Diffraction Enhanced X-ray Imaging (DEI)

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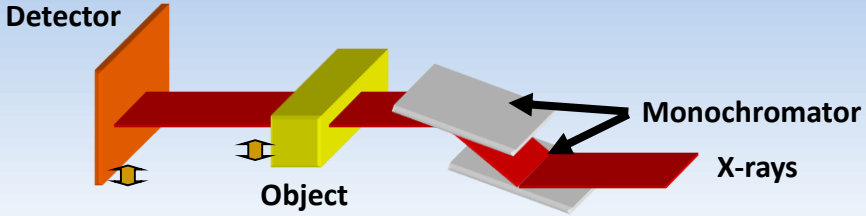
Physics 570 Final Presentation – December 6th, 2013

Bullet Points of Presentation

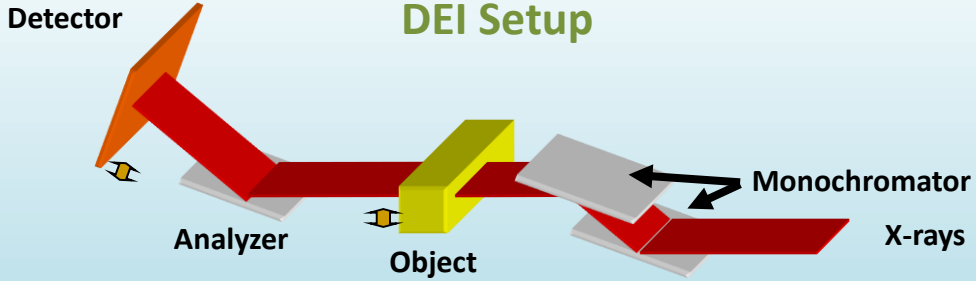
- Radiography vs. Diffraction Enhanced Imaging (DEI)
- Basic Principles of DEI
  - Absorption
  - Refraction
  - Scattering
- Extracting Image Data
  - Extinction (Scatter Rejection)
  - Refraction
  - Scattering
- Applications

