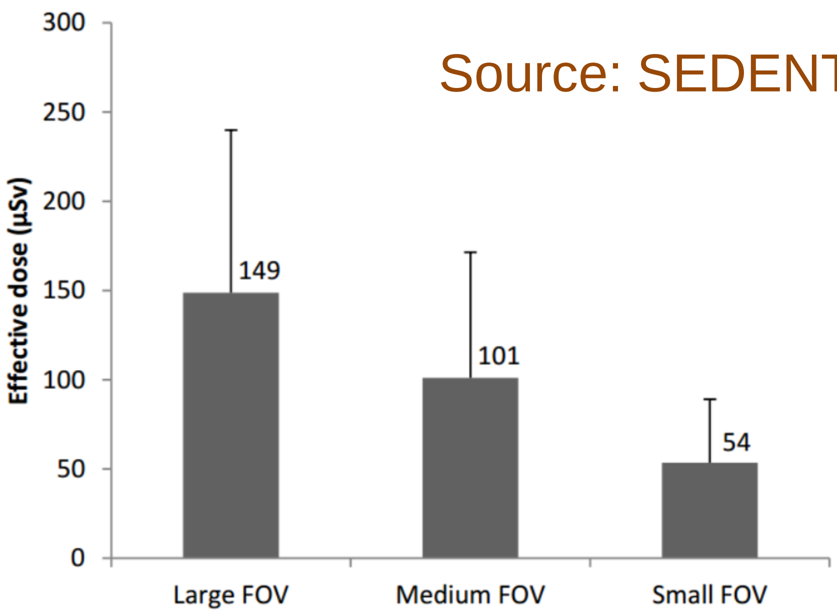
Field of View & Collimation

- Collimation: physically limiting the x-ray beam area using lead/brass blades to the area of interest
- The FOV is the cylindrical or spherical volume that can be reconstructed as a result of the beam collimation
- Some CBCT allow the a software selection of smaller FOV. The x-ray beam collimation unchanged.
- Some CBCT allow user to collimate the beam.



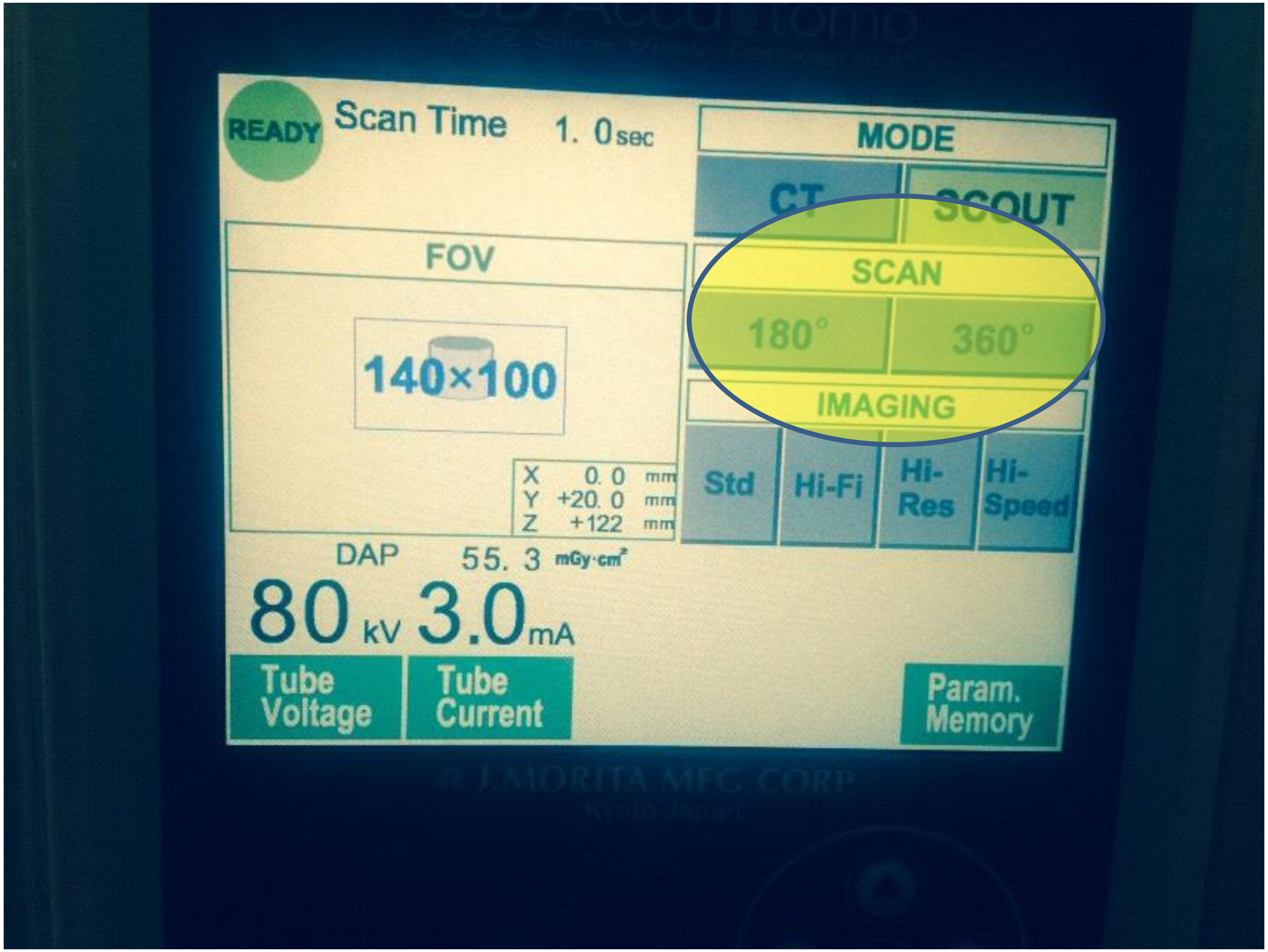
Field of View

- Large FOV (wide collimation) will increase dose
- Large FOV (wide collimation) will increase scatter (degrades image quality)
- FOV has a direct impact on patient dose/risk



Source: SEDENTEXCT Fig 5.1

Acquisition Parameters



Angular Range

- Diagnostic CT: ~1000 projections acquired over 360 rotation
- CBCT: 400-700 primary images over 360°.
- Some CBCT systems offer 180° option.
- Theoretically, 180°arc sufficient.
- More projections results in better resolution and better contrast.
- Selecting 180°reduces dose by ~ 50%. Maybe ok for certain studies.

Technique Optimization

- Increasing kVp
  - increases beam penetration→ Less artifacts
  - *may* decrease patient dose
  - Increases scatter (significant in CBCT)
- Increasing mAs (product of current and scan time)
  - Increases dose. Improves image quality
- Angular range: ½ scan lowers dose but could compromise image quality.

SEDENTEXCT Recommendation

X-ray tube voltage and tube current-exposure time product should be adjustable on CBCT equipment and must be optimised during use according to the clinical purpose of the examination, ideally by setting protocols with the input of a medical physics expert

B

Parameter (increase)	Dose	Image Quality
mA	Proportional increase	Reduces noise
kVp	Non linear	Increases contrast Reduce noise
FOV	Increase	Large FOV increases scatter
Angular range	Increases	Improves resolution and contrast
Manufacturer settings are a starting point! *Optimal parameters should be optimized with the involvement of a medical physicist!*		

Questions

- Similarities between CBCT and MSCT include:
  a) Good soft tissue contrast
  b) lower dose than radiography
  c) 1D imaging possibilities
  d) Use of detectors which convert x-rays to light

- In a CBCT scanner, the following is not true:

a) The x-ray beam is in the shape of a fan
b) The x-ray source rotates around the patient
c) Scan time is reduced because the x-ray tube is not translated.
d) Image reconstruction is necessary in spite of the faster scanning time.

- To reduce the dose in CBCT:

  a) Limit the FOV

  b) Increase the kVp

  c) Inject the patient with dose reduction drugs

  d) Use high resolution mode

- Image reconstruction is based on the mathematics of:

  a) The Laplacian transform

  b) Long division with decimals

  c) Matrix algebra

  d) Radon Transform

- X-ray photons interact with human tissue through:

  a) Scattering, which deflects the photos.

  b) Emission in which the body emits more photos.

  c) Photon-photon interaction.

  d) Electron ejection from atoms in tissue.

- In CBCT, the voxel size is determine by all but:

  a) Choice of tube potential

  b) Detector pixel size

  c) Imaging field of view

  d) Number of angular projections

  e) Size of reconstruction matrix

- Which image reconstruction algorithm has been used for the past 30 years in CT?

  a) Two dimensional Fourier transform

  b) Three dimensional Fourier transform

  c) Back projection

  d) Filtered back projection

  e) Algebraic reconstruction

- The modification of filtered back projection for the cone beam geometry is called:

  a) CBCT-FBP

  b) Feldkamp algorithm

  c) Back projection

  d) Algebraic reconstruction

The End

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CT Physics

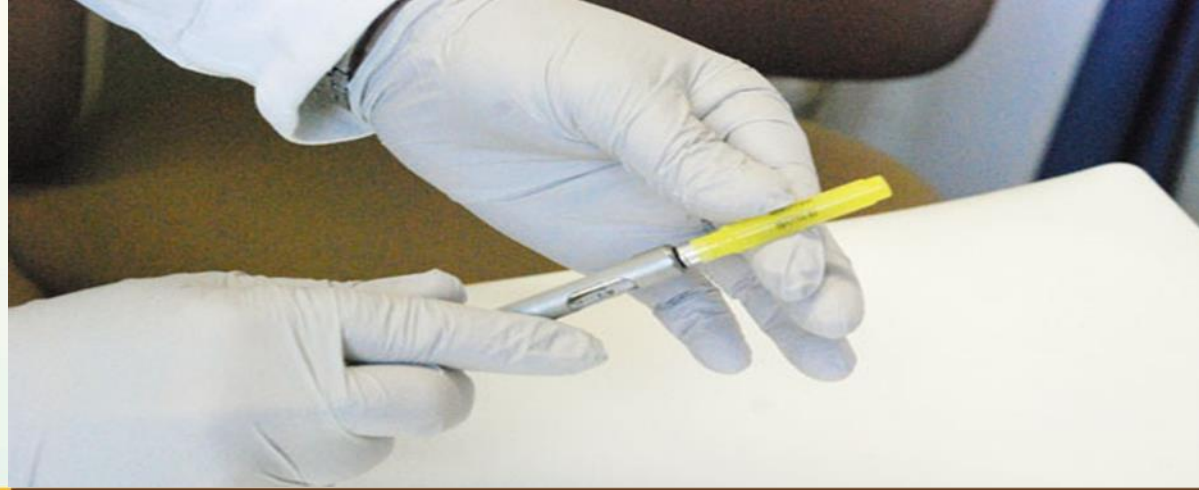

Image Quality and Technique Optimization

AN IMAGE IS WORTH A THOUSAND PHOTONS….

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Topics

- What is image quality?
- Objective image quality parameters
  - Noise
  - Resolution
  - Contrast
  - Artifacts
- Acquisition parameters and image quality
- Image display

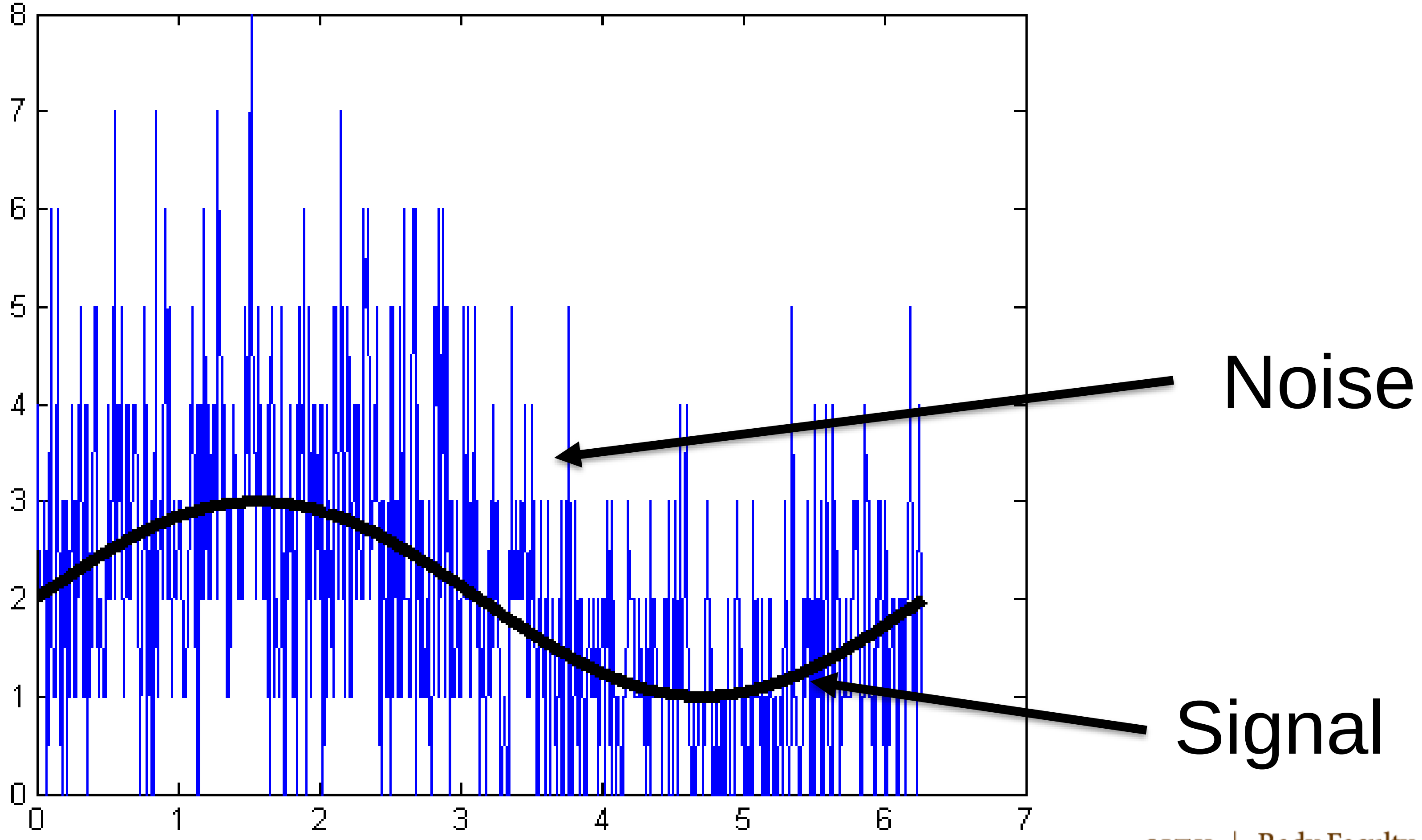
Image Quality

- What is image quality?
  - Diagnostic
  - Objective parameters meet specifications
- How do we assess image quality?
  - Subjective rubrics
  - Objective measures
- What factors impact image quality?
  - The whole imaging chain: acquisition, processing, display

Objective Image Quality Parameters

- Noise
- Spatial resolution
- Contrast resolution
- Artifacts

Noise

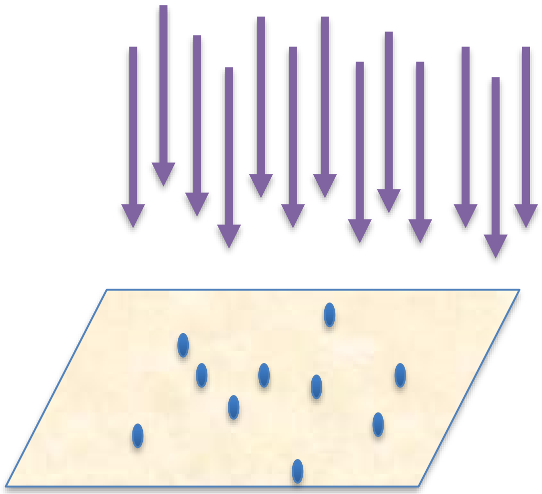


Sources of Noise

- Random processes: phenomena described by statistical distributions, not deterministic mathematical formulas.
- Quantum noise: randomness in the number of x-ray photons.
- Electronic noise – randomness in the electronics

Quantum Noise

- Quantum noise is caused by random fluctuations in the number of x-ray photos (emitted, detected…)
- Quantum noise follows the Poisson statistical distribution: SD^2 (noise) = Mean (signal)



100 Photons
Average per area

108	90	103
102	95	114
94	105	89

Average: 100 photons
Standard deviation ± 10 photos (10%)

1000 Photons
Average per area

1026	**1007**	**980**
967	984	1016
1010	1046	964

Average: 1000 photons
Standard deviation ± 33 photos (3.3%)

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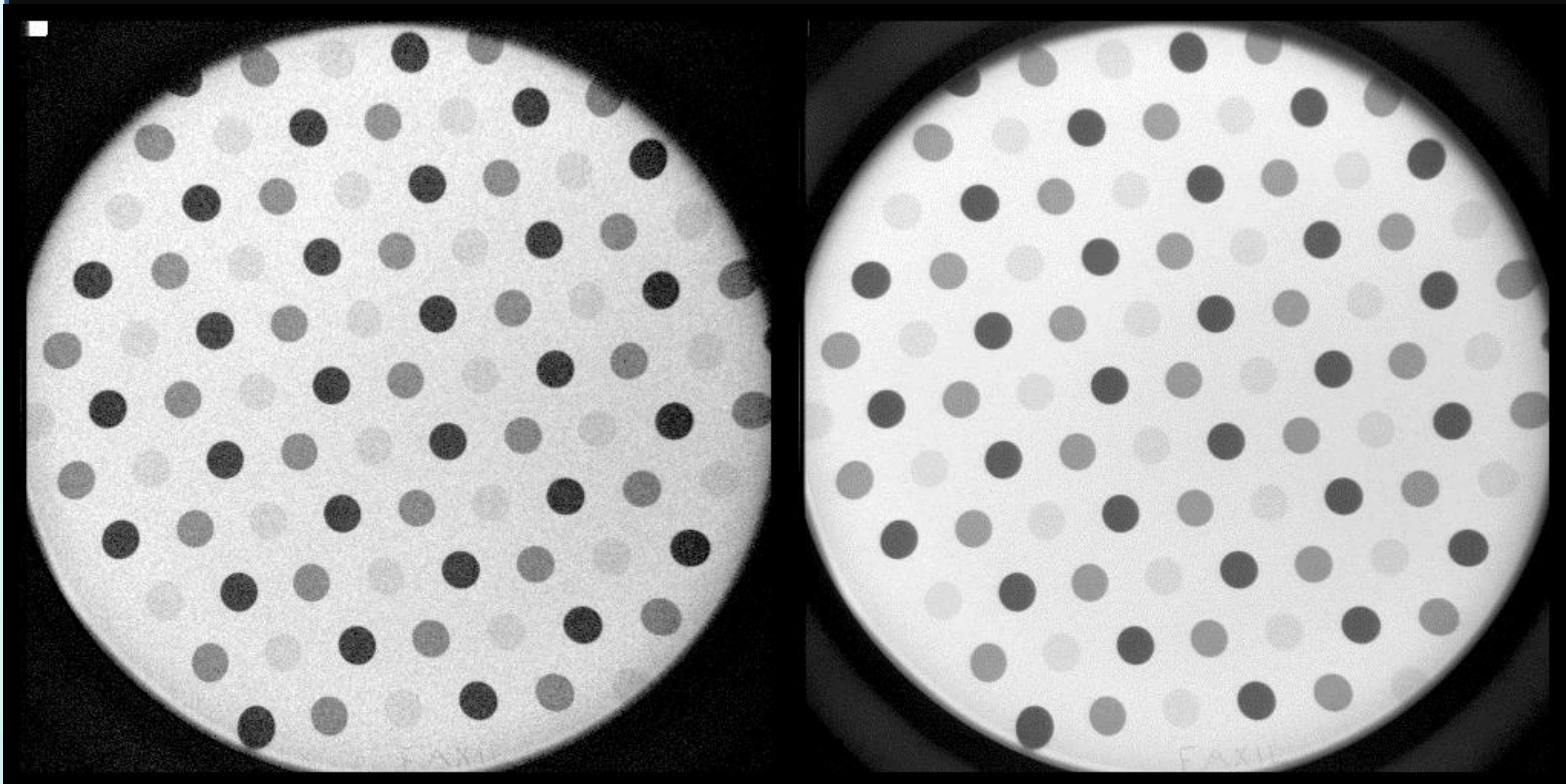
Quantum Noise

