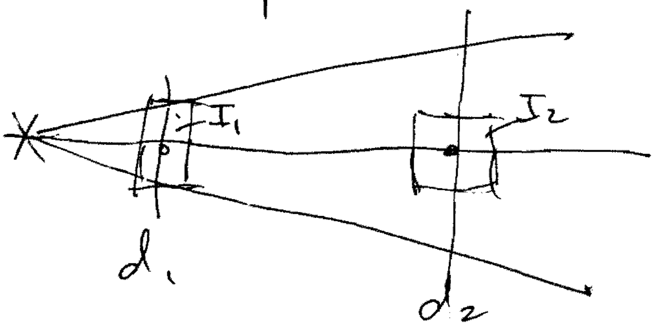
Chapter 4 Radiation Quality

Beam Divergence:

As a beam of radiation is emitted from a source, it spreads out in all directions.



Intensity: (# of photons) × (Energy) per Time per Area

if we measure the beam intensity at some distance (d_1) and then again at a further distance (d_2), the Intensity of the beam is less at d_2 (i.e. $I_2 < I_1$)

This is because most of the photons at d_2 are now missing the detector. The Intensity is a function of the distance from the source.

The Inverse Square Law states that the intensity of the beam is inversely proportional to the square of the distance from the source.

$$I \cong \frac{I_0}{d^2}$$ where I_0 = original intensity.

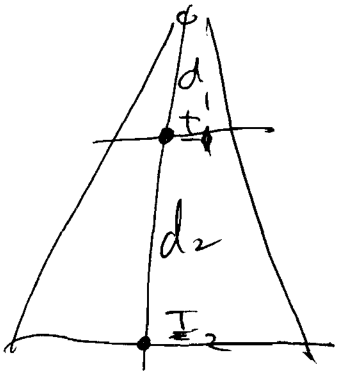
e.g. $I_0 = 100$ photons/cm^2

at a distance of 4 cm, what is the Intensity?

$$I \cong \frac{100 \text{ photons/cm}^2}{(4\text{cm})^2} \sim \frac{1}{16}\text{th of original beam}$$

Inverse Square (con't)

$$I_0 = I d^2$$



$$I_1 d_1^2 = I_2 d_2^2$$

$$\frac{I_1}{d_2^2} = \frac{I_2}{d_1^2}$$

$$I_2 = \frac{I_1 d_1^2}{d_2^2}$$

$$I = \frac{I_0}{d^2}$$

$$I_0 = I d^2$$

$$I_p = \frac{I d^2}{d_p^2}$$

Beam Attenuation:

When a beam of radiation enters a material (Lead, Copper, Tissue) the intensity of the beam is reduced.

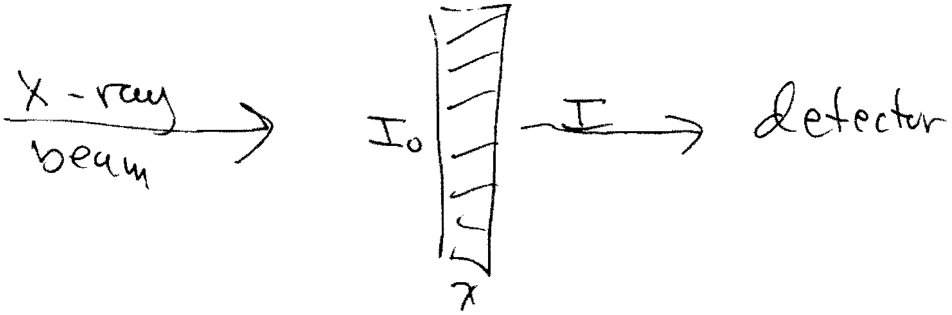
Photons are removed from the beam by <u>absorption</u> and by <u>scatter</u>. (Attenuation = absorption + scatter)

The amount of radiation detected ~~at~~ after passing through the material is the <u>Transmission</u>

Transmission is defined as:

$$\text{Transmission} = \frac{I}{I_o}$$

I - intensity of the measured beam
I_o - initial intensity



If we slowly increase the thickness of the filter and continue to measure the Transmission, we can represent the intensity by the following equation:

$$I = I_o e^{-\mu x} \qquad \left(A = A_o e^{-\lambda t} \right)$$

(for monoenergetic beams)

where, I = intensity detected
I_o = initial intesity
μ = linear attenuation coefficient
x = thickness of the attenuator.

μ - represents the probability per unit thickness that a photon will be absorbed. It has units of $\left(\frac{1}{\text{distance}}\right)$

There is a different μ for each photon energy and filter material.

<u>example</u>: I_o = 2000 photons
x = 3 mm
$\mu = 0.2 \frac{1}{mm}$

what is final number of photons?

$$
\begin{aligned}
I &= I_o e^{-\mu x} \\
&= (2000)\left(e^{-(.2\frac{1}{mm})(3mm)}\right) \\
&= 2000\ e^{-0.6} \\
&= 2000\ (0.549) \\
&= 1098 \text{ photons} \quad \left(\text{or } \frac{1098}{2000} = 55\%\right)
\end{aligned}
$$

Analagous to Half-life, we can compute the Half-Value Layer. – the thickness of material that reduces the beam intensity to ½.

$$I = I_0 e^{-\mu x}$$

$$\frac{I}{I_0} = 0.5 = e^{-\mu x}$$

$$\ln(0.5) = \ln(e^{-\mu x})$$

$$-.693 = -\mu x$$

$$x = \frac{.693}{\mu} \quad \text{HVL}$$

e.g. So from previous example $\mu = 0.2 \frac{1}{mm}$

$$HVL = \frac{0.693}{\mu} = \frac{.693}{0.2 \frac{1}{mm}} = 3.465 \text{ mm}$$

For a bremstrahlung beam, which contains many different energies, ~~there are many tsza continuous~~ each energy has a value of μ.

As the beam passes through a material, lower energies are removed in a process called Beam Hardening.

Because the average energy of the beam changes with material thickness, the HVL value will change also

Refer to graphs on p. 38.

<u>Homogeneity Coefficient</u> (HC)

$$HC = \frac{1^{st}\ HVL}{2^{nd}\ HVL}$$

eg 1^{st} HVL = 0.48 mm Cu
2^{nd} HVL = 0.90 mm Cu

$$HC = \frac{0.48}{0.90} = 0.53$$

(*) The higher the HC, the more uniform the beam.

HVL's are used to specify a beam's penetrability when speaking of bremsstrahlung beams.

Mass attenuation Coefficient:

$$\mu_m = \frac{\mu}{\rho} \left(\frac{cm^2}{gm}\right)$$

where: $\mu_m \equiv$ mass attenuation coefficient $\left(\frac{cm^2}{gm}\right)$
$\mu \equiv$ linear " " $\left(\frac{1}{cm}\right)$
$\rho \equiv$ material density $\left(\frac{gm}{cm^3}\right)$