Radiography vs. DEI

Conventional Setup

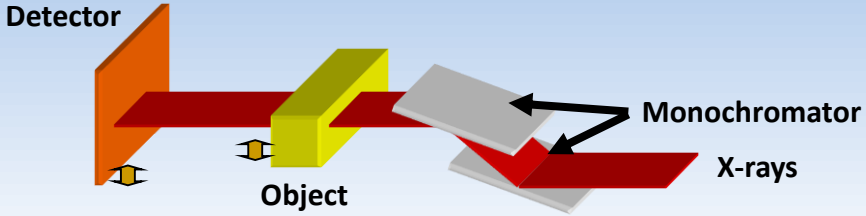


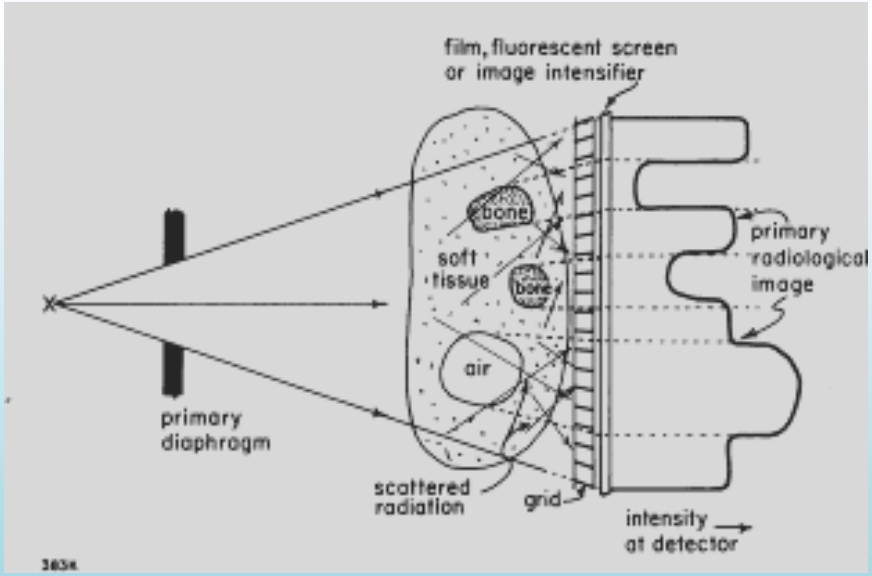
DEI Setup



Basic Principles of DEI

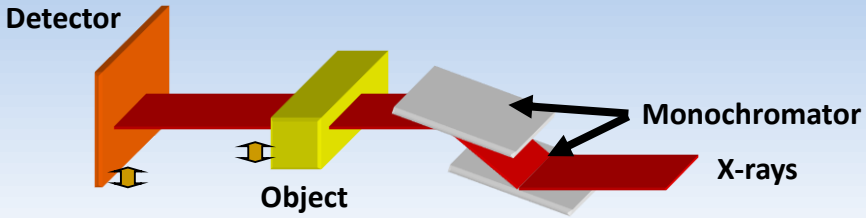
Conventional Setup





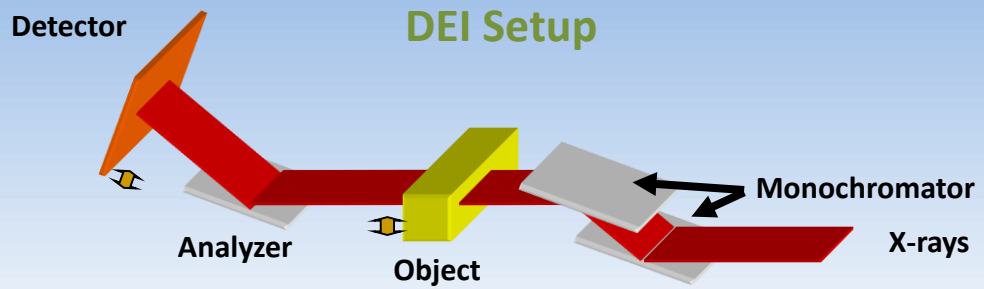
Basic Principles of DEI

Conventional Setup



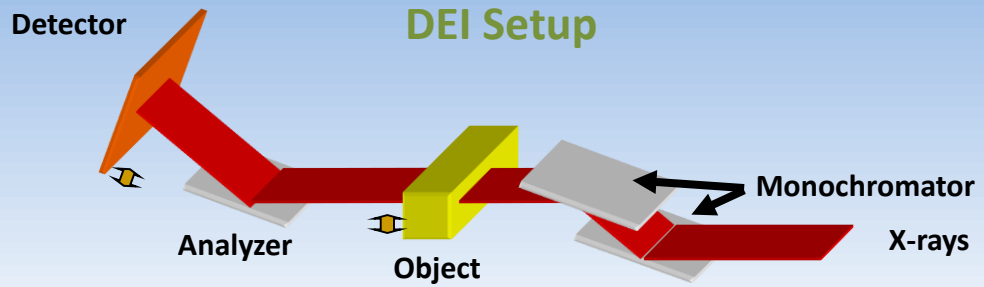
Absorption

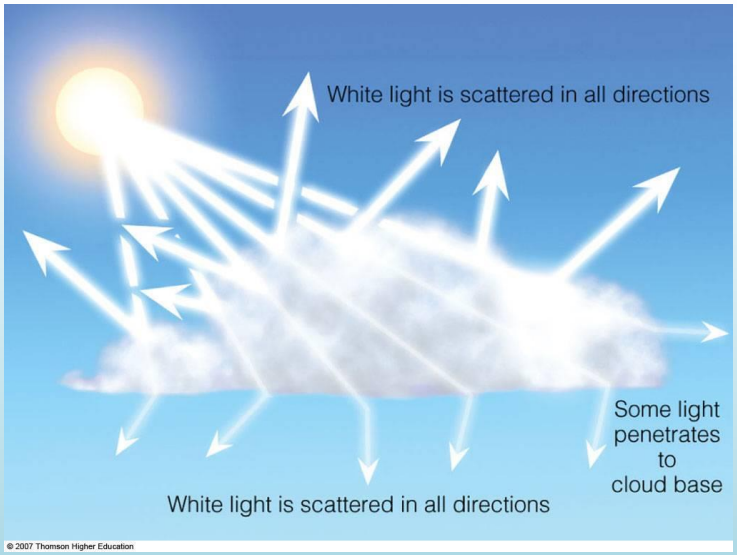
Basic Principles of DEI



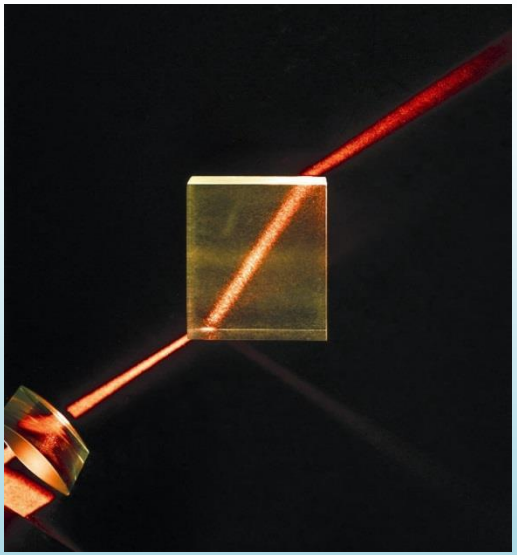
Absorption

Basic Principles of DEI



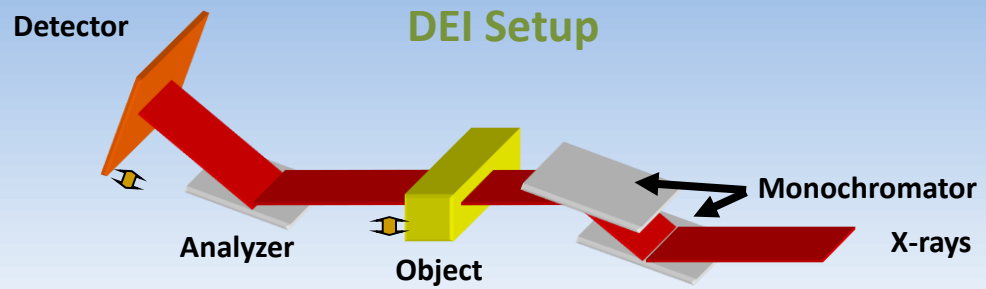


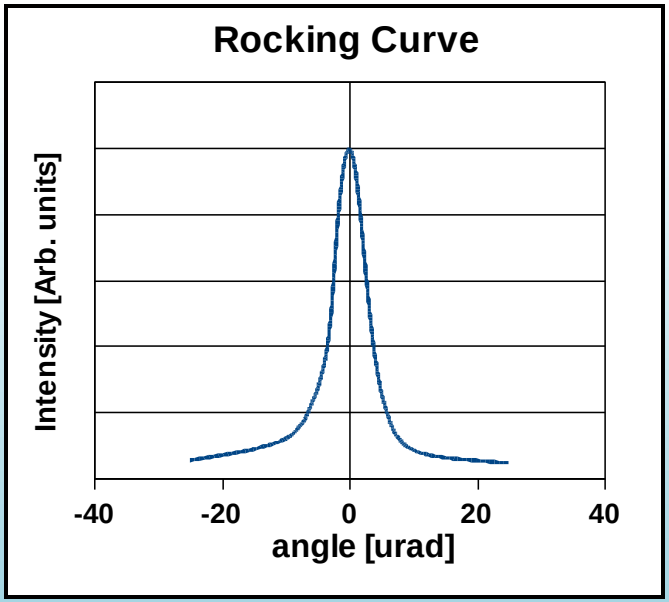
Scattering



Refraction

Basic Principles of DEI





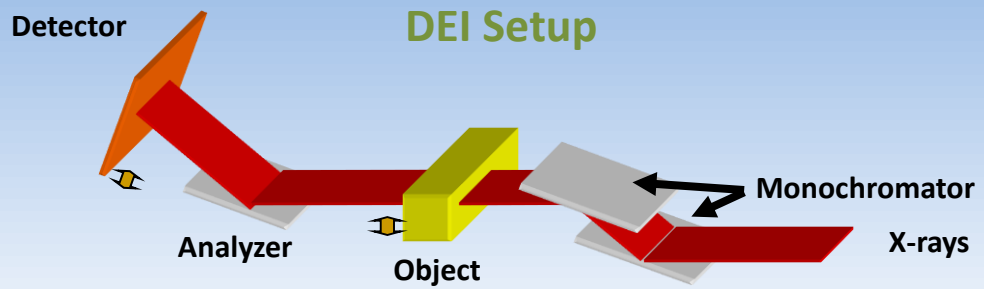
What makes DEI different from conventional radiography?