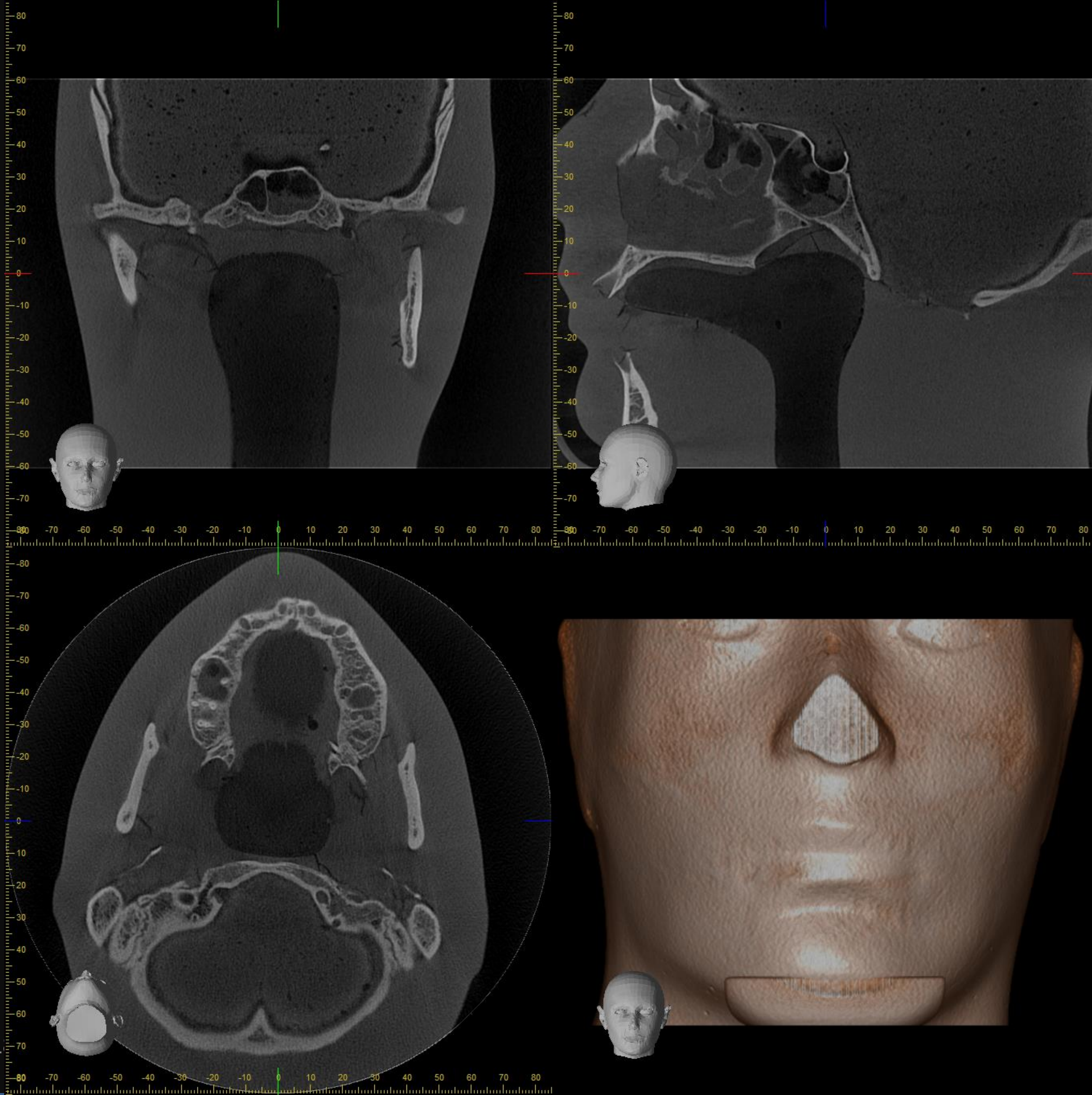
- Implication of Poisson statistics: the visual impact of noise will decrease when the dose (number of photons) increases.
- Signal to Noise ratio (relative perception of noise):

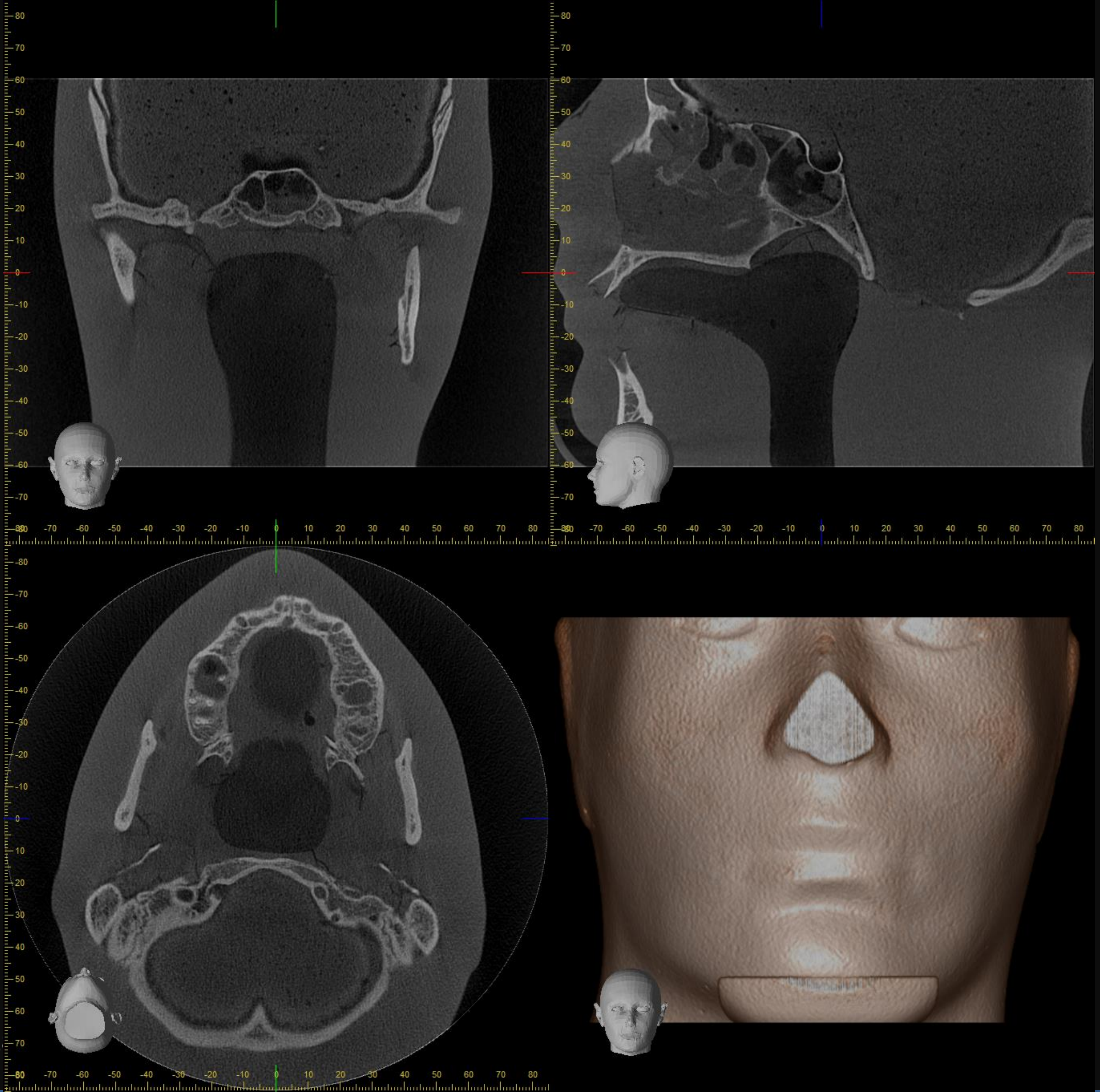
$$\frac{mean}{SD} = \frac{N}{\sqrt{N}} = \sqrt{N}$$

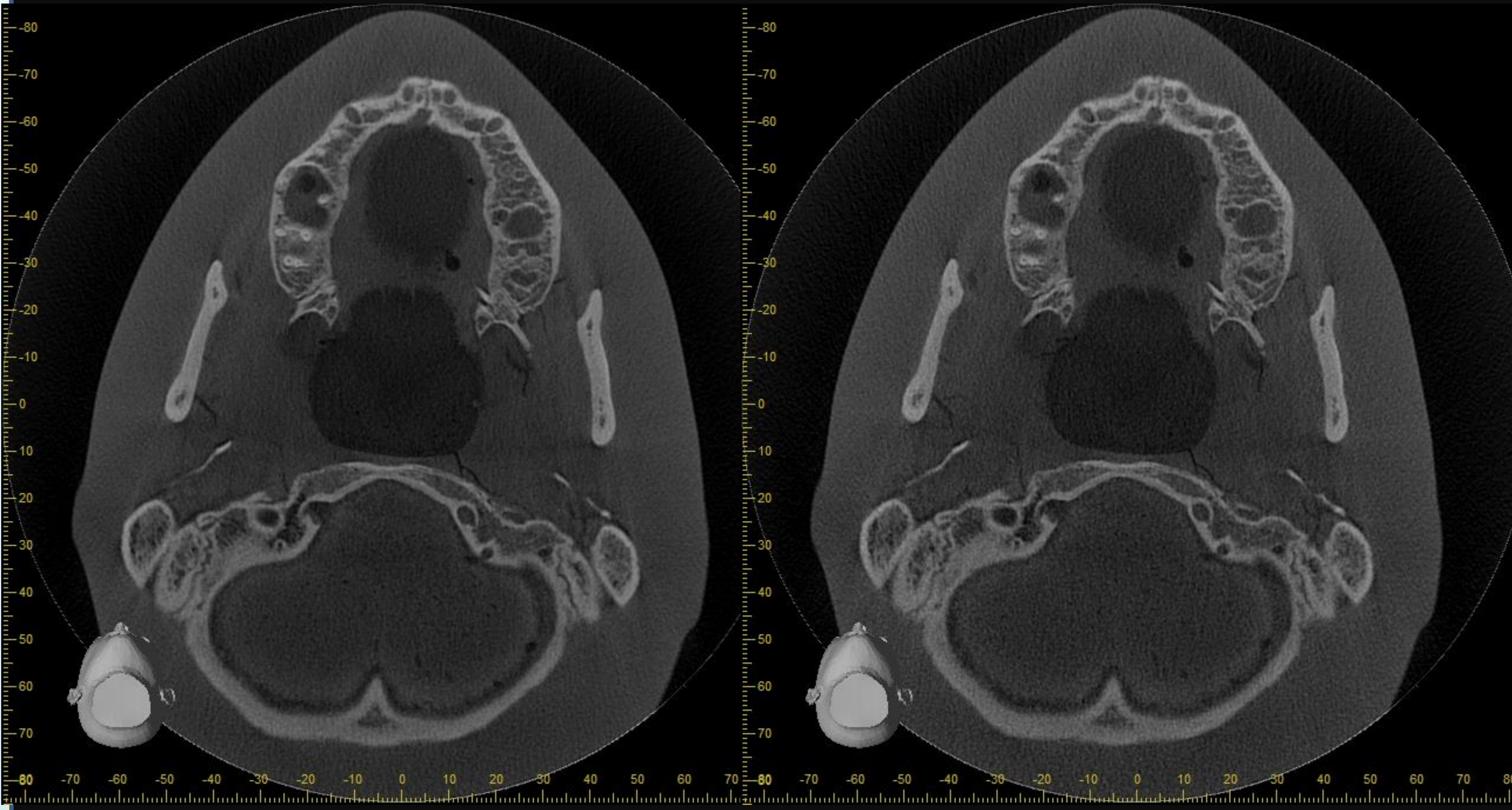
Which is the fairest of them all?

an image made with more x-rays (high SNR) will look better



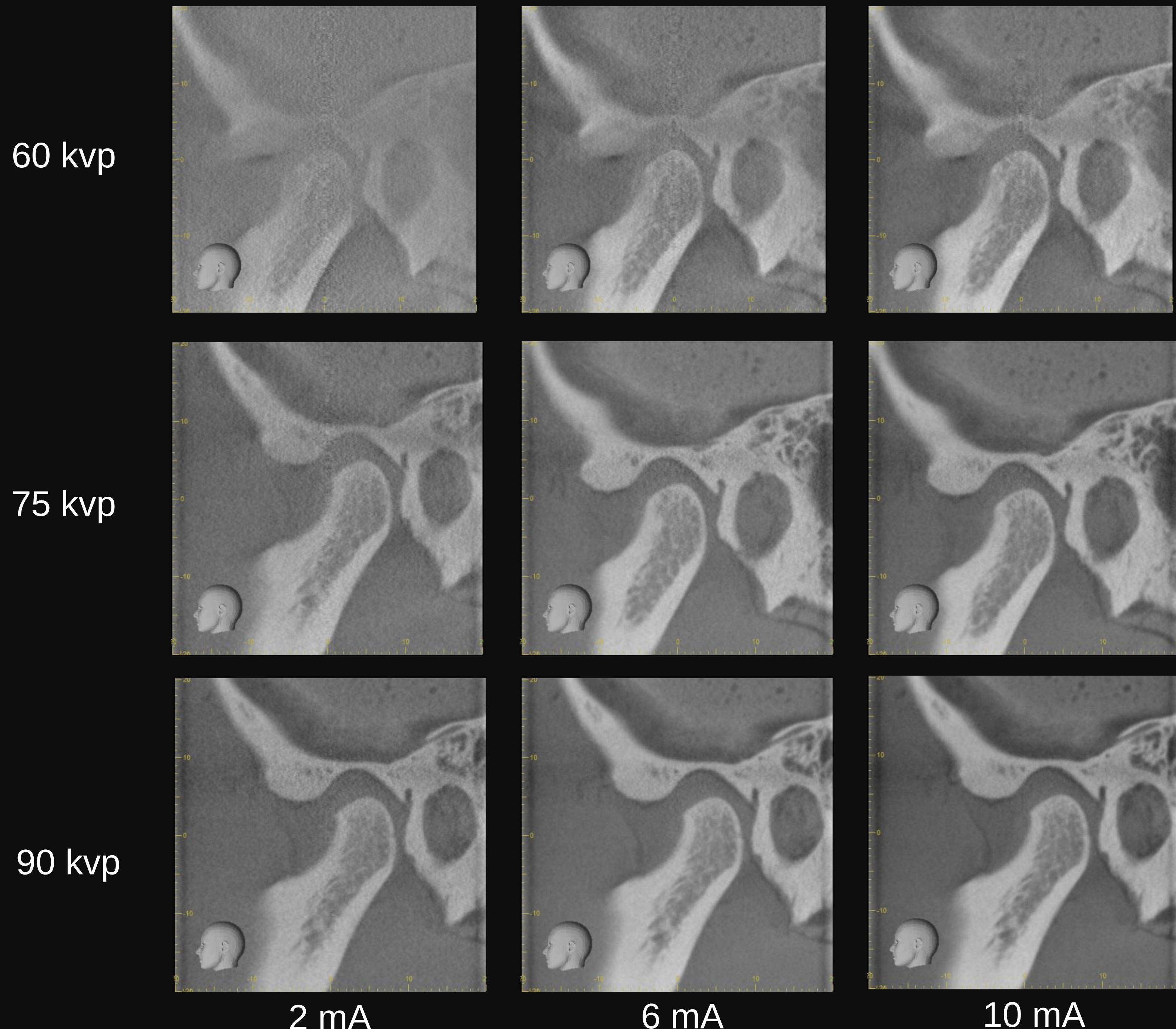







90 kVp
4 mA

90 kVp
? mA

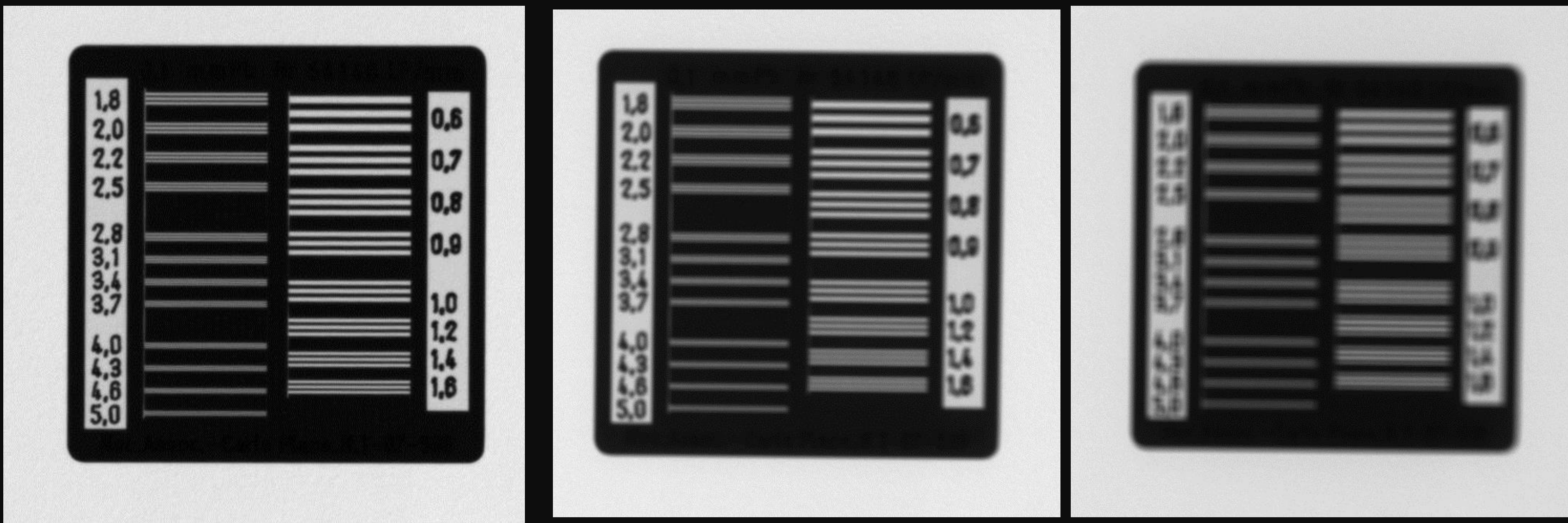

60 kvp
75 kvp
90 kvp
2 mA
6 mA
10 mA

Noise

- Any increase in dose will increase the SNR
  - Increase kVp (double dose for every 5 kVp)
  - Increase mA
- Reconstruction and post processing filters can also smooth (or enhance) perception of noise.
- High resolution modes will decrease SNR. Sometimes compensated for with increase in dose.

Spatial Resolution

- Ability to see small details


1,8
2,0
2,2
2,5
2,8
3,1
3,4
3,7
4,0
4,3
4,6
5,0
0,6
0,7
0,8
0,9
1,0
1,2
1,4
1,6

Spatial Resolution

- In plane spatial resolution: the resolution inside each cross-sectional CT slice
- Longitudinal resolution is the spatial resolution between slices.
- The in plane and longitudinal resolutions are often different in clinical CT, but identical in CBCT.
- CBCT has *isotropic resolution.* Clinical CT has *anisotropic resolution.*

Factors Affecting Resolution

- Spacing between detector elements.
- Binning of detector elements.
- Angular spacing between primary images.
- Reconstruction algorithm.
- Reconstructed image voxel size.

Detector Binning

- CBCT systems have “high resolution” mode
- The primary images are acquired at the native detector pixel size - ie, no binning.
- Binning is when neighbouring pixels are averaged together. It reduces noise.
- High resolution modes increases noise.
- Noise compensated for by dose increase

Detector Binning

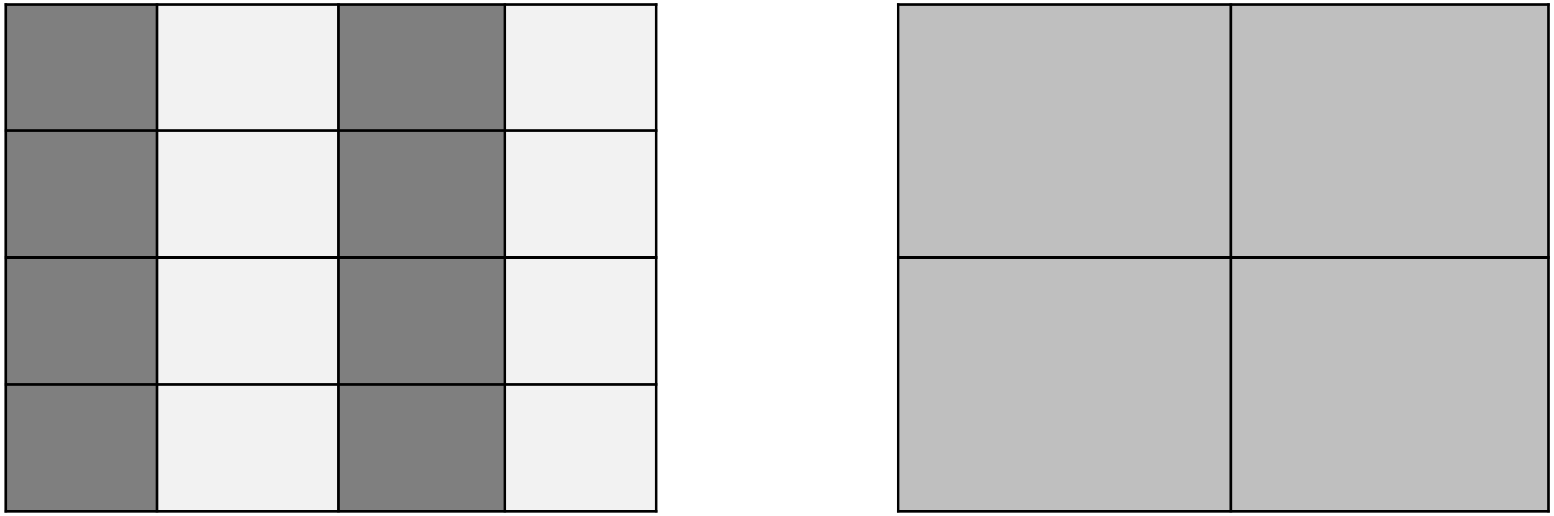
97	120	120	87
105	89	103	105
102	92	105	101
94	101	87	95

