X-ray Basics

X-ray Basics: Basic Physics

THE ELECTRO MAGNETIC SPECTRUM

<table>
<thead>
<tr>
<th>Wavelength (metres)</th>
<th>Radio</th>
<th>Microwave</th>
<th>Infrared</th>
<th>Visible</th>
<th>Ultraviolet</th>
<th>X-Ray</th>
<th>Gamma Ray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10^3$</td>
<td>$10^{-2}$</td>
<td>$10^{-5}$</td>
<td>$10^{-5}$</td>
<td>$10^{-8}$</td>
<td>$10^{-10}$</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>

Frequency (Hz)

- $10^4$
- $10^8$
- $10^{12}$
- $10^{15}$
- $10^{16}$
- $10^{18}$
- $10^{20}$
X-ray Basics: Basic Physics

- Factors Affecting Amount of Transmission:
  - Photon Energy
  - Thickness
  - Atomic Number (Z)

- Exponential Attenuation with Distance Traveled in the Material

- Material:
  - Incident X-ray Photons
  - Exponential Attenuation With Distance Traveled in the Material
  - Amount of Attenuated Photons
  - Transmitted X-ray Photons

Image Source: http://www.ndted.org/EducationResources/CommunityCollege/Radiography/Physics/radininteraction.htm

X-ray Basics: Imaging Concepts

- Image = X-ray Population Map

- Dark Areas
  - = Sample Absorption
  - = less photons

- Bright Areas
  - = Sample Transmittance
  - = more photons
Increasing the current increases the number of X-rays
Increasing the voltage increases the penetrating power of X-rays

Resolution
Spatial differentiation

Geometric magnification
Specimen = 12mm diameter
2 cells = 6mm resolution
Resolution
Spatial differentiation

Geometric magnification
Specimen = 12mm diameter
6 cells = 2mm resolution

Resolution
Spatial differentiation

Geometric magnification
Specimen = 12mm diameter
12 cells = 1mm resolution
Sample preparation

- Maximize the resolution of the scan
  - Square Detector plate
- Efficient use of space
  - Cylindrical is better
  - Centralized position
- Multi-scan used for odd shaped samples
  - Increased time
  - Can lead to truly colossal file sizes
Choose the resolution that fits the project!
**Contrast**

density differentiation

- Contrast
  - X-ray energy (KV)
  - kV=X-ray penetrating power
  - Too high
    - No X-rays stopped by object
    - loss of resolvability in low density areas
  - Too low
    - All X-rays stopped by object
    - loss of resolvability in high density areas
  - Maximize grayscale range

**Noise**

- Too few photons to produce a clear image
  - Grainy reconstructions
- Increase photons
  - Increase current
    - = increase photons
  - Increase detector capture time
    - = Increase photons
Geometric unsharpness

Higher power (W) ≤ the resolution (μm)

Detector calibration
A series of trade-offs

Resolution

Power
Filtering
Averaging
Magnification
Detector Capture Time

Speed

Signal to noise

X-ray Summary

• Voltage: Increases Penetrating Power of X-rays
• Current: Increases number / Intensity of X-rays
• Resolution: spatial differentiation
• Contrast: attenuation differentiation
• Noise: a result of insufficient signal
• Geometric unsharpness: focal spot too large