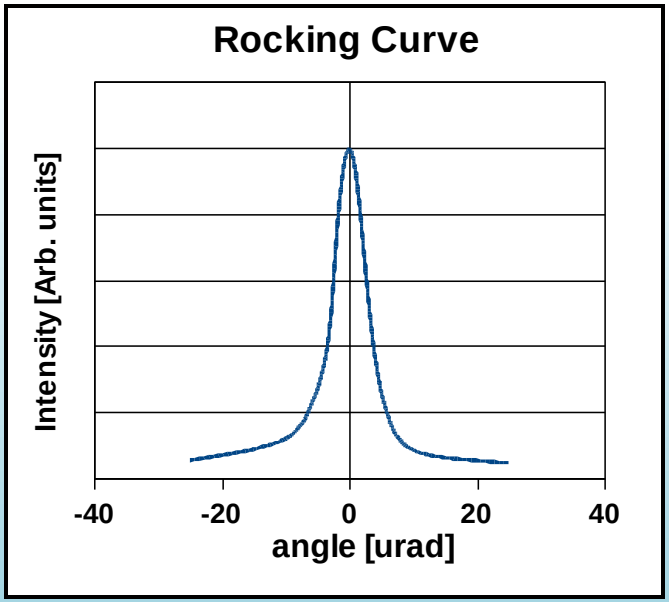
The Analyzer Crystal – used to create a rocking curve (micro-radian width)

From the Rocking Curve the Principles of DEI can be extracted.

Here is how it works.

Basic Principles of DEI





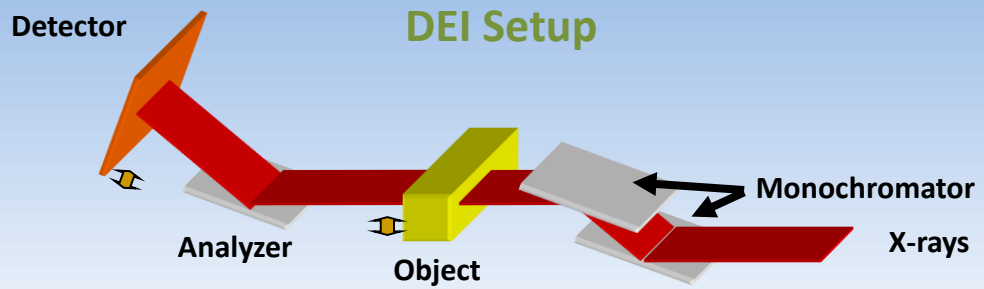
Conventional Radiograpy uses the Recorded Intensity to get an image, variation in intensity gives a contrast.

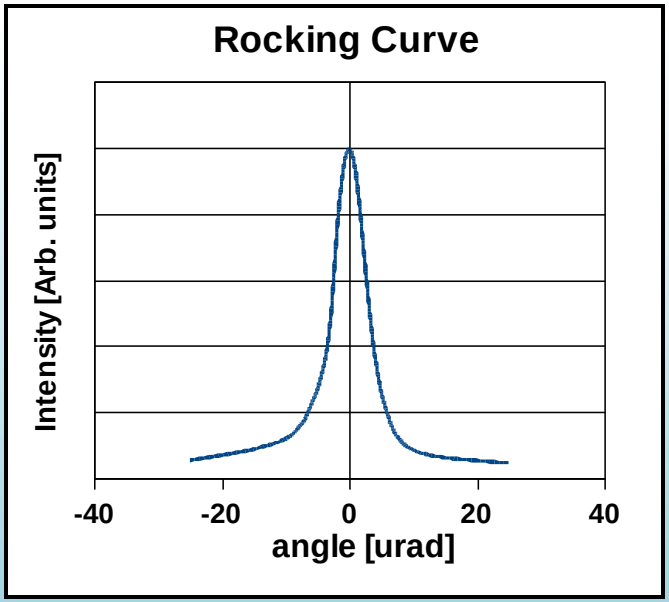
Scattering components (I, C) and Small-angle scattering (D) lead to a loss in contrast as well as spatial resolution.

Refraction (R) is lost

$$I_N = I_R + I_D + I_C + I_I$$

Basic Principles of DEI



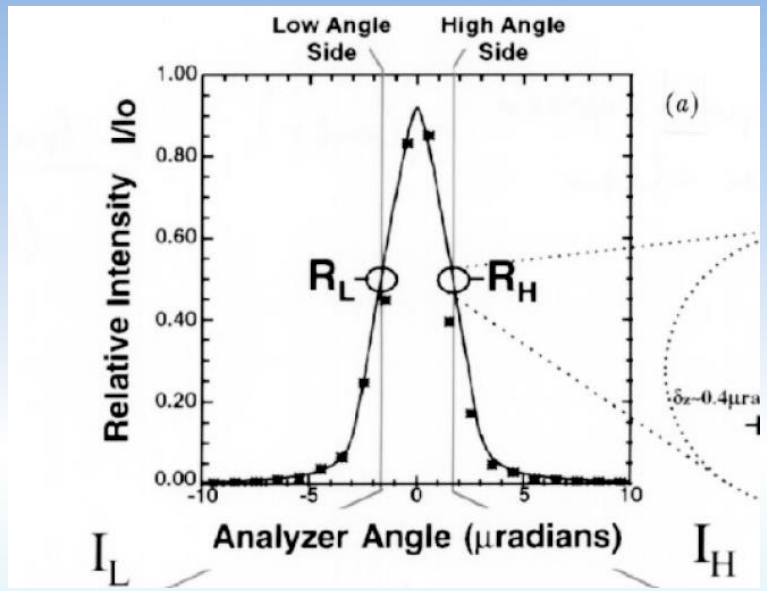


DEI (analyzer crystal) preserves many of these components and takes advantage of them.