Average: 100 photons
SD ± 10 photons

103	104
97	97

2 x 2 binning
Average: 100 photons
SD ± 3.6 photons
Resolution ¼

Detector Binning

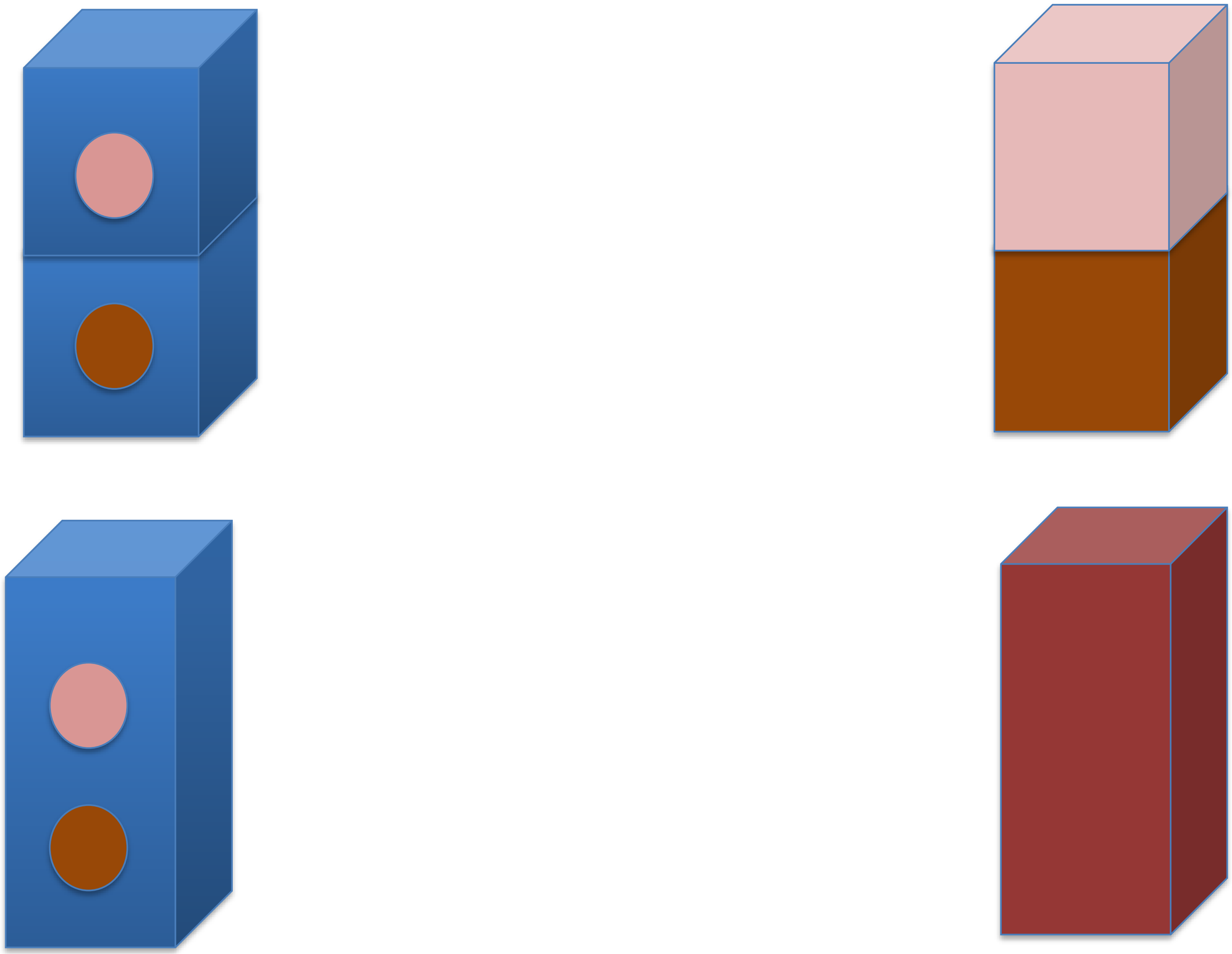


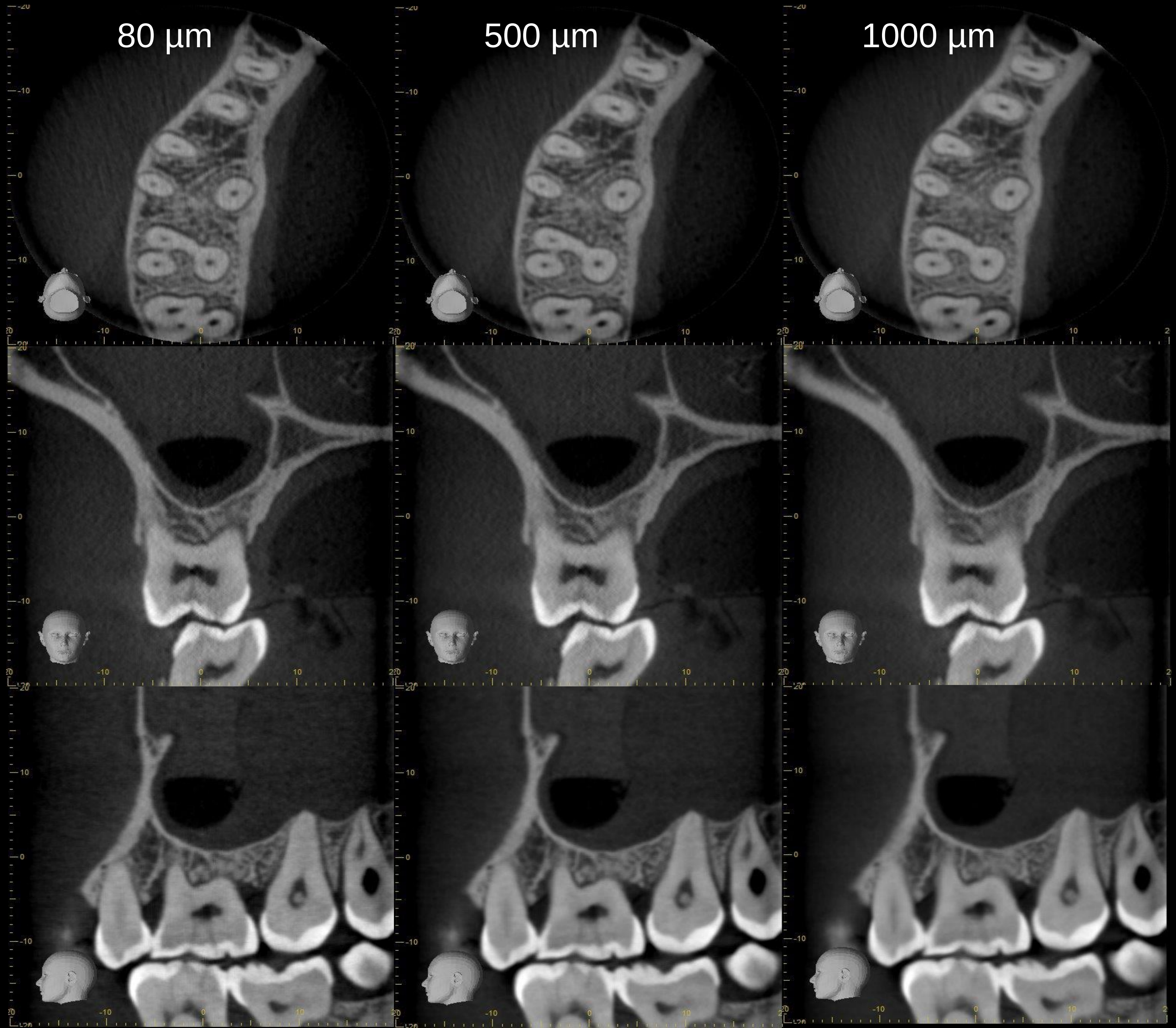
Voxel Size

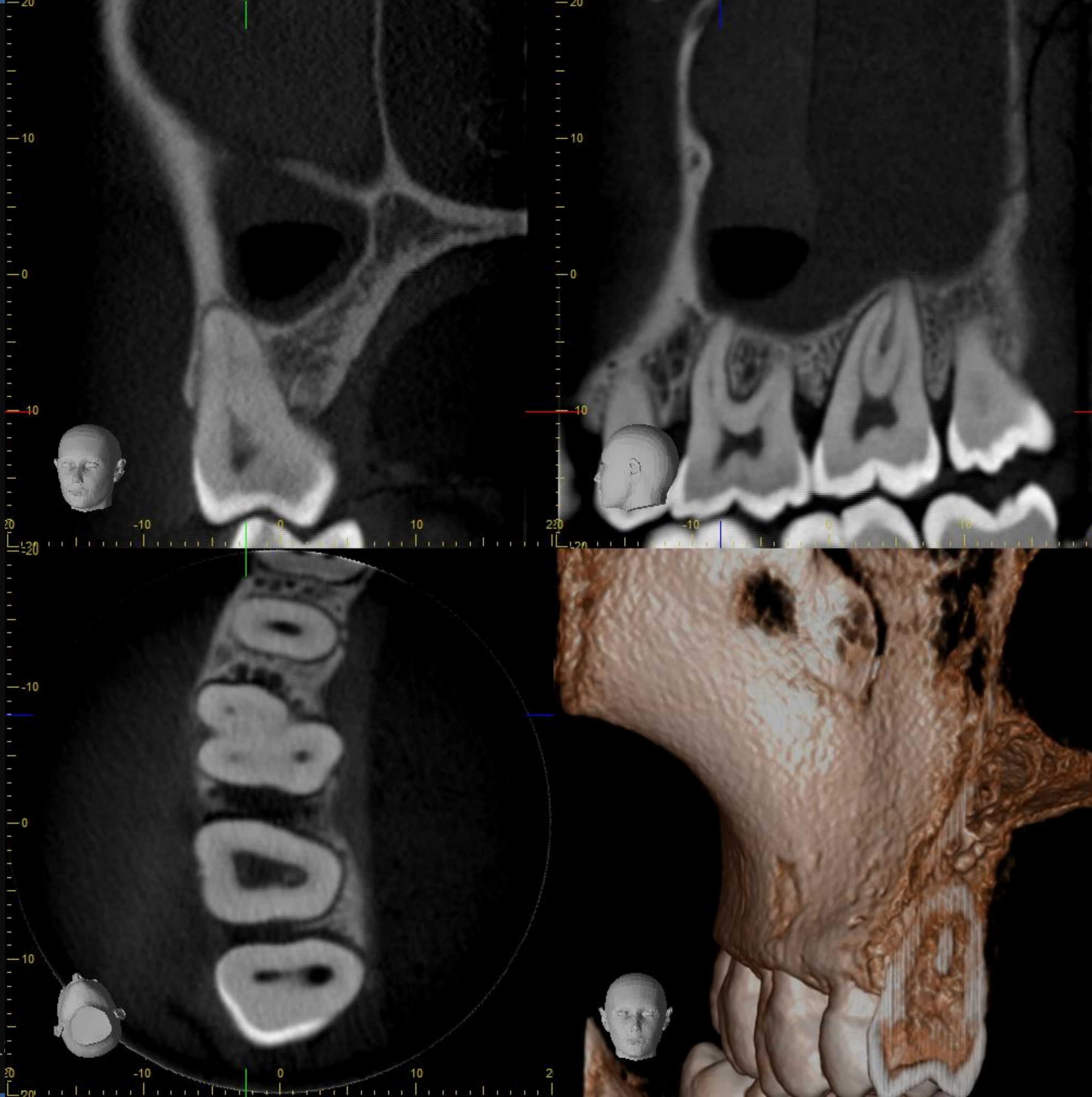
- The CT volume is cut into slices.
- Each image represents a certain thickness.
- Each pixel has depth. It is actually a *voxel.*
- A voxel is the average of all of its contents.
- The larger the voxel, the more materials are averaged and less detail is seen.
- Bigger voxels result in more *volume averaging.*
- Voxel sizes range from 80 – 400 microns.

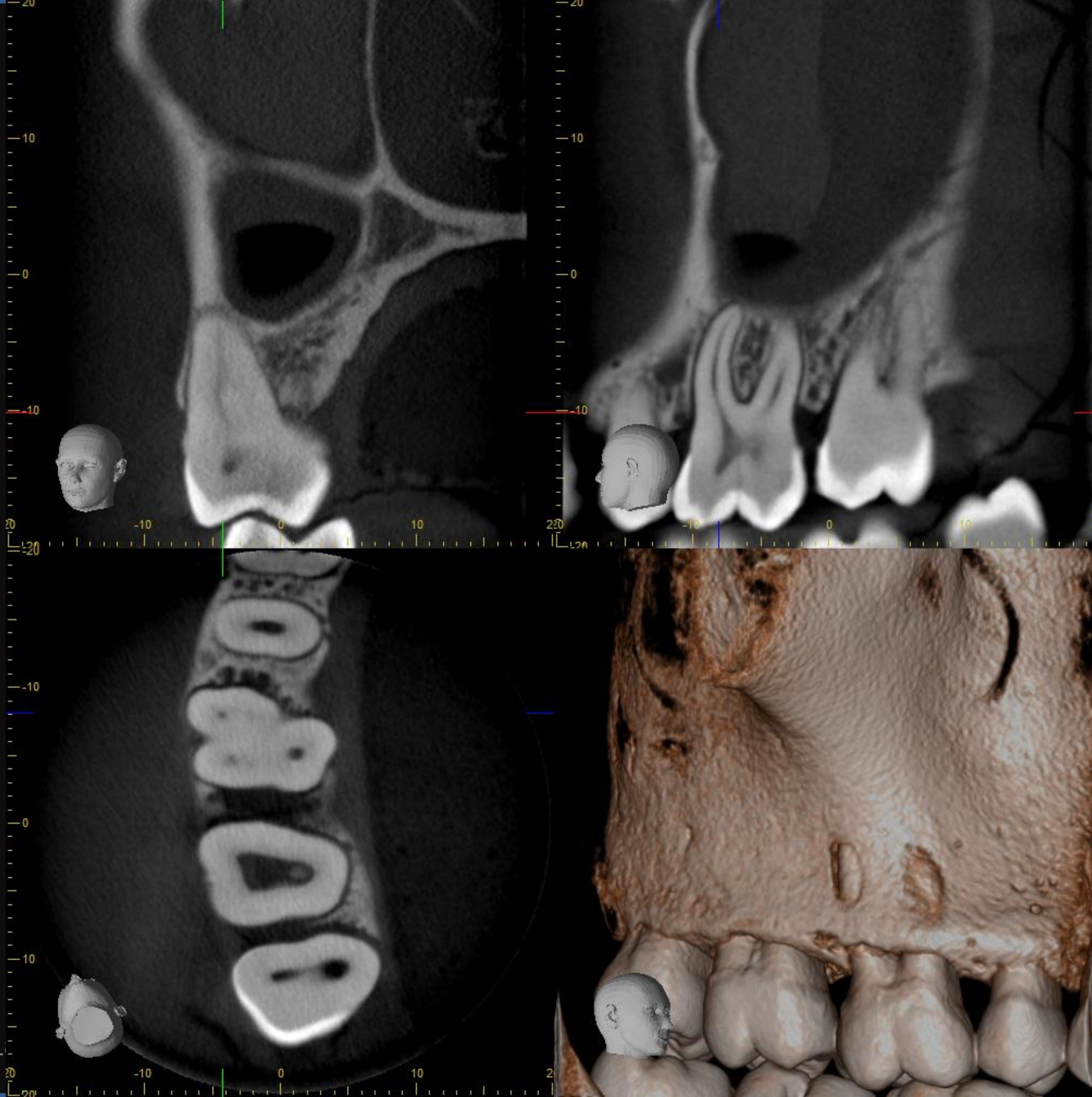
Voxel Size

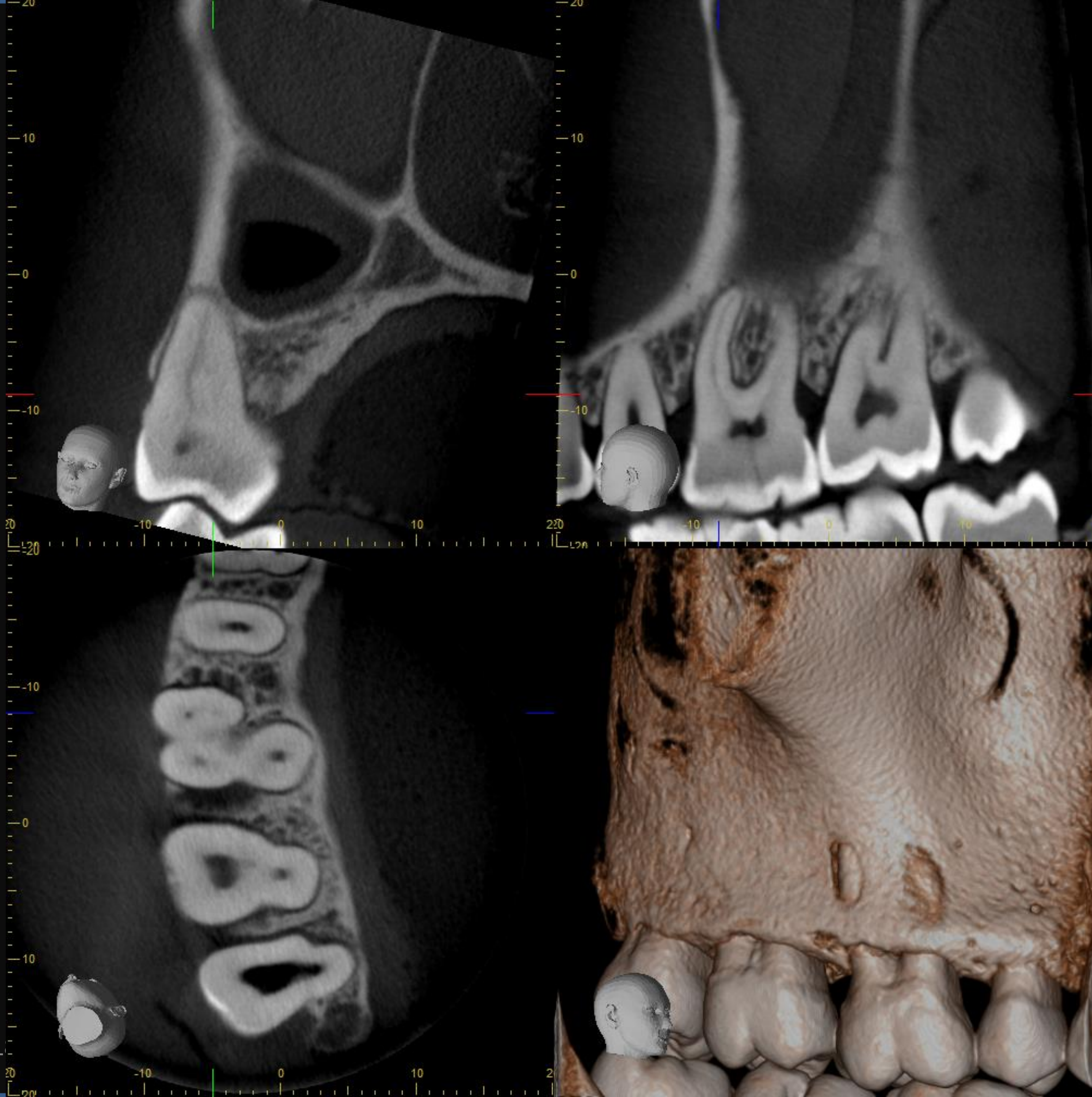
- Voxel size = FOV/number of voxels.
- The voxel size determines the smallest size of a detail in the image that can be distinctly reproduced.
- A voxel represents a single number. All of its contents are averaged to give the digital value of the voxel.
- Voxel contents cannot be distinguished apart.

