Topic 2 – Theory about X-ray attenuation: The Beer-Lambert Law

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Dr Franck P. Vidal

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X-photons/matter Interactions (1/2)

- X-photons cross matter;
- During their path into any material, they can interact with matter.

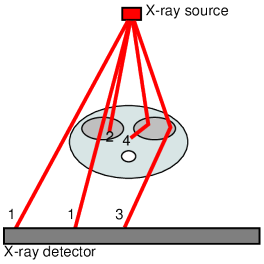


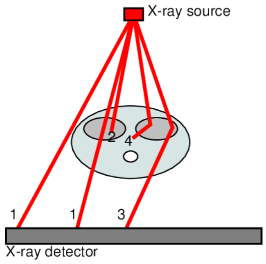
Illustration of X-ray photon/matter interaction

1. Directly transmitted photons (no interaction);
2. Absorbed photons;
3. Scattered photons;
4. Absorbed scattered photons.

X-photons/matter Interactions (2/2)

For most X-rays imaging modalities, only directly transmitted photons are essential:

- Scattered photons decrease the image quality;
- Absorbed photons do not reach the detector;
- Scattered photons may be ignored (but not necessarily).



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Beer-Lambert Law (Attenuation Law)

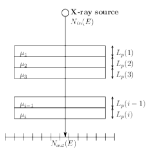

Illustration of the Beer-Lambert law

- Nout(E) = Nin(E) e(-Σi i(E,,Z) Lp(i))
  - Nin(E) the number of incident photons at energy E;
  - Nout(E) the number of transmitted photons of energy E;
  - i the linear attenuation coefficient (in cm-1) of the ith object. It depends on:
    - ⋆ E the energy of incident photons;
    - ⋆ the material density of the object;
    - ⋆ Z the atomic number of the object material.
  - Lp(i) the path length of the ray in the ith object.
- Eout = Nout(E) x E
  - Eout the energy received by the pixel, i.e. as recorded in the X-ray image.

Example (monochromatic case)

`http://gvirtualxray.sourceforge.net/validation/validation_03/beer_lambert_law_monochromatic.php`

Beer-Lambert Law in the polychromatic case

- There are more than one energy in the incident beam spectrum
- Just iterate over the energy channels:

Eout = Σj Ej x Nout(Ej)

Eout = Σj Ej x Nin(Ej) e(-Σi i(Ej,,Z) Lp(i))

with j the j-th energy channel

Example (polychromatic case)

`http://gvirtualxray.sourceforge.net/validation/validation_05/beer_lambert_law_polychromatic.php`

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