Small-angle scattering (D) is mostly eliminated due to the xstal rejecting all angles above the micro-radian range. Imaged objects are usually in milli-radian range well above the crystal optics

Refraction (R) is all that is left and can be separated.

Basic Principles of DEI



DEI there are two images taken. Each side of the rocking curve.

Apparent absorption and refraction information.

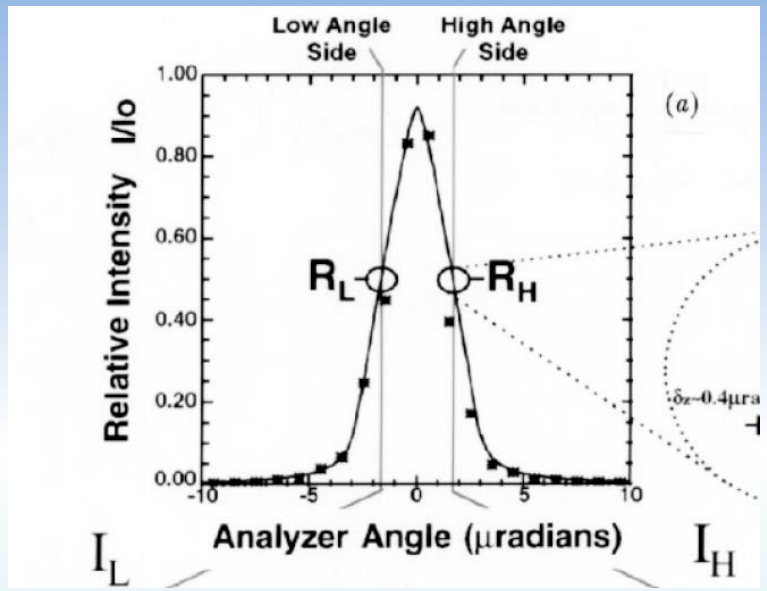
Intensity diffracted by analyzer crystal I(B)

Darwin Width

$$I_B = I_R R(\theta_B + \theta)$$

$$I_B = I_R R\left(\theta_B \pm \frac{\Delta\theta_D}{2} + \Delta\theta_Z\right)$$

Basic Principles of DEI

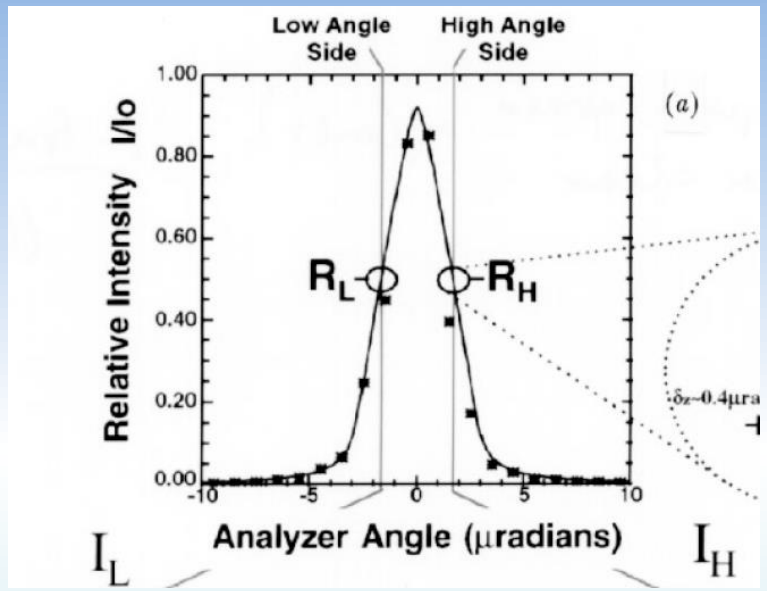


Reflectivity of the analyzer crystal

For small values of $\Delta\theta z$ using Taylor Series approximation for Reflectivity of the analyzer.

$$R(\theta_0 + \Delta\theta_Z) = R(\theta_0) + \frac{\mathrm{d}R}{\mathrm{d}\theta}(\theta_0)\Delta\theta_Z$$

Basic Principles of DEI



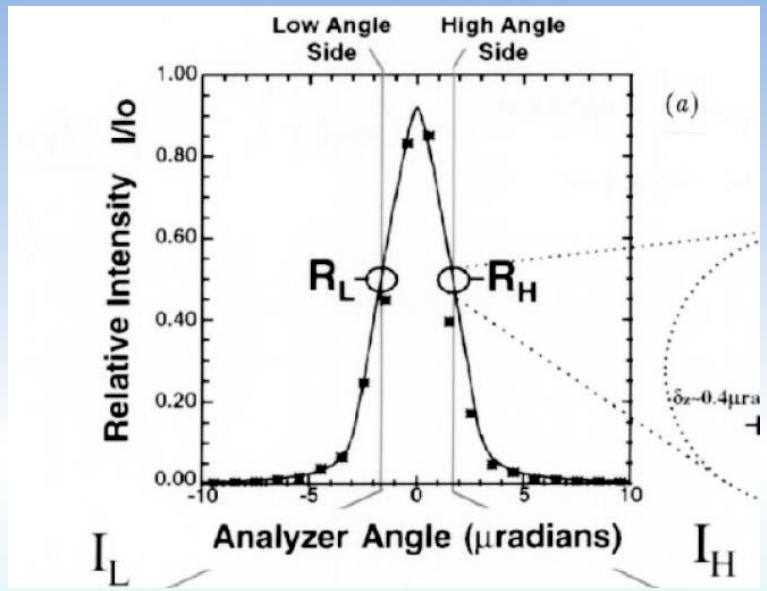
Intensity of the Images can be calculated for the left side and right side of the rocking curve.

Solving these two equations for Extinction and Refraction.

$$I_L = I_R \left(R(\theta_L) + \frac{dR}{d\theta}(\theta_L)\Delta\theta_Z \right)$$

$$I_H = I_R \left(R(\theta_H) + \frac{dR}{d\theta}(\theta_H)\Delta\theta_Z \right)$$

Basic Principles of DEI



Intensity of the Images can be calculated for the left side and right side of the rocking curve.

Solving these two equations for Refraction and Extinction.