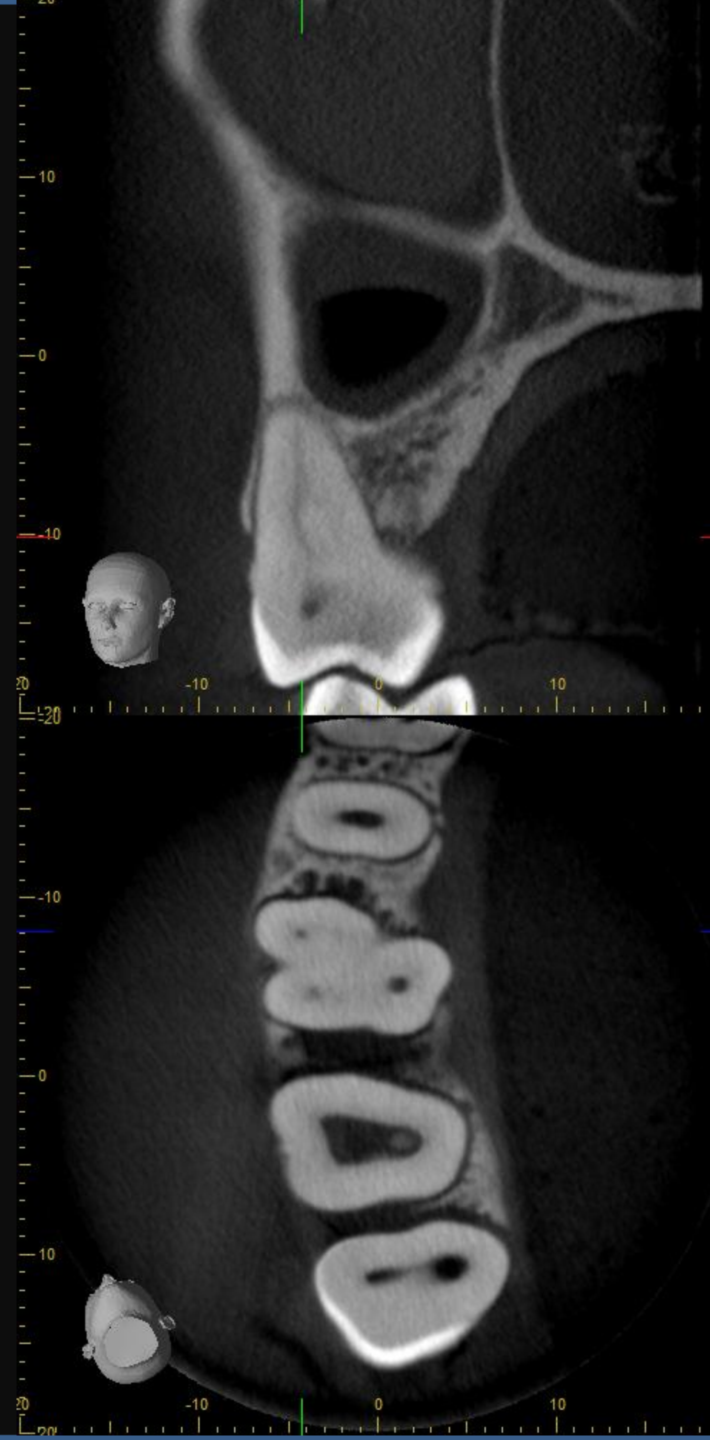



80 µm
500 µm
1000 µm





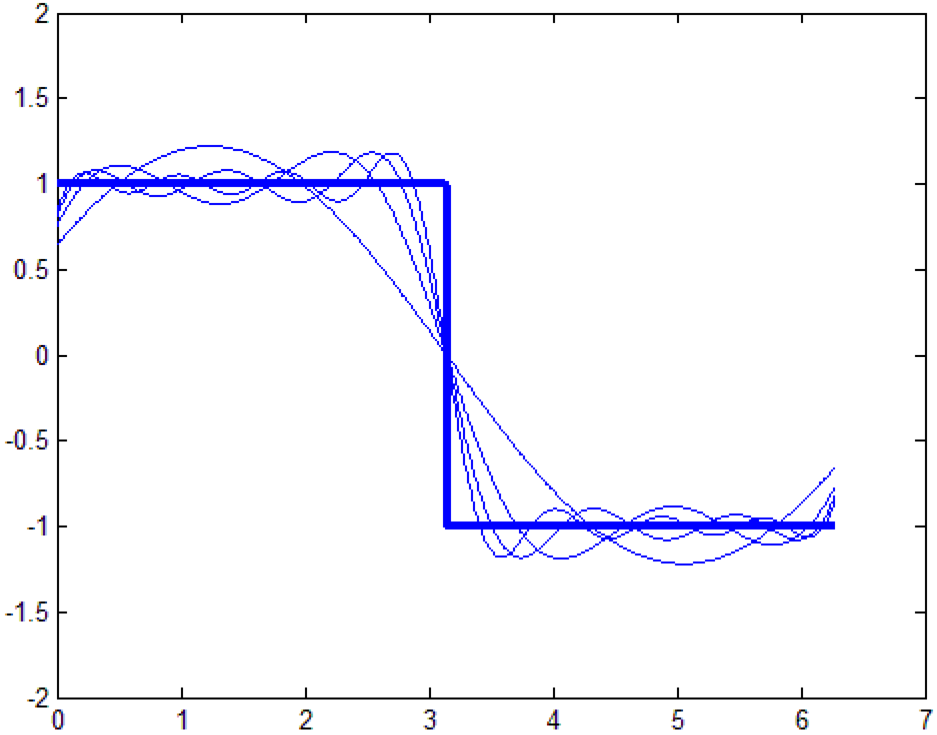


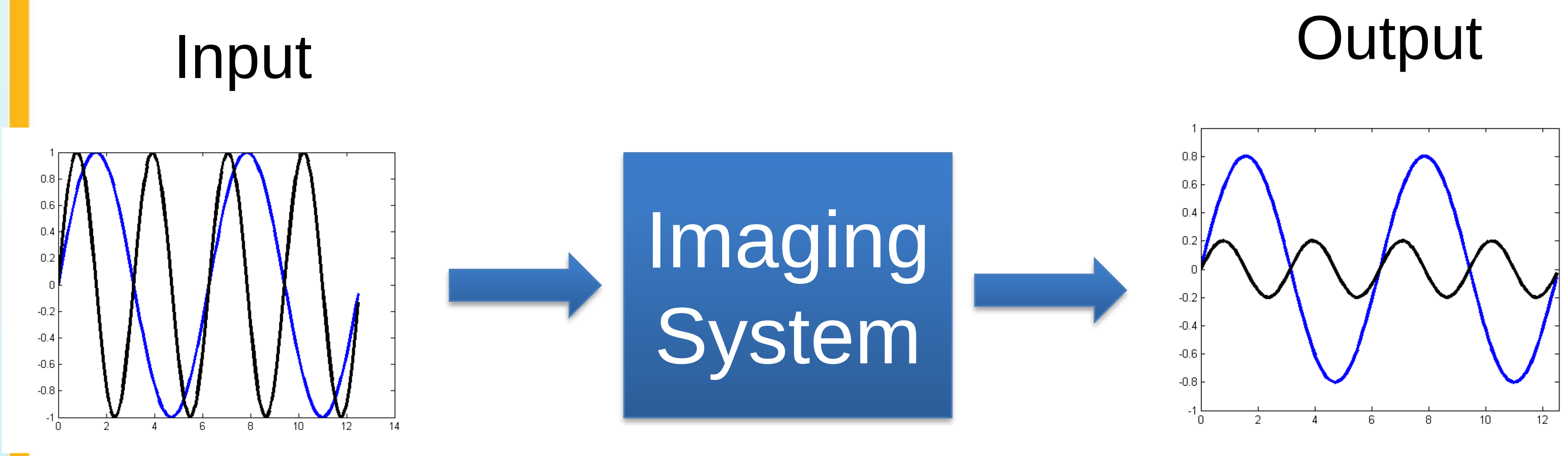


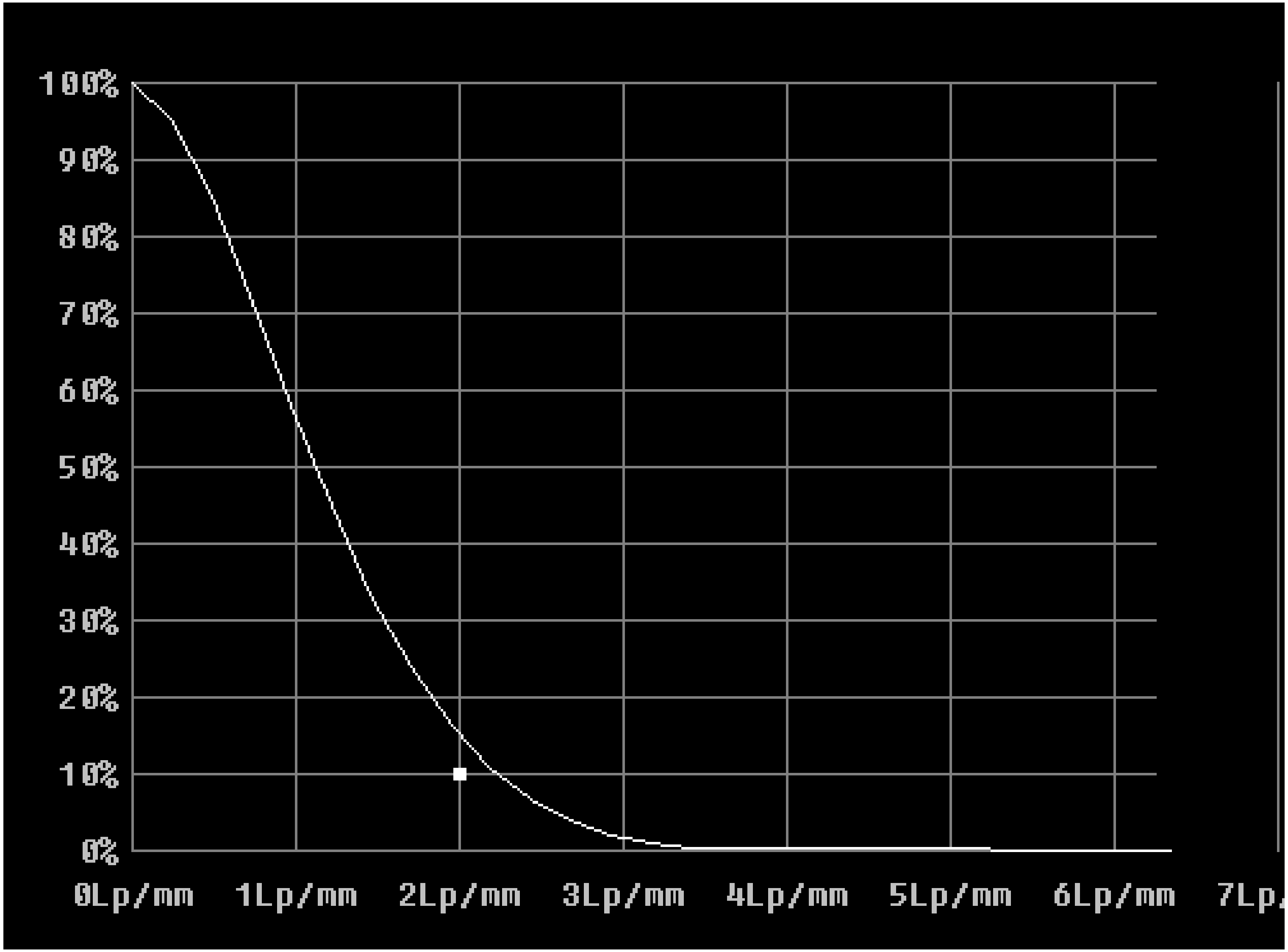
Modulation Transfer Function

- The Modulation Transfer Function is a measure of the system spatial resolution performance.
- MTF is a measure of how the system “passes” information at different frequencies.
- MTF = 5% means that 5% of a certain frequency is passed.

Everything is made of sinusoids!




Input
Output
Imaging System
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
2
4
6
8
10
12
14

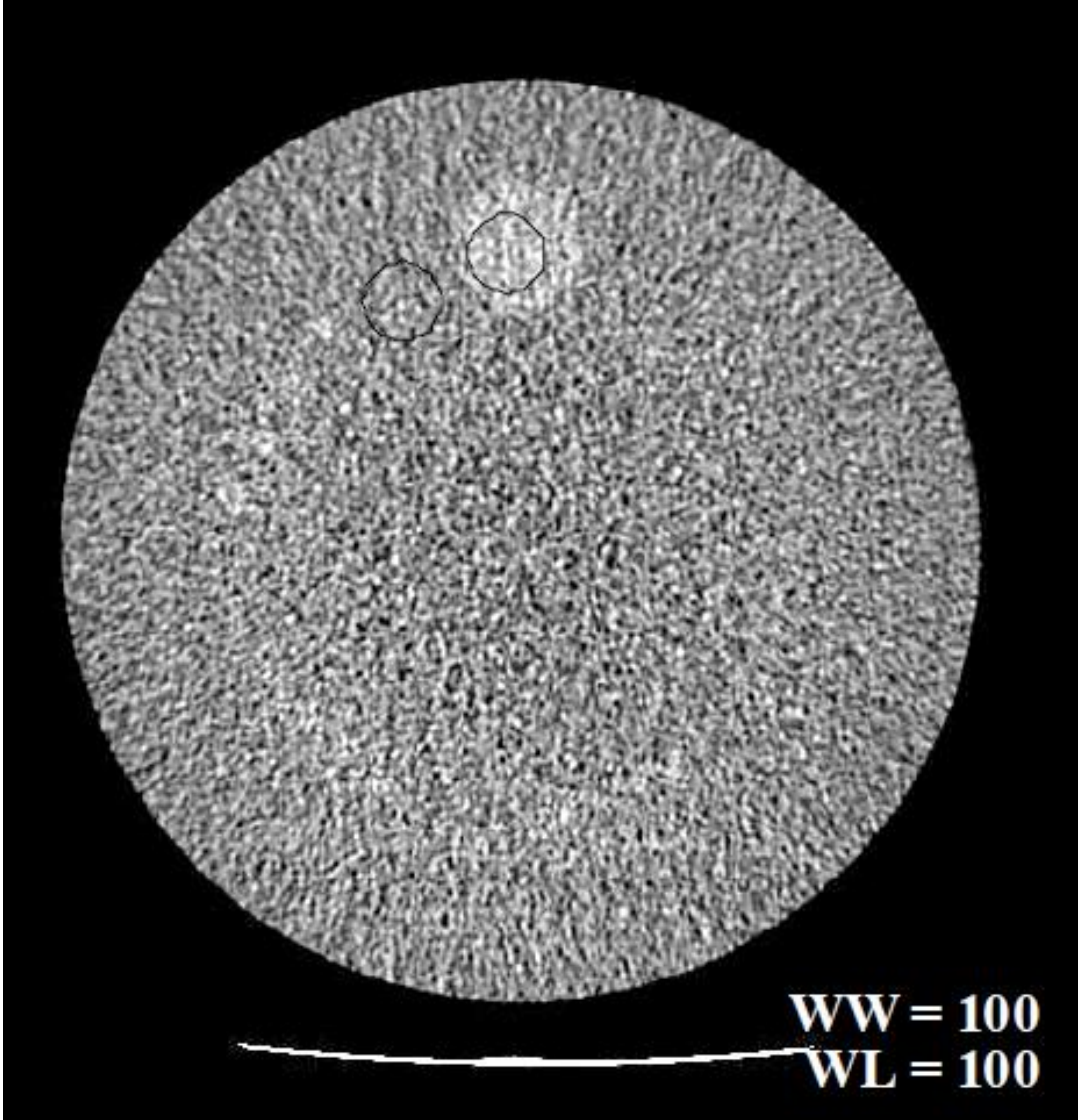

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0Lp/mm
1Lp/mm
2Lp/mm
3Lp/mm
4Lp/mm
5Lp/mm
6Lp/mm
7Lp

MTF

- The MTF says how much of the signal at a certain spatial frequency is reproduced.
- MTF = 1 means the signal is reproduced 100%.
- MTF = 0.5 means the signal is weakened by 50%.
- MTF = 0.1 is considered the limiting resolution.

Contrast Resolution

- CR is sometimes referred to as low contrast resolution, or contrast sensitivity
- It refers to the ability to distinguish an object that is almost the same density as its background.
- In radiography, for example, a difference needs to be about 5% to be seen
- Clinical CT has sub 1% contrast resolution
- CBCT?


WW = 100
WL = 100

Contrast to Noise Ratio

- Ability to distinguish low contrast depends on the noise
- Signal can be “buried” in the noise
- Contrast also depends on the physical differences in attenuation values.

CNR = (40-12)/10=2.8

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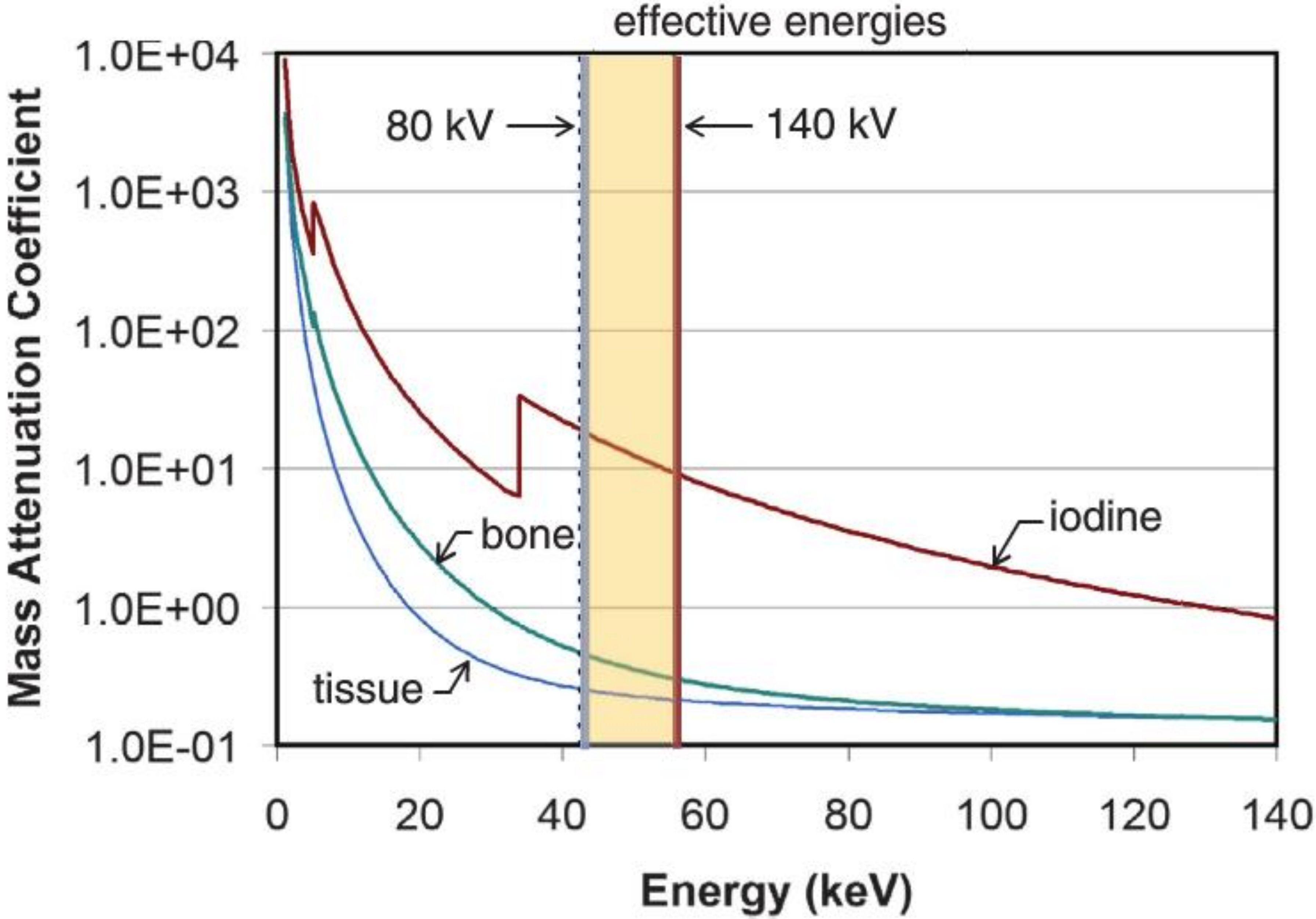
CNR = (41-12.7)/28=1.01


effective energies
80 kV
140 kV
Mass Attenuation Coefficient
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-01
bone
iodine
tissue
0
20
40
60
80
100
120
140
Energy (keV)

Parameter	Dose	Noise	Contrast Visibility	Resolution
mA	+	-	+	N/A
kVp	+	-	-	N/A
FOV	+	N/A	-	N/A
Angular range	+	-	+	+
Detector Binning	N/A	-	+	-
Voxel Size	N/A	-	+	-

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Optimal Technique

- ALARA: lowest dose without compromising diagnosis
- ***Generally:***
  - High kVp, low mA.
  - Appropriate FOV and resolution for clinical task
  - Consideration of patient abilities

Image Artifacts

CT Artifacts

- Artifacts are systematic discrepancies between the CT image and the true attenuation map of the object:
  - Streaking
  - Shading
  - Rings
  - Distortion

Beam Hardening

- Patient body acts like an x-ray filter, altering the energy distribution of the x-ray beam
  - Lower energy photons are preferentially attenuated
  - Average energy of the beam increases
- This leads to inconsistencies in data
- Artifacts include cupping and streaking

Scatter

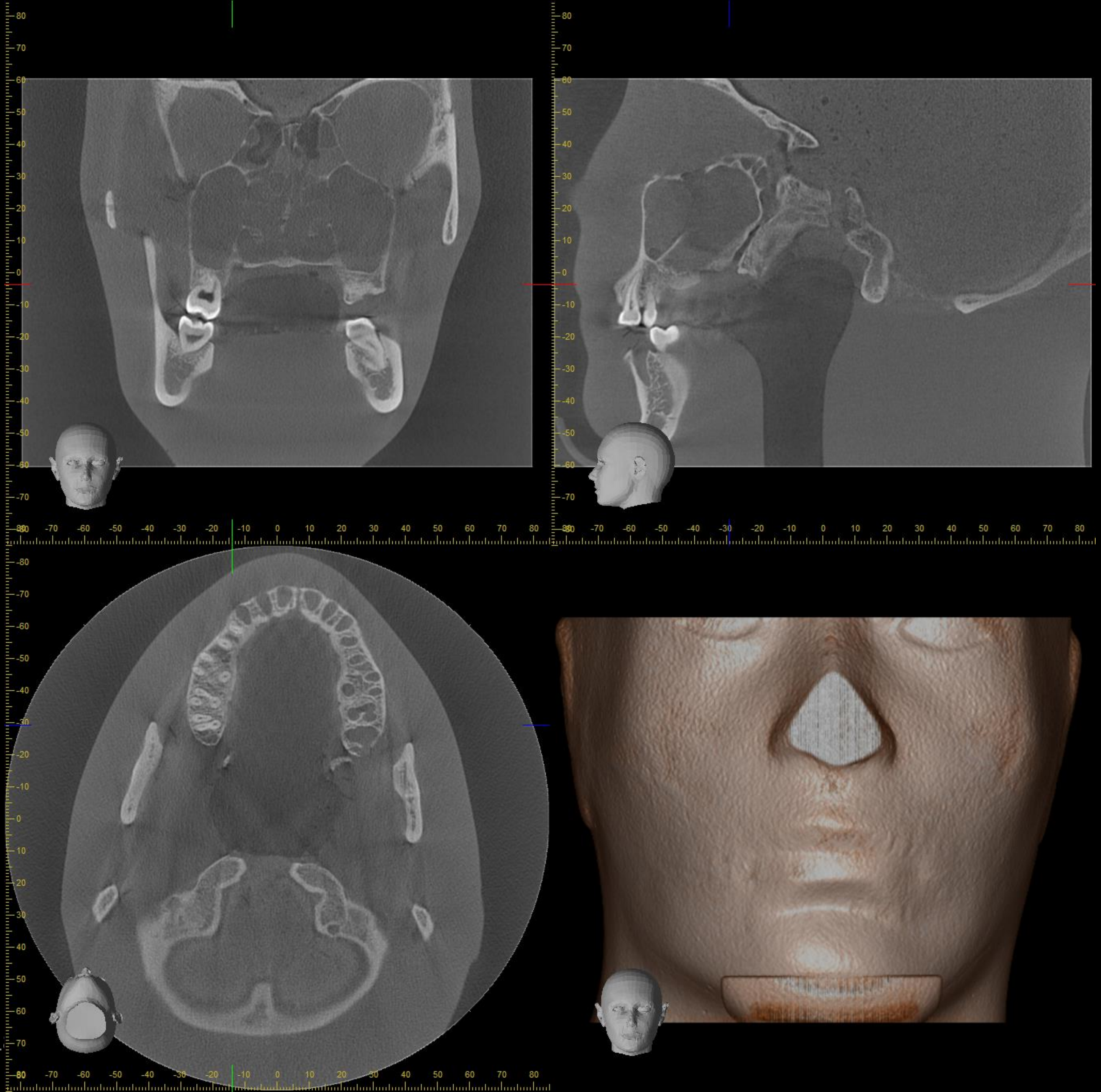
- Many x-ray photons interact in tissue and are diverted from original straight path towards detector
- Scattered x-rays causes data inconsistency and create artifacts
- CBCT geometry causes significant scatter.
- That's why soft tissue contrast is poor