The algorithm can be applied to each pixel from both sides of the rocking curve to form the DEI images.

$$I_L = I_R\left(R(\theta_L) + \frac{\mathrm{d}R}{\mathrm{d}\theta}(\theta_L)\Delta\theta_Z\right)$$

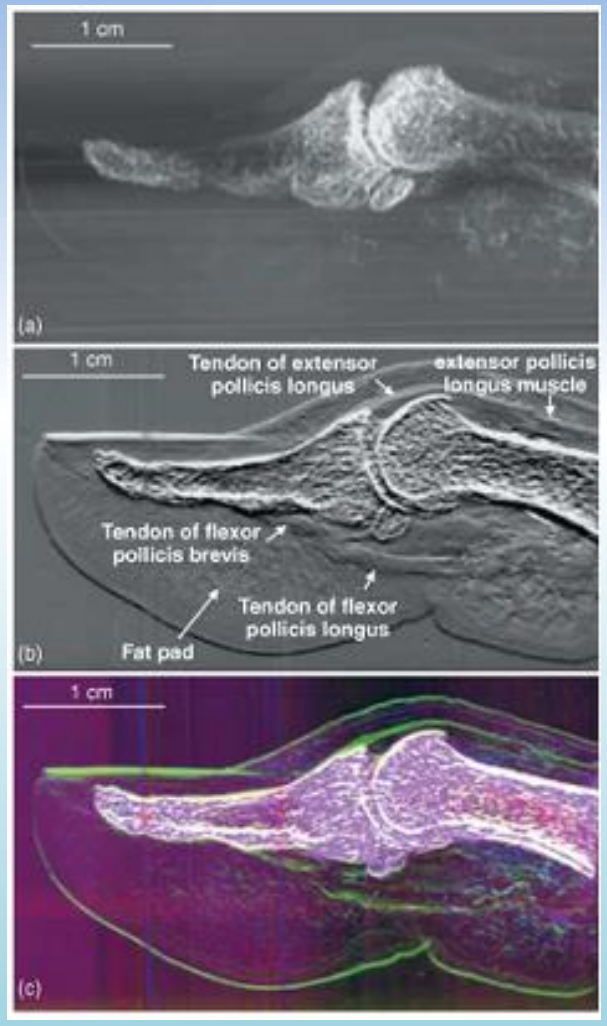
$$I_H = I_R\left(R(\theta_H) + \frac{\mathrm{d}R}{\mathrm{d}\theta}(\theta_H)\Delta\theta_Z\right)$$

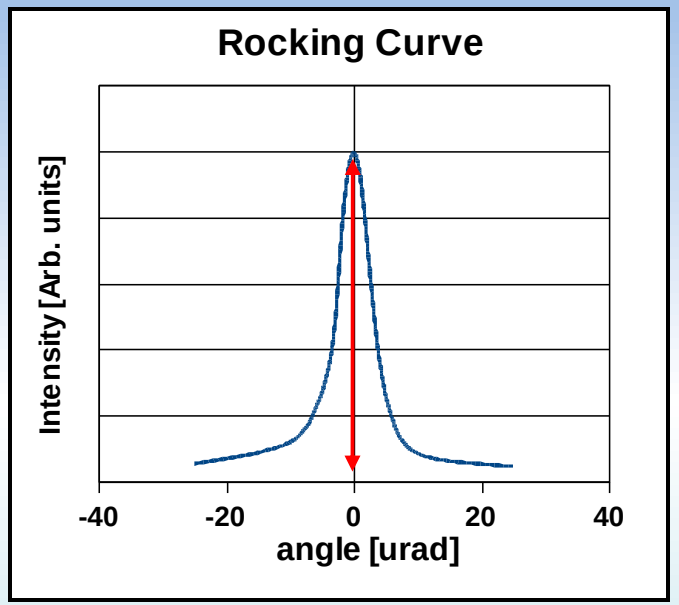
$$I_R = \frac{I_L\left(\frac{\mathrm{d}R}{\mathrm{d}\theta}\right)(\theta_H) - I_H\left(\frac{\mathrm{d}R}{\mathrm{d}\theta}\right)(\theta_L)}{R(\theta_L)\left(\frac{\mathrm{d}R}{\mathrm{d}\theta}\right)(\theta_H) - R(\theta_H)\left(\frac{\mathrm{d}R}{\mathrm{d}\theta}\right)(\theta_L)}$$

$$\Delta\theta_Z = \frac{I_H R(\theta_L) - I_L R(\theta_H)}{I_L\left(\frac{\mathrm{d}R}{\mathrm{d}\theta}\right)(\theta_H) - I_H\left(\frac{\mathrm{d}R}{\mathrm{d}\theta}\right)(\theta_L)}.$$

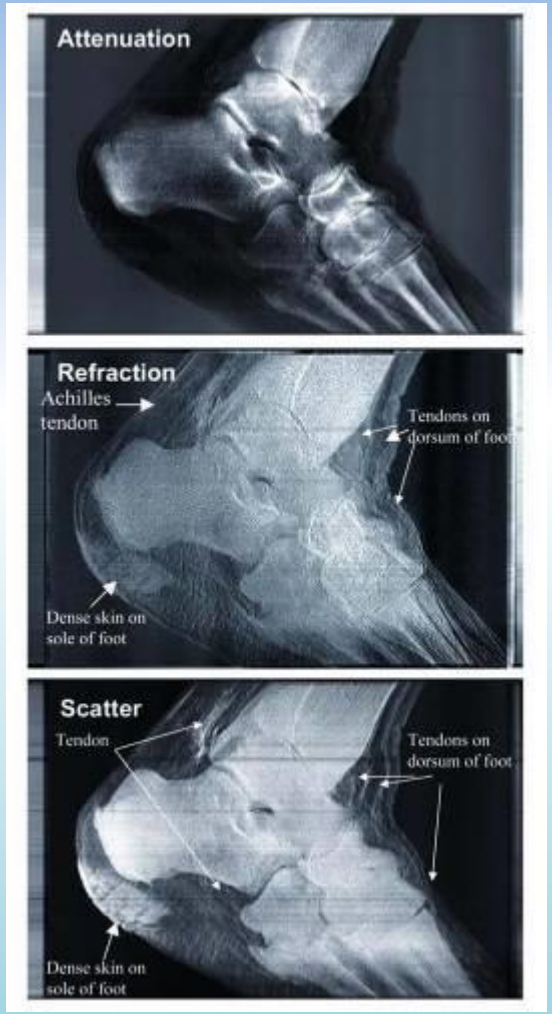
Extracting Image Data

Extinction



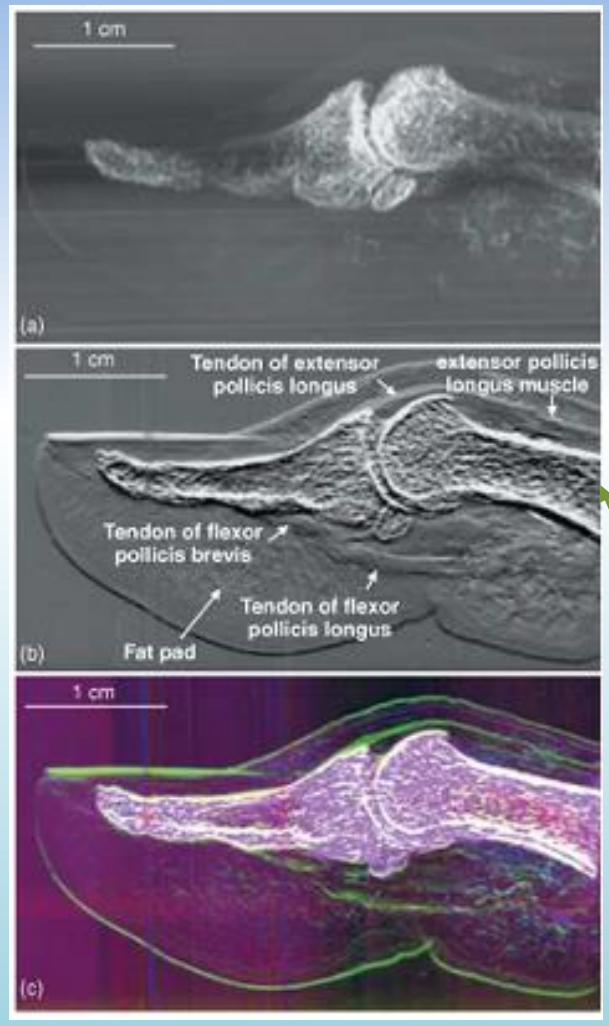


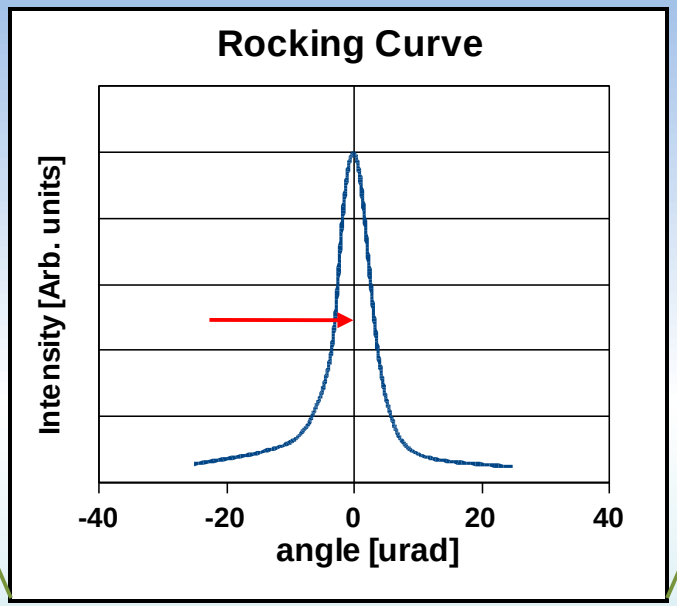
Based only on the absorption properties of the object. Refraction and Small Angle Scattering are eliminated.