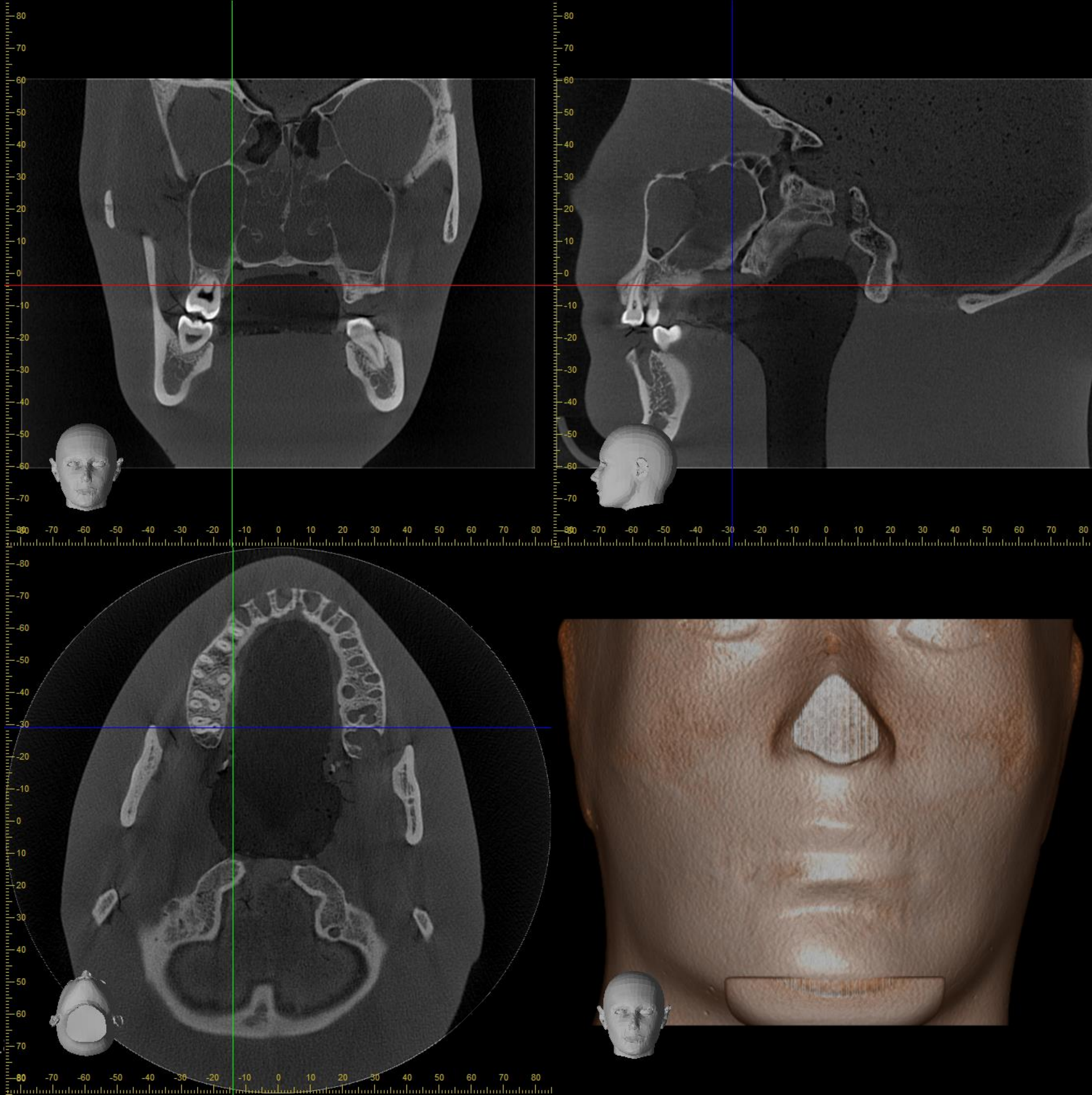
High Density/Metal Artifacts

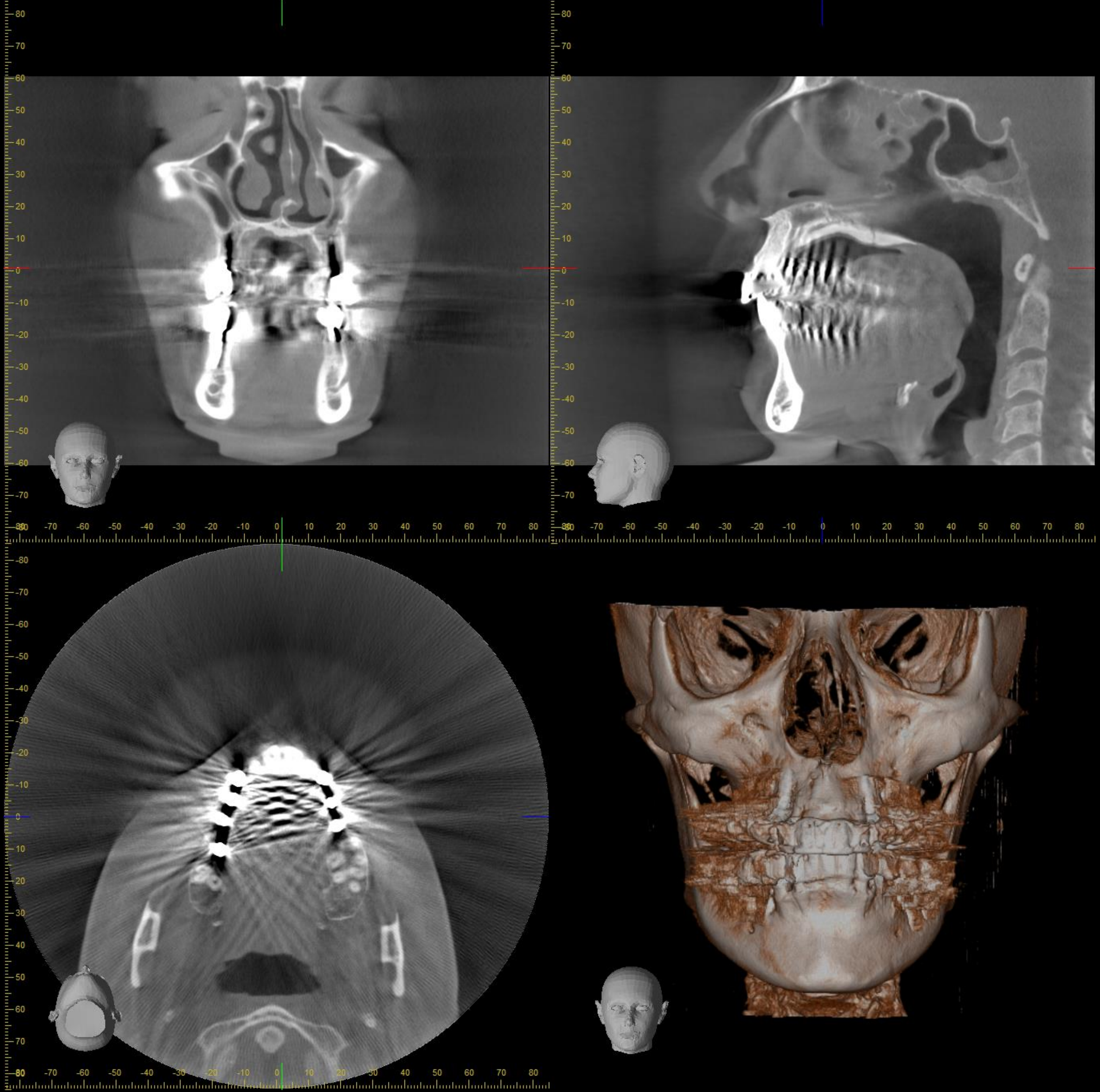
- Presence of metal objects can cause severe streaking
  - Very high material density
  - Beam hardening
  - Partial volume
- Avoidance:
  - Removal of metallic objects (earrings)

Photon Starvation

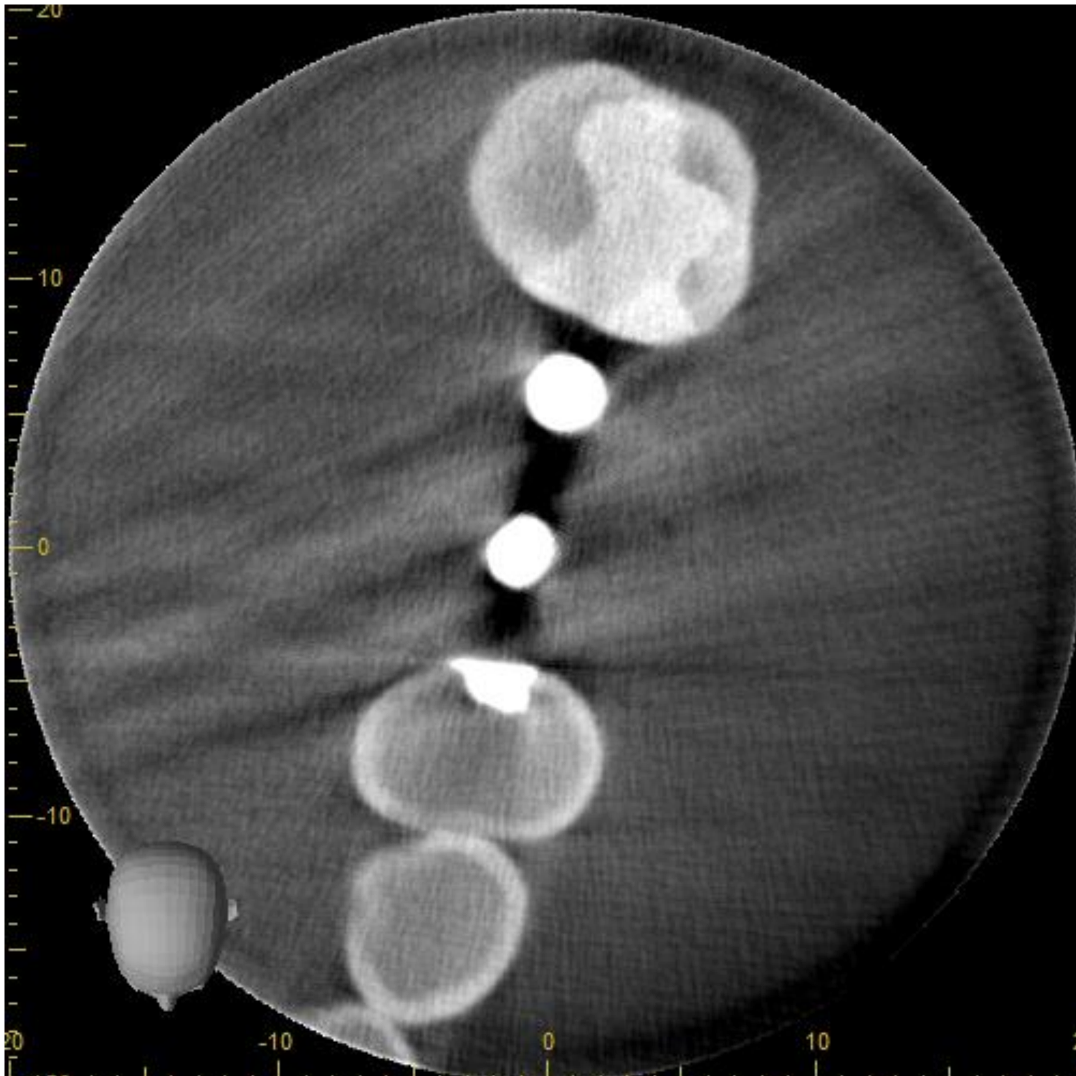
- Highly attenuating areas can cause low photon statistics in the detector causing streaking
- Effect can be reduced with tube current modulations and adaptive noise filtering






80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80

High Density Artifacts



5

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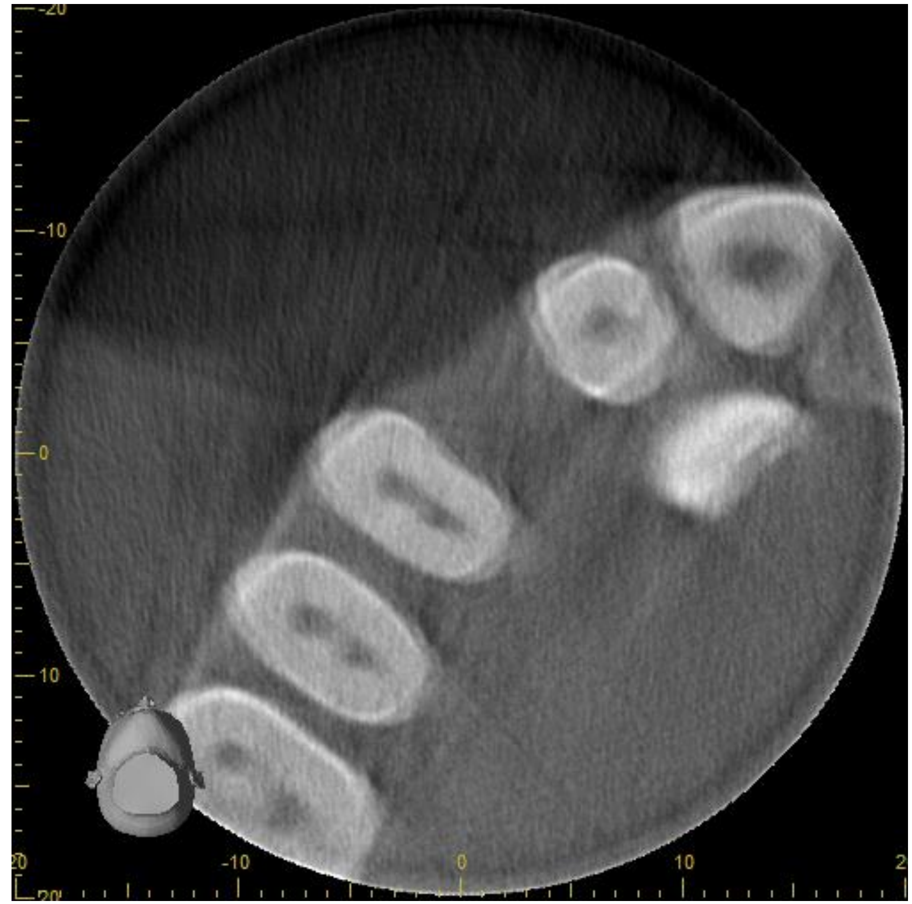
Patient Motion



Questions

- Visibility of low-contrast lesions may improve with increasing:

a) kVp

b) mAs

c) Display window width

d) X-ray FOV

- Image noise is not affected by

a) Voxel size

b) Reconstruction algorithm

c) mAs

d) Scanning speed

e) Distance between patient and detector

- In CT, the ROI tool placed over a uniform area of an image will return values of "mean“ and "standard deviation" of the voxel numbers within the ROI boundary, The standard deviation is most closely associated with the:

a) X-ray attenuation.

b) Spatial resolution.

c) Image noise.

d) Image contrast.

e) Atomic number of the tissue in the ROI.

- Patient dose is not directly affected by
    a) Reconstruction algorithm
    b) Matrix size
    c) mAs
    d) Display settings (window/level)
    e) Electronic collimation

- Concerning image artifacts in x-ray CT:

a) Patient movement results in streak artifacts.

b) Beam hardening is caused by the shift in beam energy

c) Ring artifacts are associated with the presence of metallic objects in the reconstruction circle.

d) Detectors made of high-density material may cause streak artifacts.

- If the radiation dose is increased, the perception of noise in the image will

a) Increase because more photos will cause more quantum noise

b) Decrease because of Poisson statistic

c) Not change. Noise depends on the reconstruction algorithm.

d) Increase if the dose increase is a result of change in kVp

Image Display

Image Display

- Displays must be medical grade
- High resolution
- Sufficient brightness (luminance)
- ACR-AAPM-SIIM technical standard for electronic practice of medical imaging (2012)

Display Scale

- Clinical CT has a standardized display scale called the “Hounsfield” scale
- The Hounsfield scale expands the attenuation values

$$HU = 1000 \times \left(\frac{\mu - \mu_{water}}{\mu_{water}} \right)$$

- No such scale for CBCT. Soft tissue contrast in CBCT is limited.

Display Window

- A monitor can only usually display 256 gray levels from black to white.
- The human eye is worse and can differentiate about 40 levels
- Display window adjustments can enhance relative contrast of voxel values

Display Window Adjustment

- So how do we display the image? How do we enable the viewer to make use of the available information?
- We use tools in the display monitor called
  - Window width
  - Window level

Window Width

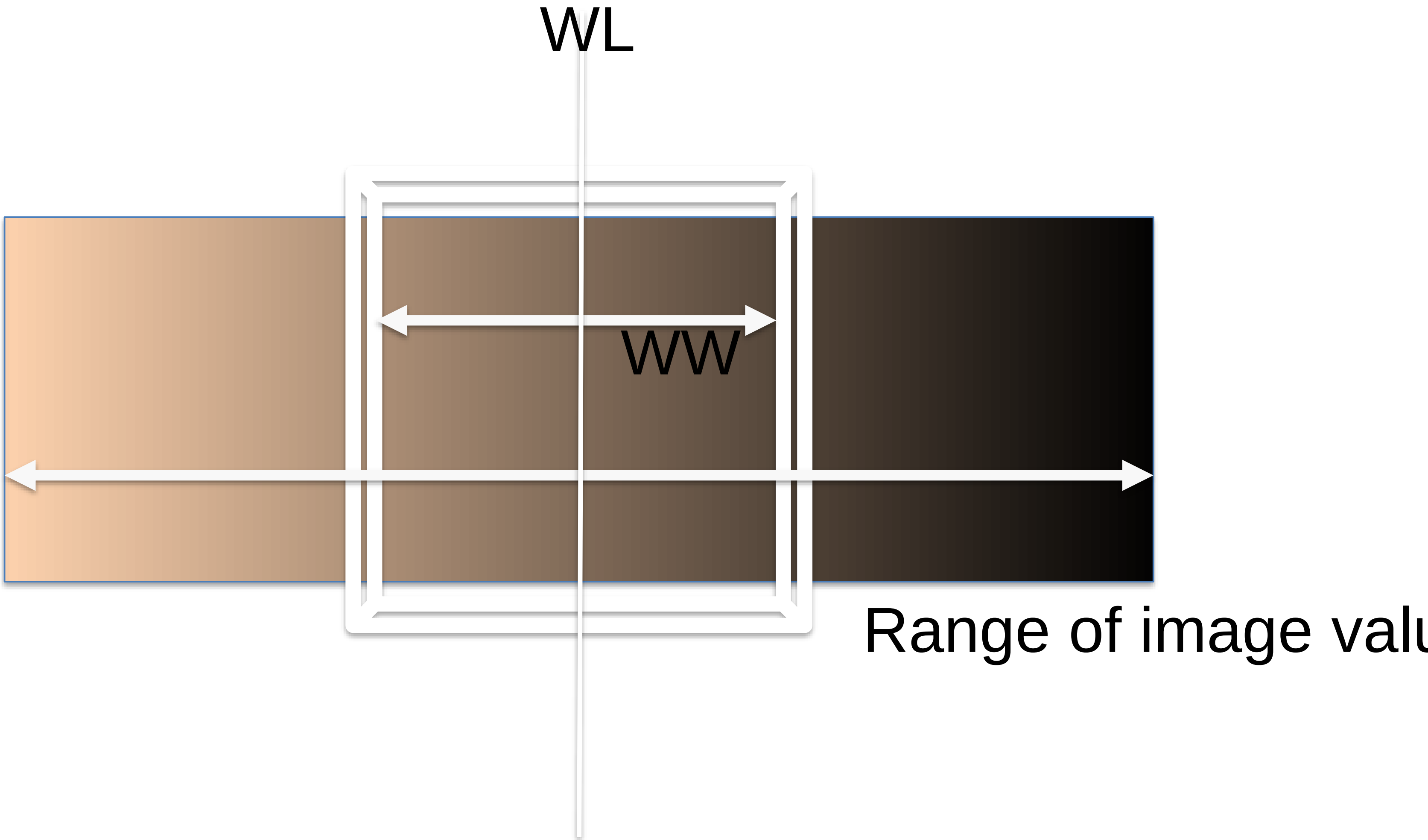
- Window width is the range of digital values that are displayed on the monitor
- Voxel values higher than the WW are shown as white
- Voxel values lower than the WW are shown as back.
- The available gray scale is assigned to the values between the WW minimum and maximum
- The user can adjust the WW. Expanding it compresses more gray levels in the available monitor range.
- Narrowing it enables the user to see smaller differences in contrast.