Extracting Image Data

Refraction

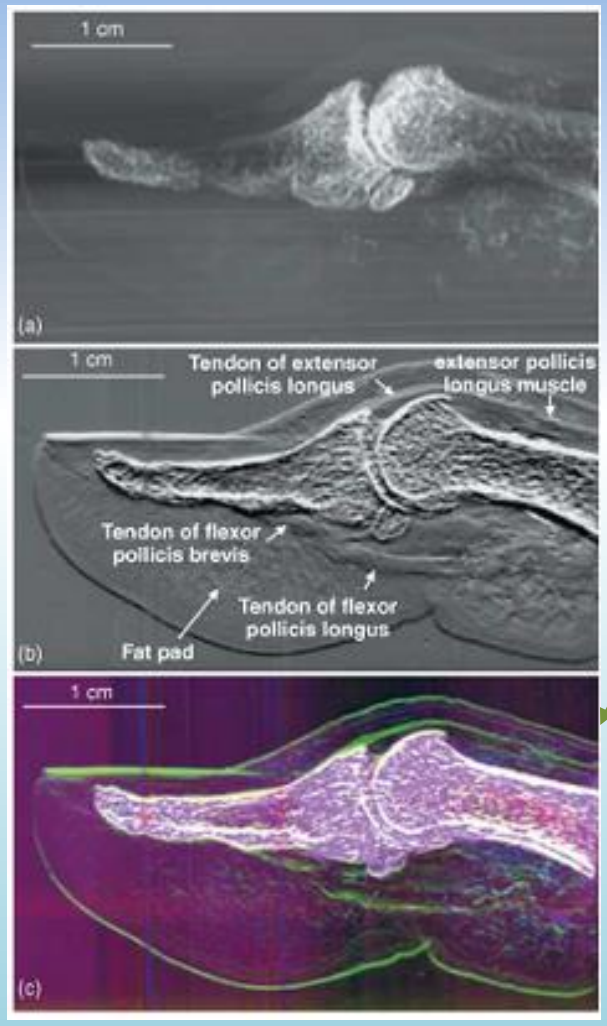


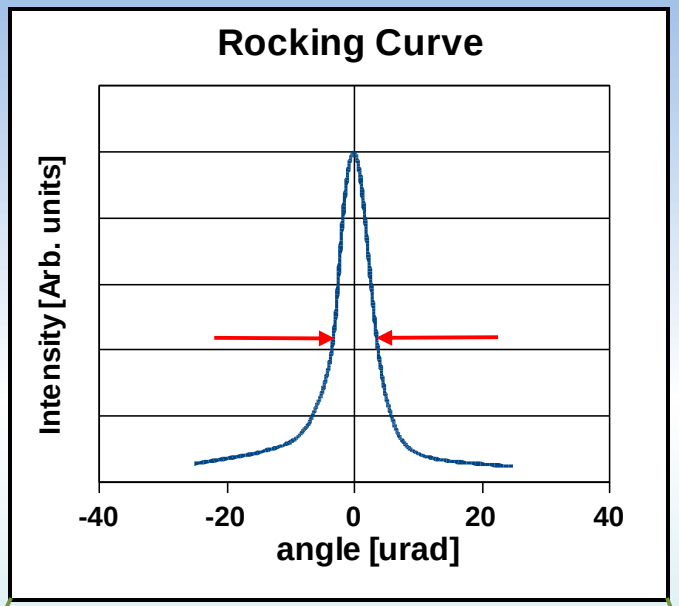


Based only on the Refraction properties of the object. Extinction and Small Angle Scattering are eliminated.