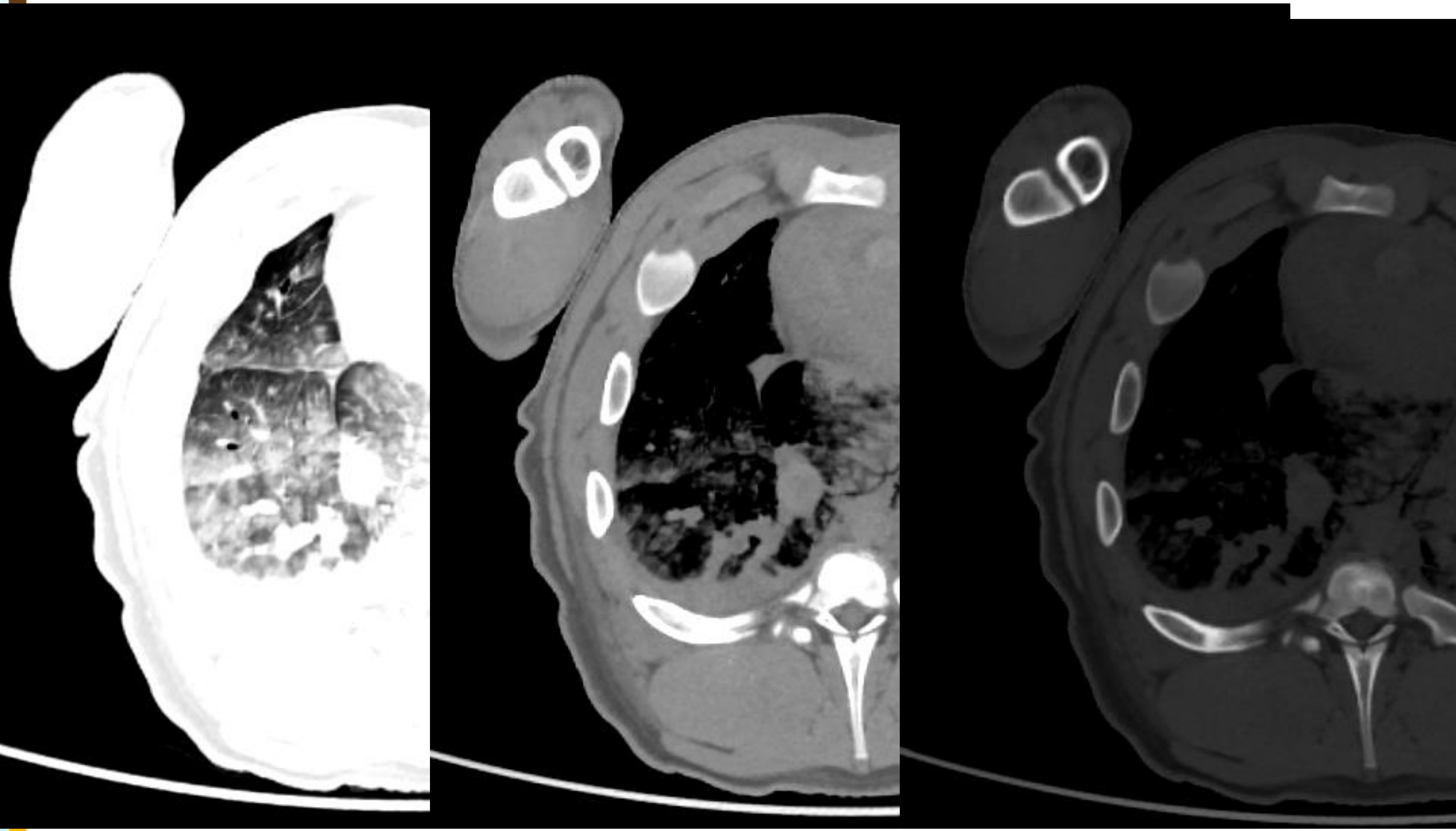
Window Level

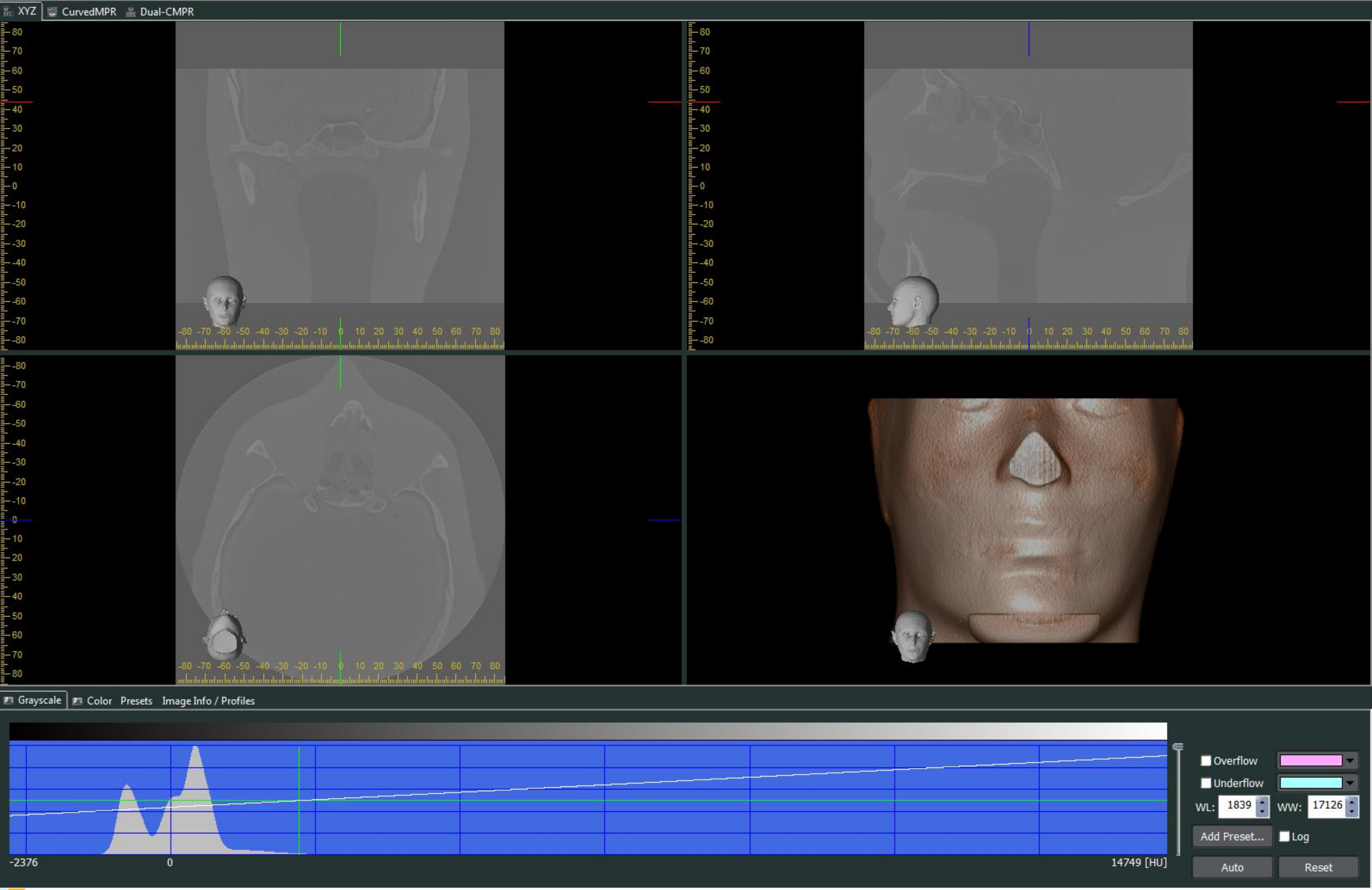
- WL is the center gray level of the window width.
- WL=0, WW=300 means that digital values from -150 to 150 are displayed. Above 150 is white and below -150 is black.
- WL should be set close the average voxel value of the tissue of interest.

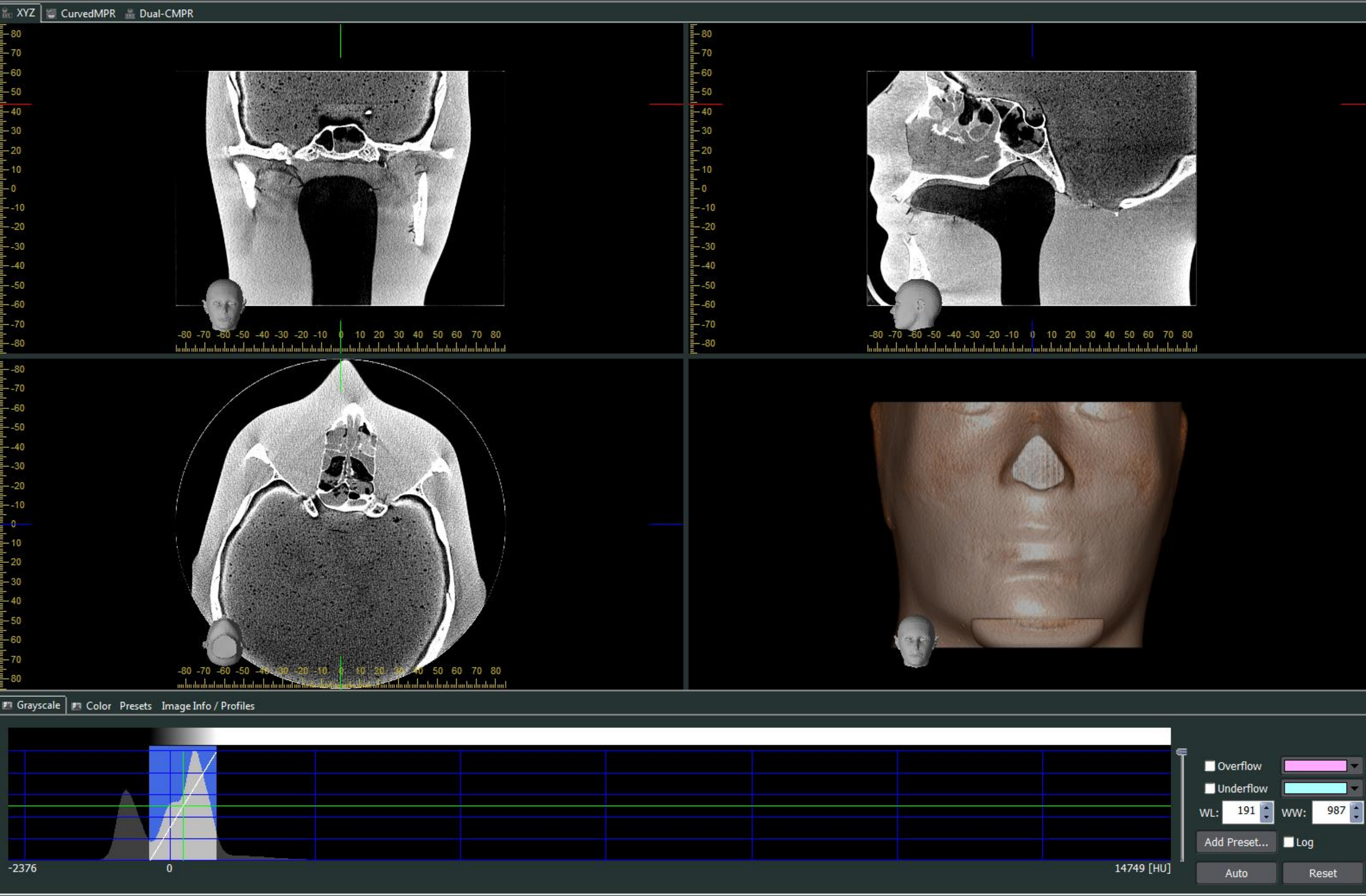
Window With Selection

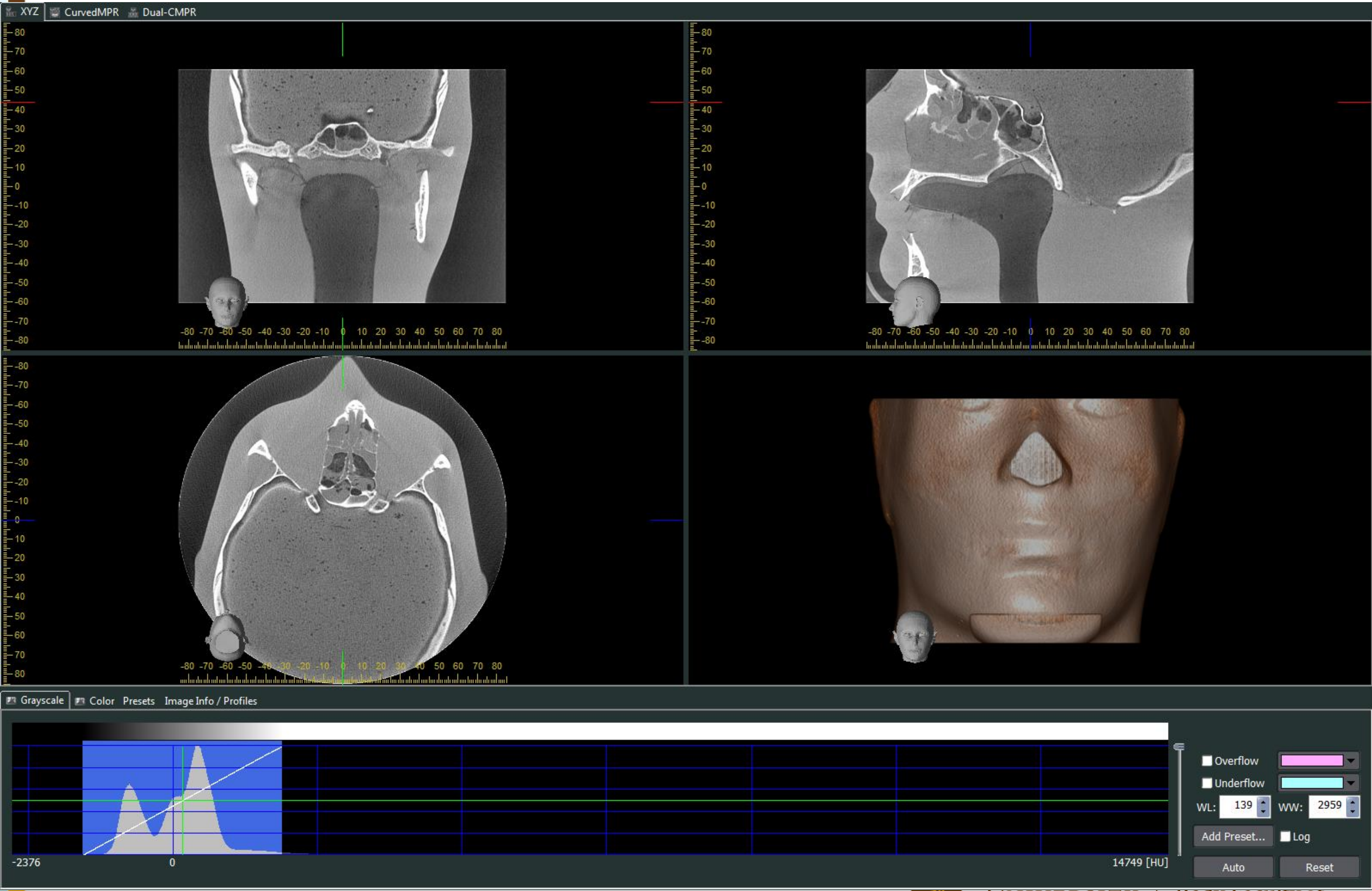
- Wide WW:
  - Noise is averaged
  - Subtle differences are not seen
  - Wide variety of tissue levels
- Narrow WW
  - Use when tissues have similar densities
- Users of a viewing workstation can modify WW/WL to their liking

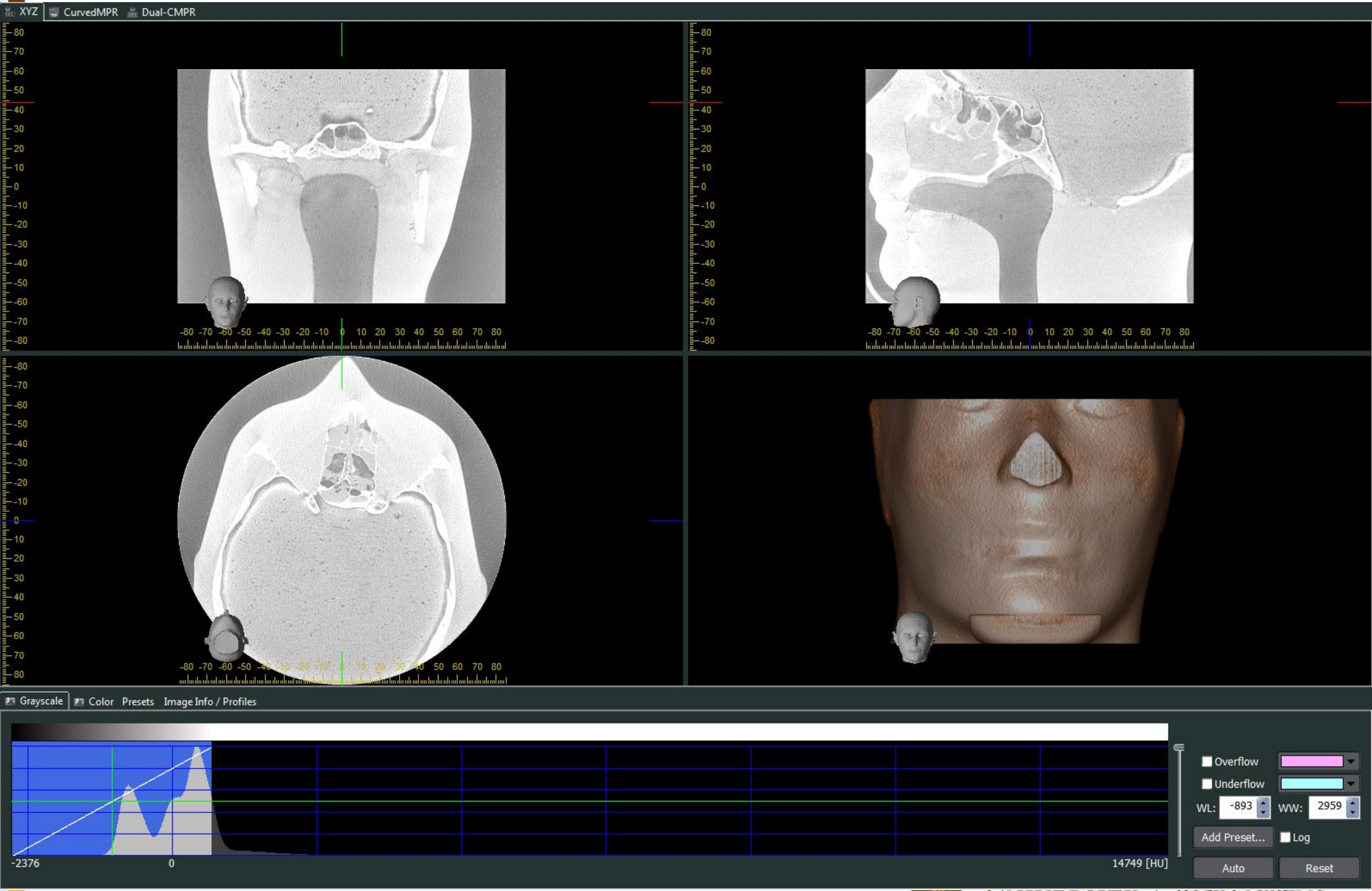

WL
WW
Range of image valu

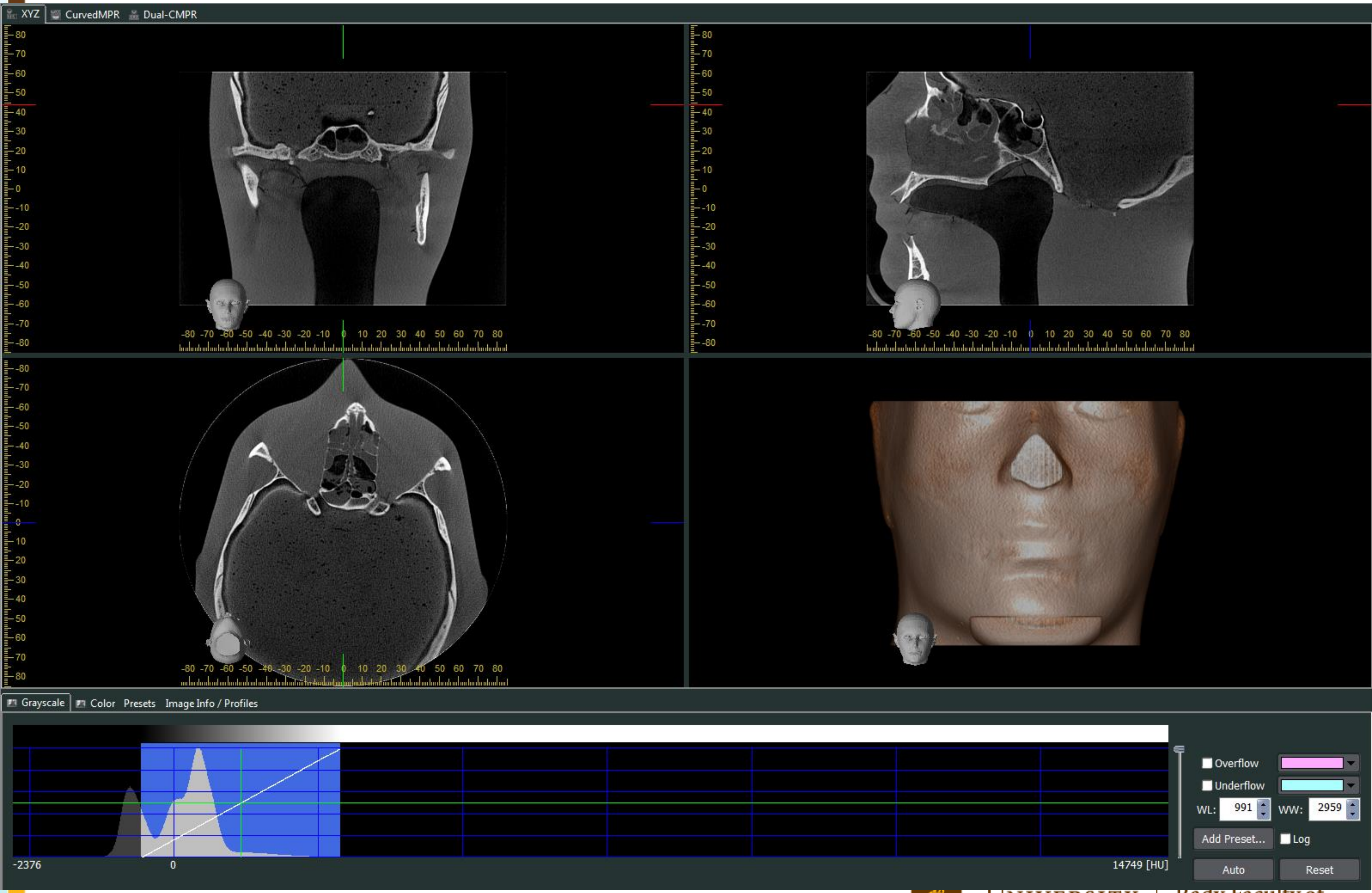



XYZ
CurvedMPR
Dual-CMPR
Grayscale
Color
Presets
Image Info / Profiles
-2376
0
14749 [HU]
Overflow
Underflow
WL: 1839
WW: 17126
Add Preset...
Log
Auto
Reset


XYZ
CurvedMPR
Dual-CMPR
Grayscale
Color
Presets
Image Info / Profiles
-2376
0
14749 [HU]
Overflow
Underflow
WL: 191
WW: 987
Add Preset...
Log
Auto
Reset


XYZ
CurvedMPR
Dual-CMPR
Grayscale
Color
Presets
Image Info / Profiles
-2376
0
14749 [HU]
Overflow
Underflow
WL: 139
WW: 2959
Add Preset...
Log
Auto
Reset

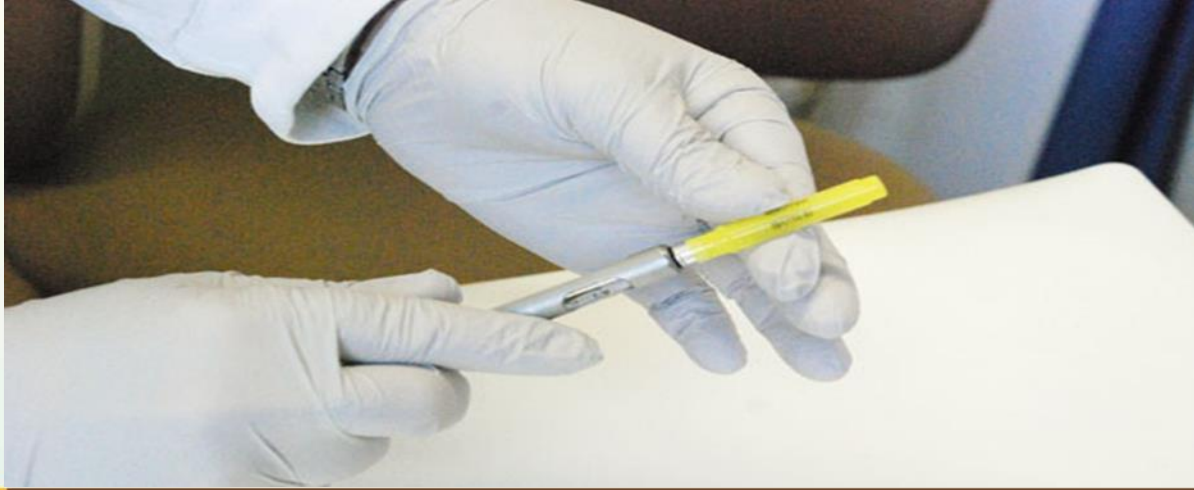

XYZ
CurvedMPR
Dual-CMPR
Grayscale
Color
Presets
Image Info / Profiles
-2376
0
14749 [HU]
Overflow
Underflow
WL: -893
WW: 2959
Add Preset...
Log
Auto
Reset



XYZ
CurvedMPR
Dual-CMPR
Grayscale
Color
Presets
Image Info / Profiles
-2376
0
14749 [HU]
Overflow
Underflow
WL: 991
WW: 2959
Add Preset...
Log
Auto
Reset

The End

CT Physics



Quality Assurance and Control

DOSE, DOLLARS, DIAGNOSIS

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CDA Position on Control of X-Radiation in Dentistry

"A quality assurance program should be established in all aspects of radiological practice in the dental office on a regular basis in accordance with provincial regulations."

https://www.cda-adc.ca/en/about/position_statements/xray/

Health Canada Sant Canada

Radiation Protection in Dentistry

Recommended Safety Procedures for the Use of Dental X-Ray Equipment

Safety Code 30

Quality Assurance is defined as the planned and organised actions necessary to provide adequate confidence that dental X-ray equipment will produce quality radiograms reliably with minimal doses to patients and staff. A Quality Assurance program includes **quality control** procedures for the monitoring and testing of dental X-ray equipment and related components, and administrative methodology to ensure that monitoring, evaluation and corrective actions are properly performed.

SEDENTEXCT Recommends:

- Performance of X-ray tube and generator
- Quantitative assessment of image quality
- Display screen performance
- Patient dose assessment
- Clinical image quality assessment
- Clinical audit

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- **Quantitative assessment of image quality**
- **Display screen performance**
- **Patient dose assessment**
- Clinical image quality assessment
- Clinical audit

Division of Medical Physics @ CCMB

- Radiation protection
  - Inspectors. Empowered by legislation
  - Radiation safety, room shielding, clinical doses
- Imaging Physics
  - Technology expertise
  - Oversight of quality assurance programs
  - Academic

Who Performs QC (ideal world) ?

- Medical Physics
  - Periodic inspection
  - Dose and x-ray tube related measurements
  - Image quality
- Technologist/Dental assistant
  - Weekly, monthly, quarterly checks
  - Image quality, rejects/repeats, system integrity

Who defines QC tests?

- Manitoba Provincial Regulations
- Health Canada Safety Codes
- Manufacturer recommendations
  - perform QC tests at least monthly)
- Consult with medical physicists

New Installation

- Contact Radiation Protection Dept @ CCMB
  – Post-installation inspection
  – Periodic inspection
- Register system with Rad Pro
- Lead shielding required
- CBCT requires dedicated exclusive space

http://www.cancercare.mb.ca/home/cancer_research/medical_physics/radiation_protection/

Rad Pro Inspections

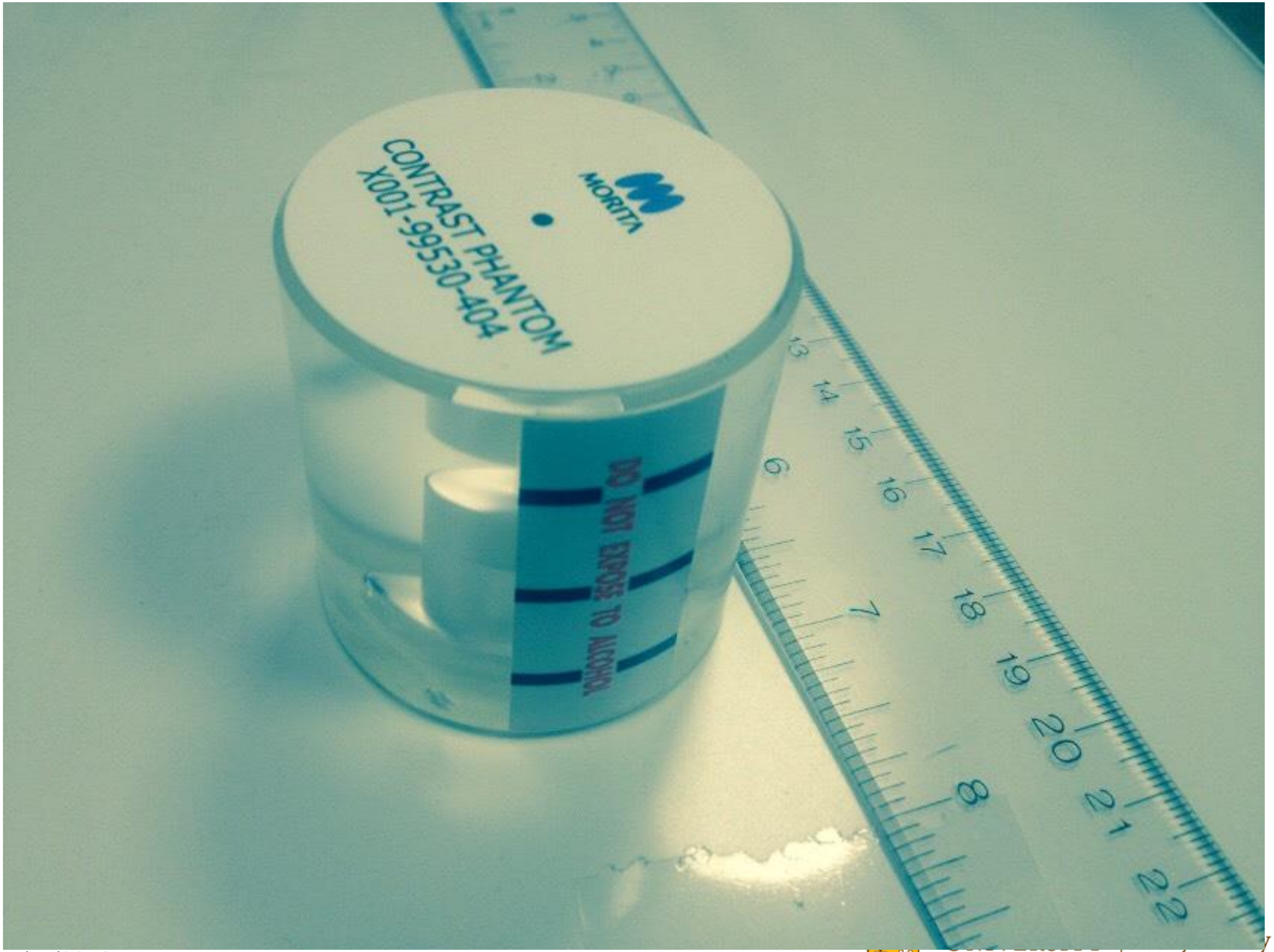
- Basic radiation safety checks
  - Tube exposure output
  - kVp
  - Half Value Layer
  - “Typical” patient exposure
  - Scatter and leakage
- Verification of shielding (new installation)

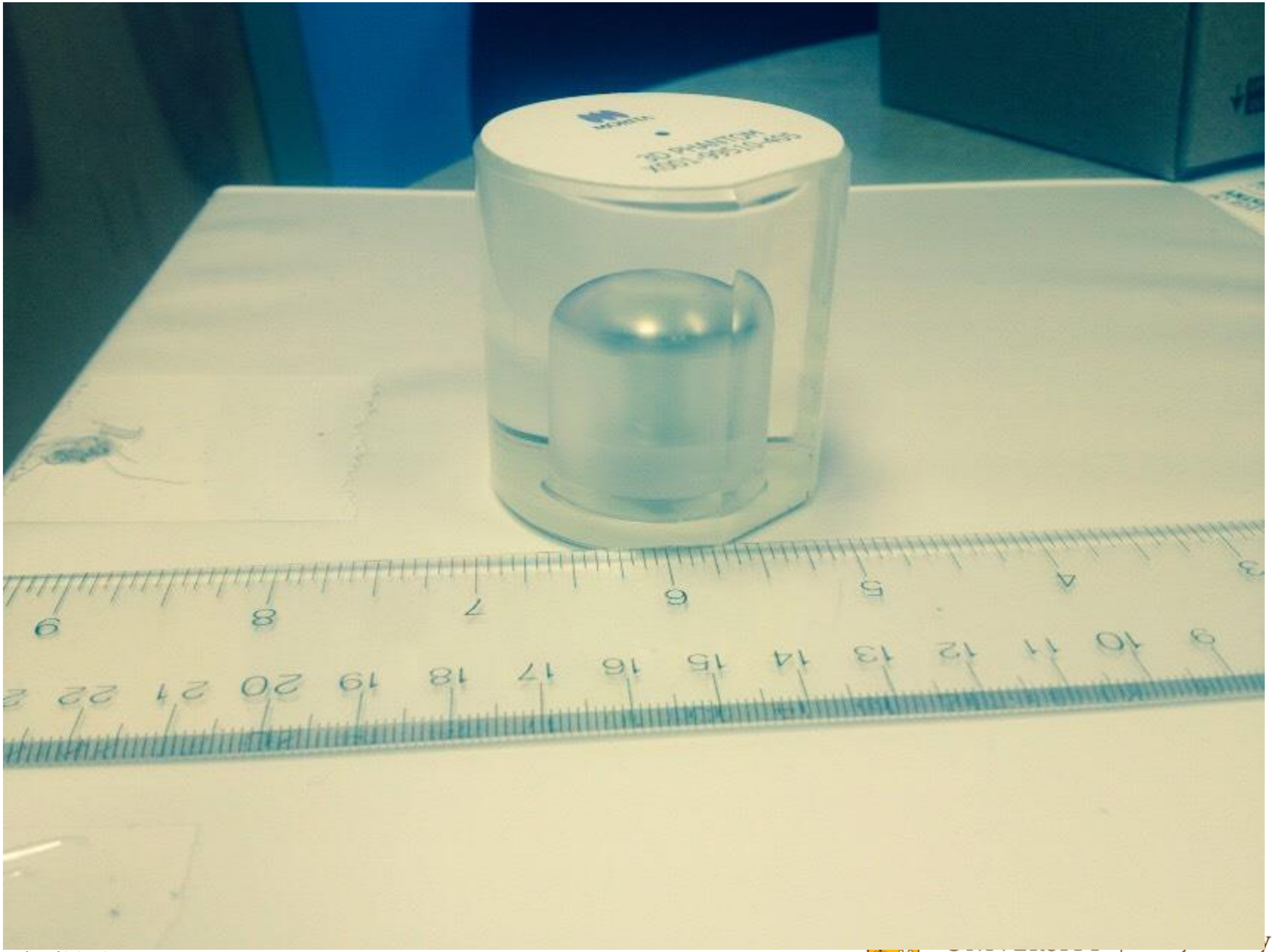
Your Responsibilities

- Register with Radiation Protection
- Ensure appropriate shielding
- Perform routine quality control
- Recommended that you keep patient dose log and set diagnostic reference levels
- When in doubt….ask!

Sample Site QC Tests

- J Morita in the F D
- Illustrative example / no endorsement


MORITA
CONTRAST PHANTOM
X001-99530-404
DO NOT EXPOSE TO ALCOHOL



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MORITA
WIRE PHANTOM
X001-99520-404