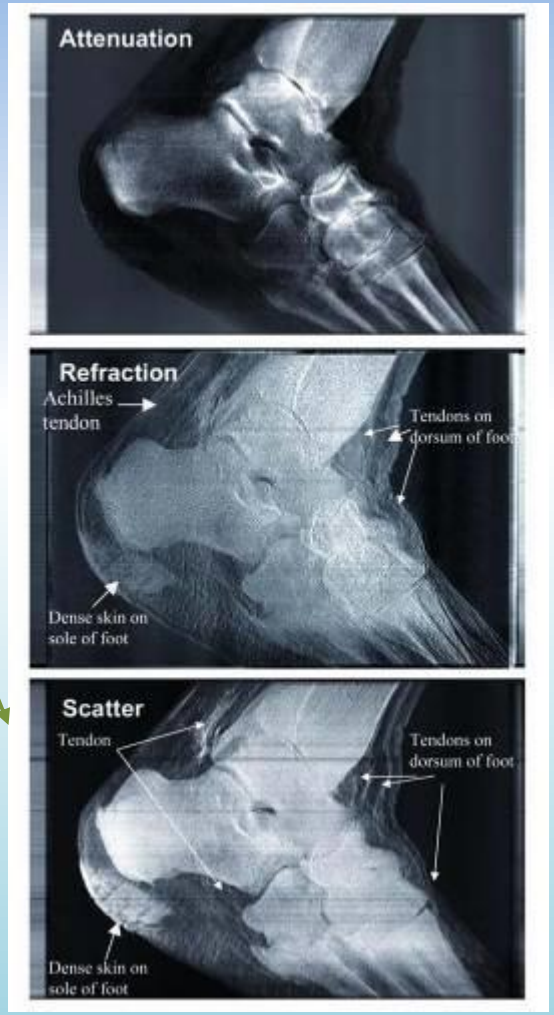
Extracting Image Data

Scattering



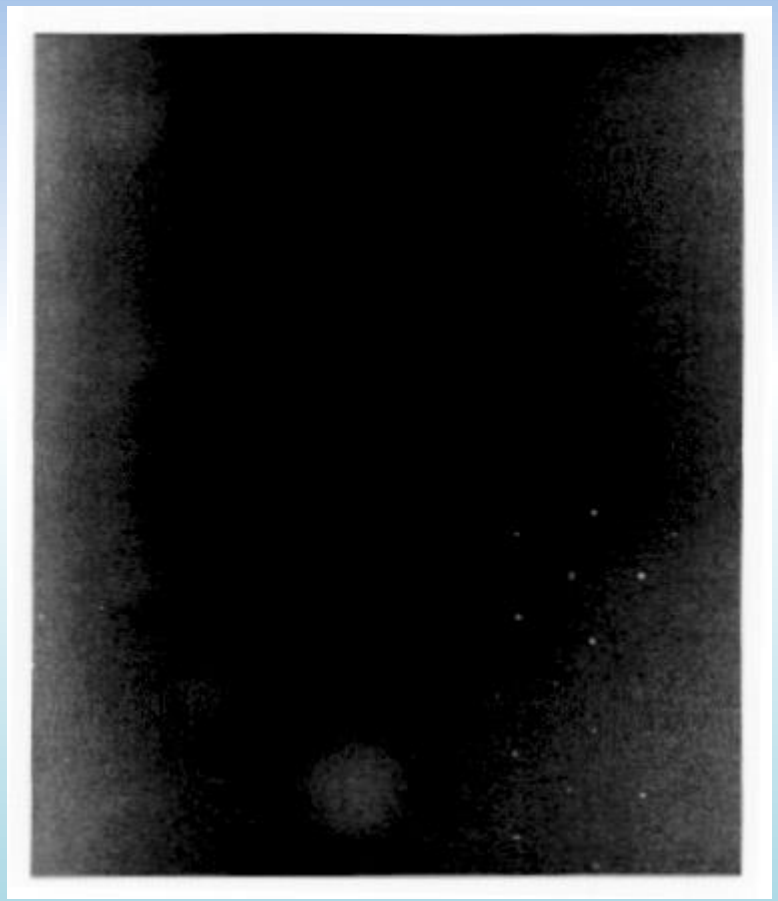


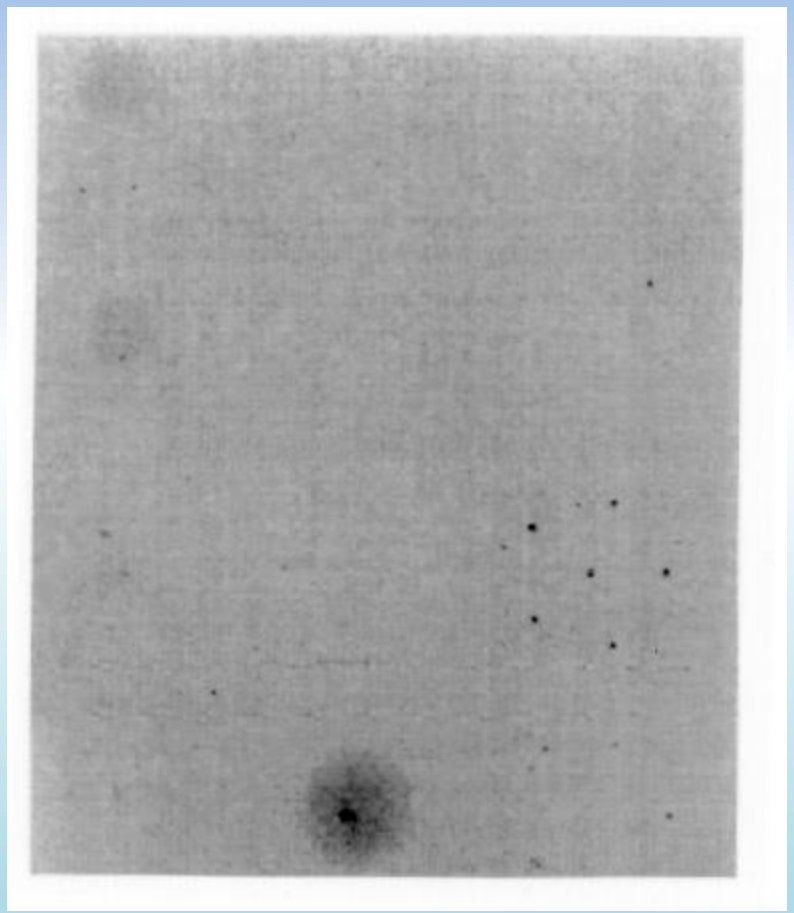
Based only on the scattering properties of the object. Refraction and Extinction are eliminated.



Applications

Mammography





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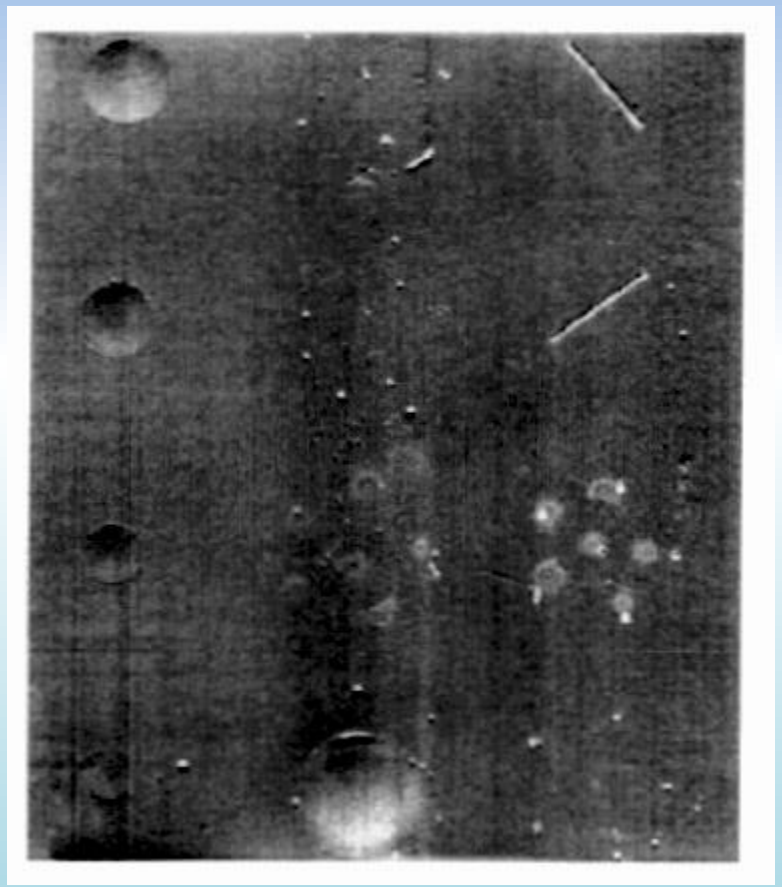

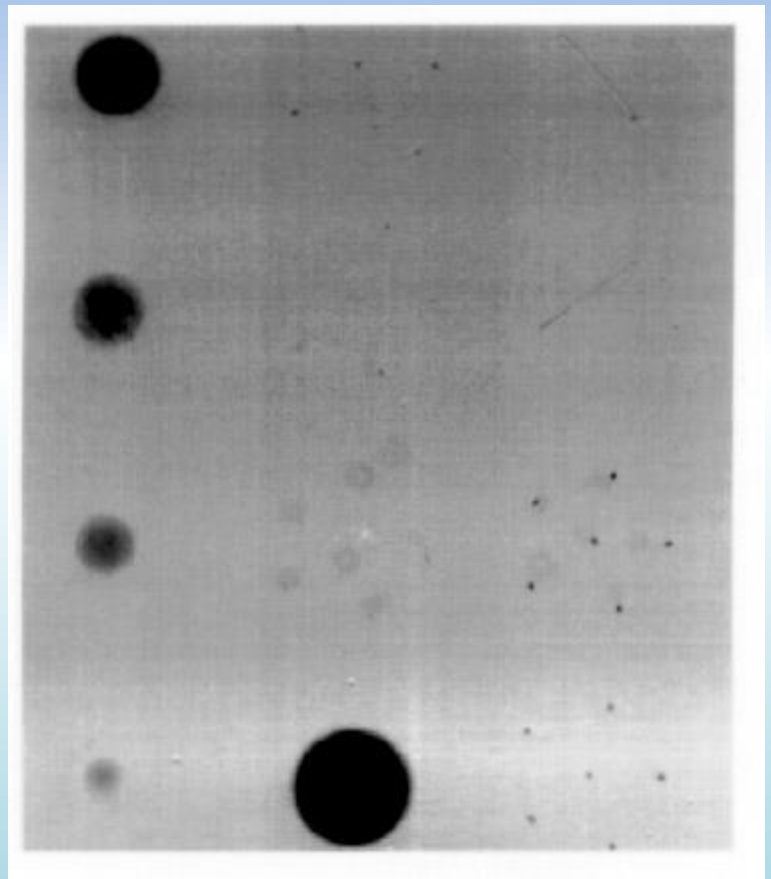

The Future and Thanks

- Lab based machines (mammograms/children)
- CT Imaging with Refraction

- Dean Chapmann, Zhong Zhong – Inventors of the method
- US Army – Grant funding the research
- NSLS/DOE – research location

- Questions?