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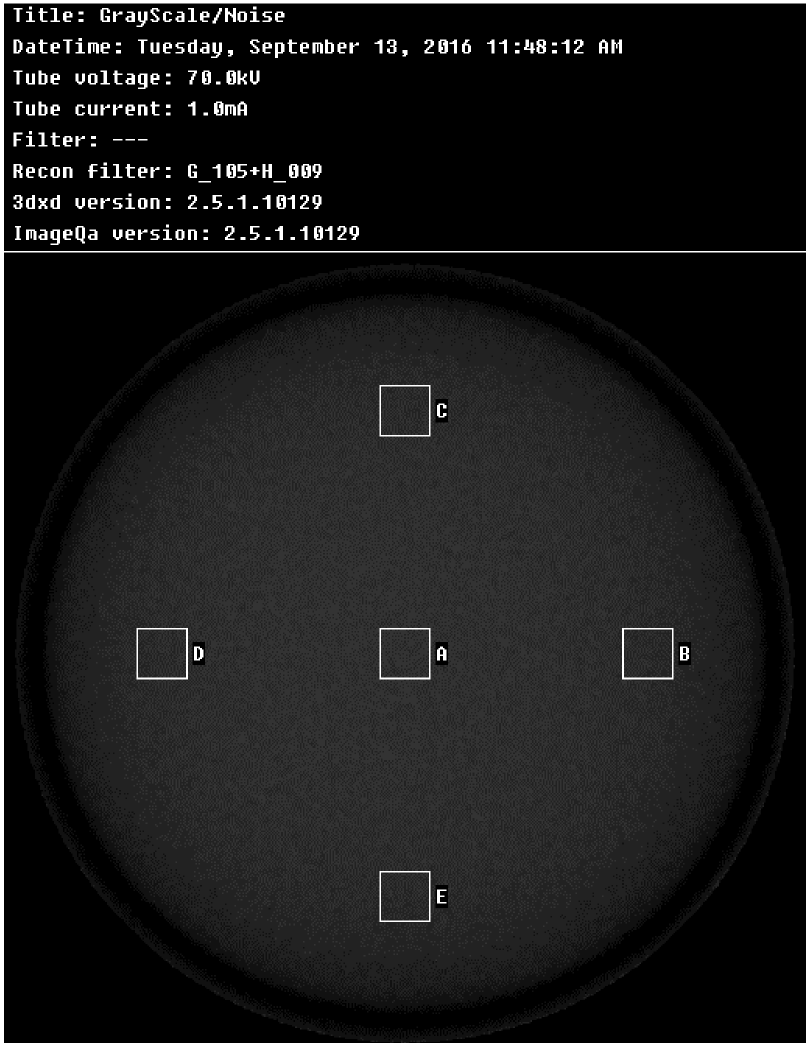
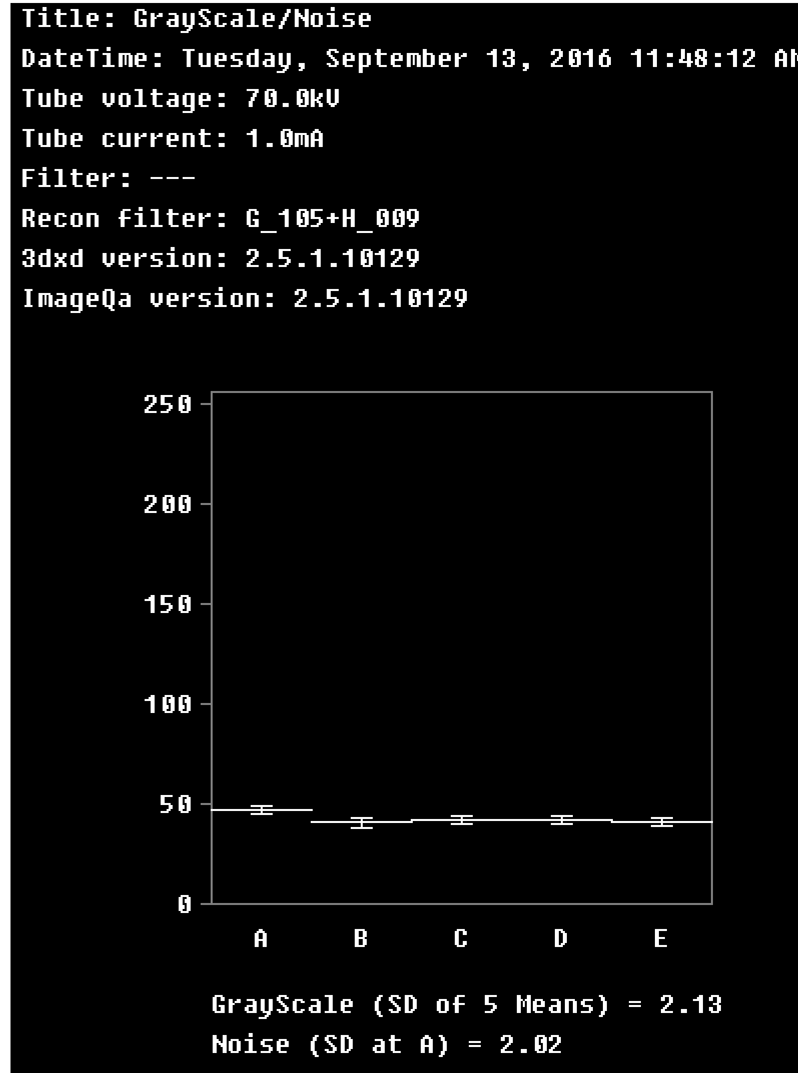
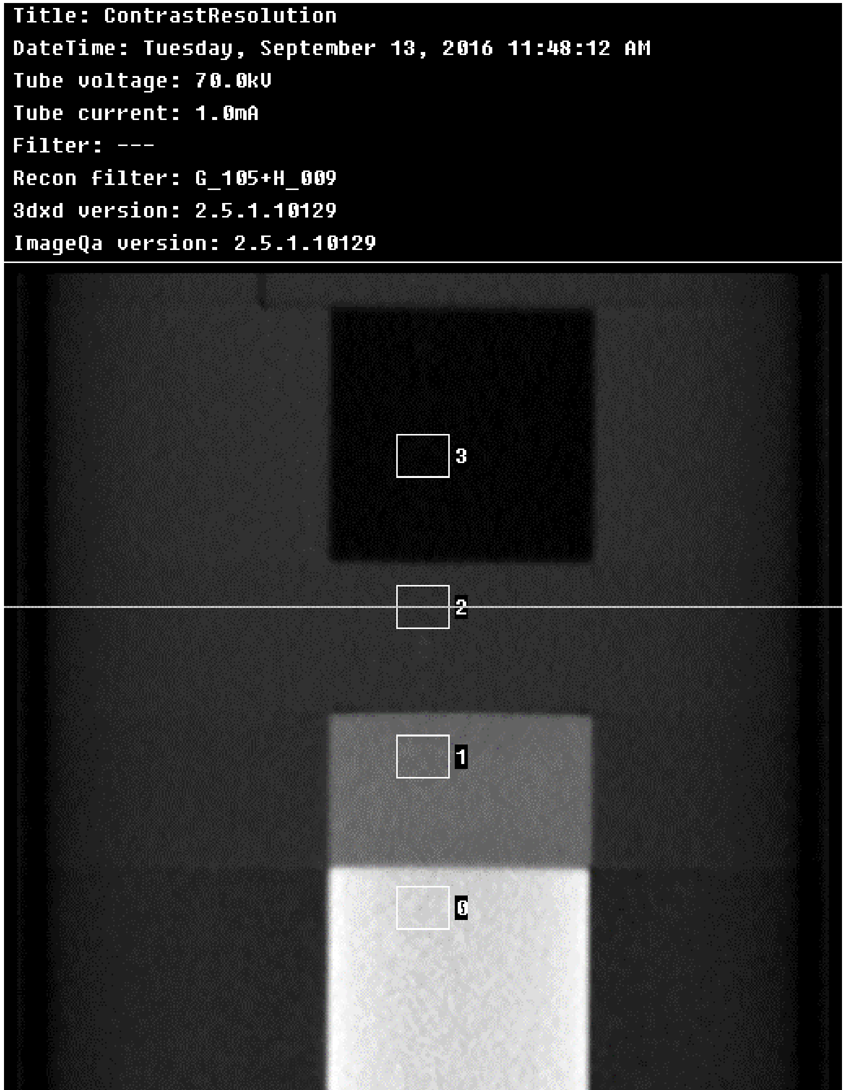
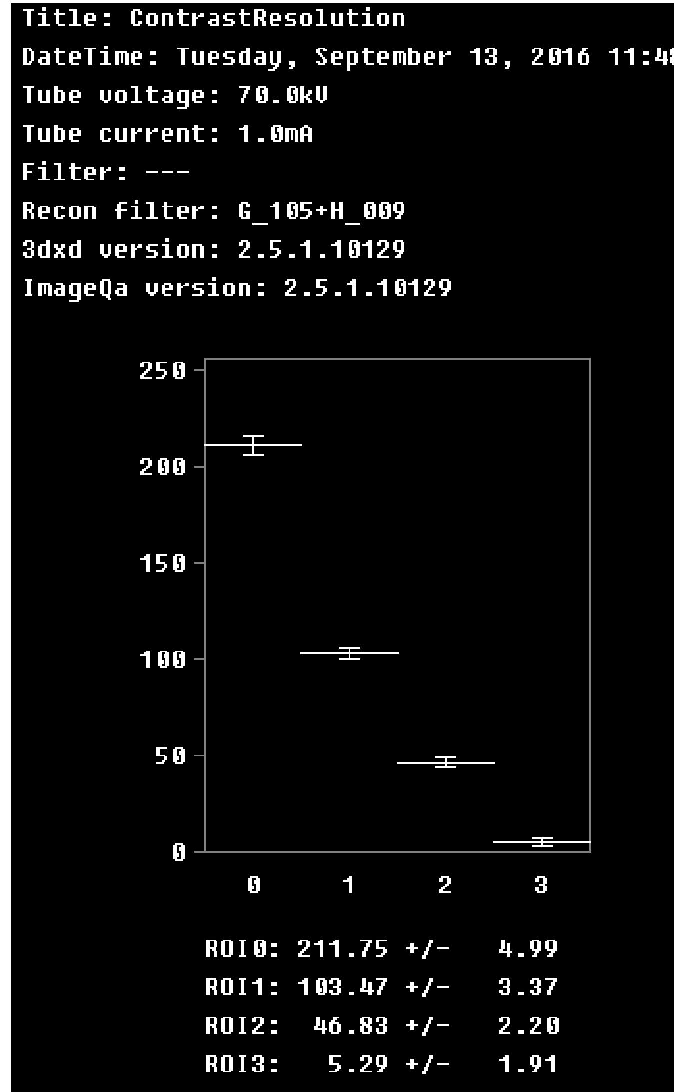
Image Uniformity



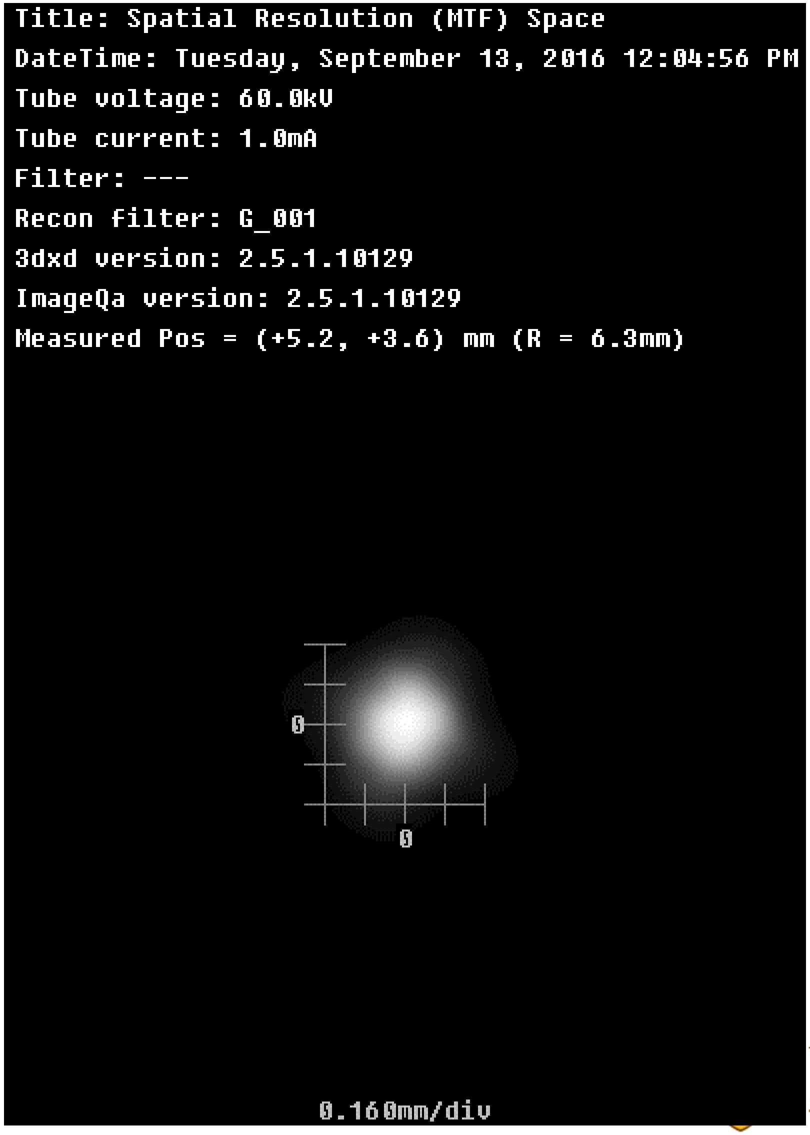


Gray Scale Accuracy

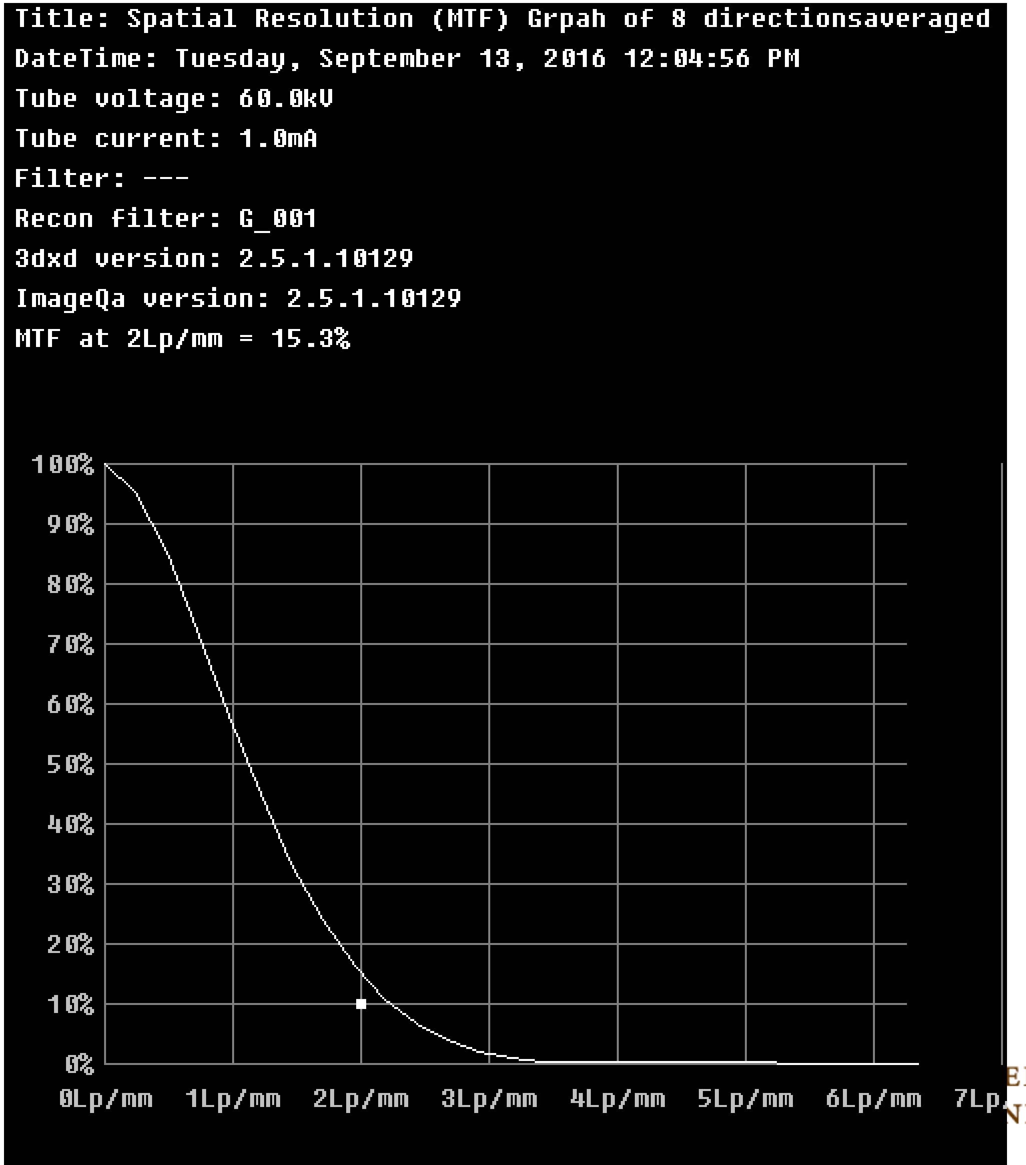




Spatial Resolution



MTF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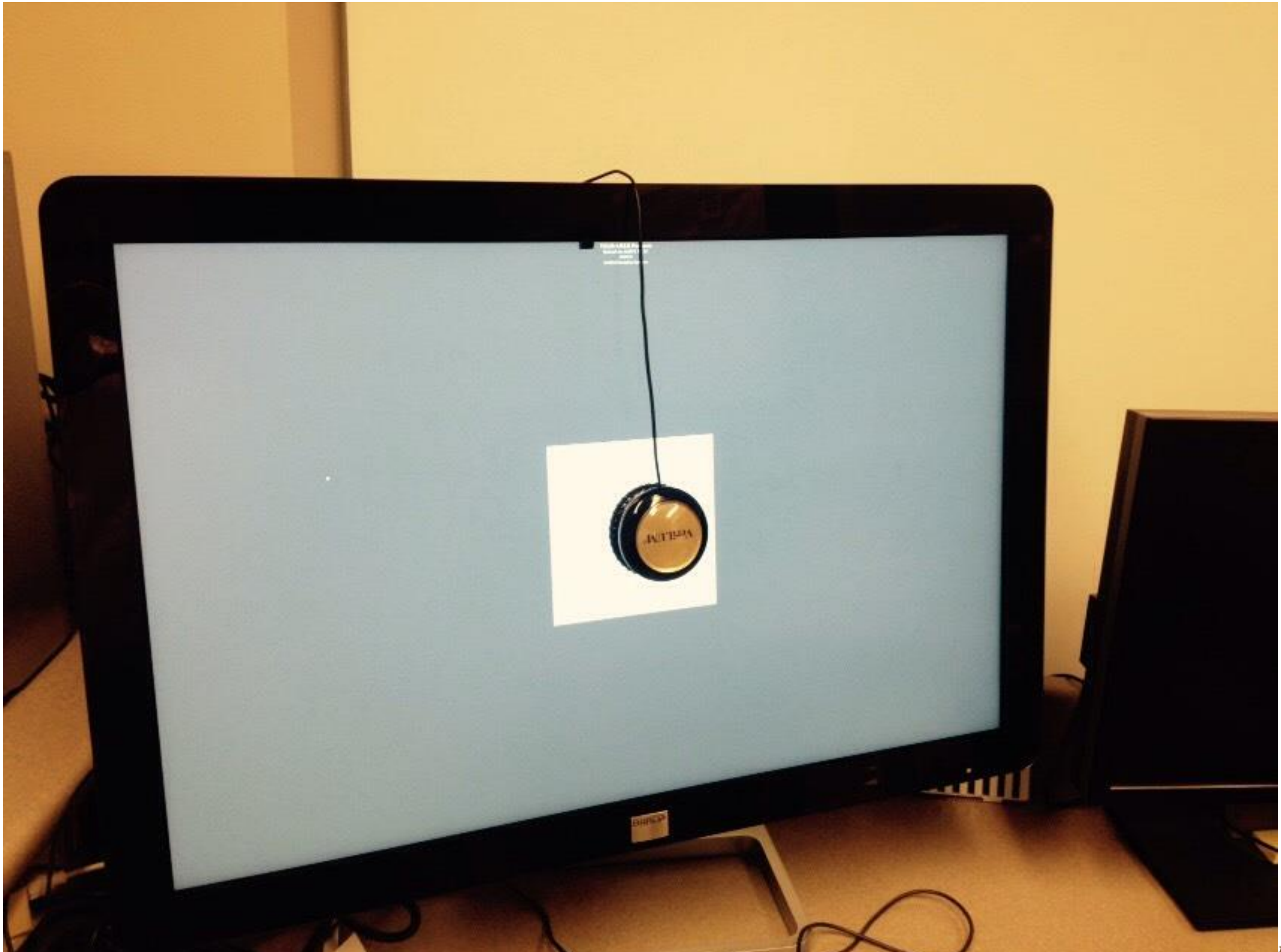
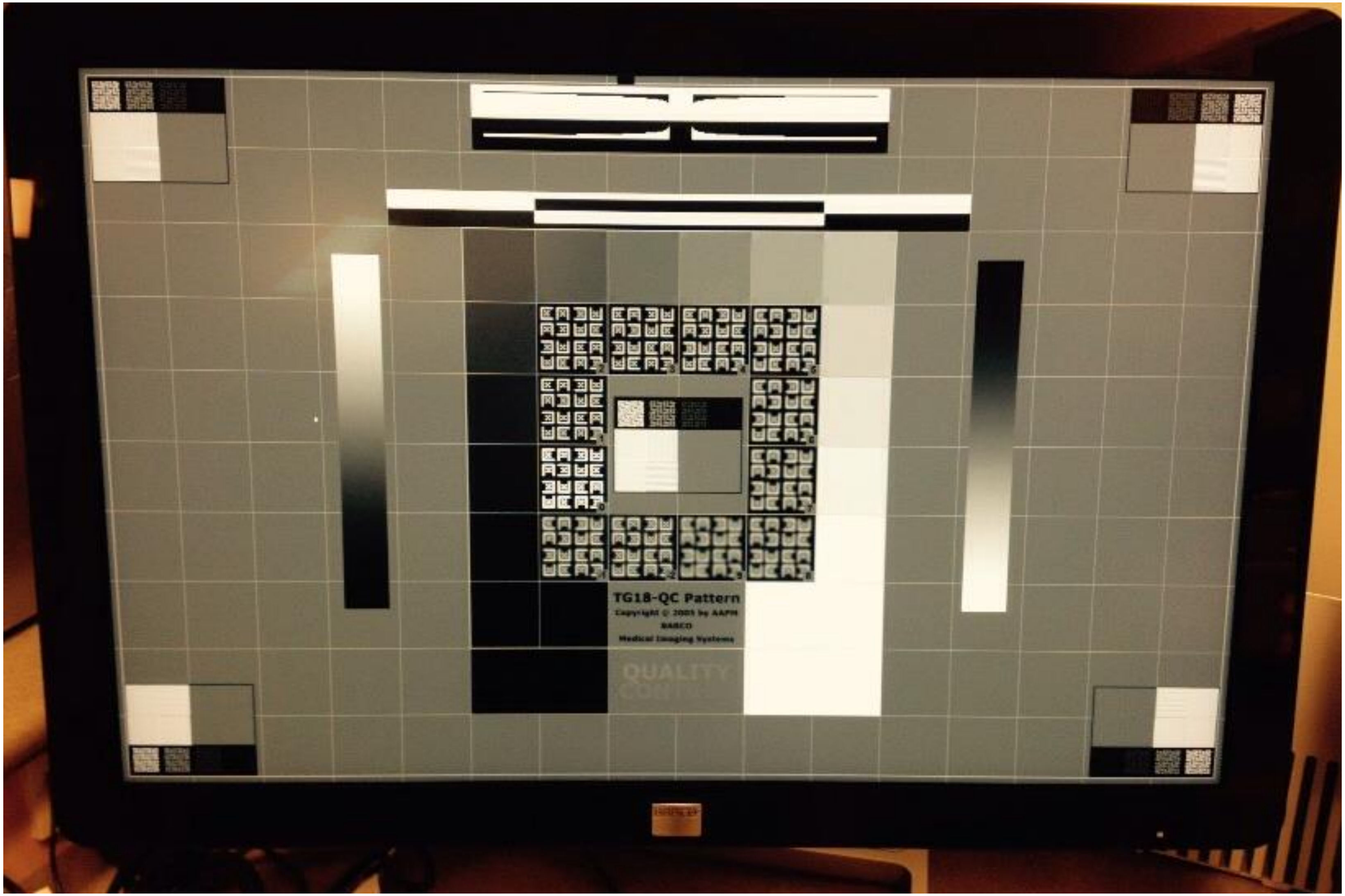
DateTime: Tuesday, September 13, 2016 12:04:56 PM
Tube voltage: 60.0kV
Tube current: 1.0mA
Filter: ---
Recon filter: G_001
3dxd version: 2.5.1.10129
ImageQa version: 2.5.1.10129
MTF at 2Lp/mm = 15.3%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0Lp/mm
1Lp/mm
2Lp/mm
3Lp/mm
4Lp/mm
5Lp/mm
6Lp/mm
7Lp

Display Quality Control

- Use medical grade displays
- Calibrated in accordance with the DICOM standard
  - Meets minimum brightness criteria
  - Contrast response matches HVS
- Get a medical physicist to help




TG18-QC Pattern
QUALITY

Organ Shielding

- Literature suggests that use of lead-equivalent thyroid shields and eye glasses reduces dose to those organs
- Goren et al. Dentomaxillofacial Radiology 2013
  - Phantom equivalent to female
  - 74% dose reduction to eye
  - 61% dose reduction to eye lens
  - 42% dose reduction to thyroid

Organ Shielding

- Hidalgo et al. Dentomaxillofacial Radiology 2015
  - Pediatric 10 year old phantom
  - Large FOV
  - 40% reduction in thyroid dose
  - Shield > 0.25 mm Pb

Organ Shielding: Precautions

- Shields introduce high-density artifacts if they are in the primary beam/reconstructed image
- If system sets kVp/mA based on x-ray scout, please shield ***after*** the scout image is acquired.
- If organs outside of primary beam, shields guard against scatter and x-ray tube leakage.

- The owner of a CBCT scanner must not:

a) Implement a CBCT QC program

b) Purchase only Health Canada licensed device

c) Register with the provincial radiation protection department

d) Determine the amount of wall shielding

e) Allow the machine to be operated by their secretary

The End