Centre for the Clinical Application of Particles

December 28, 2020

Nuclear medicine

Week 1; Lecture 3; Section 3: Gamma camera: collimator

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Section 3

Collimator

Image formation

Image is formed using an "absorptive" collimator:

- The collimator absorbs "unwanted" γs

Collimator selects direction of observed γs:

- This determines the "pointing geometry"
- Wasteful of γs, most are absorbed in collimator

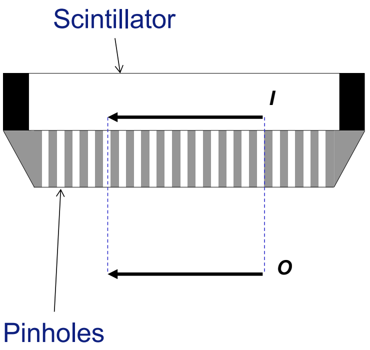
Absorptive collimator made from lead or tungsten:

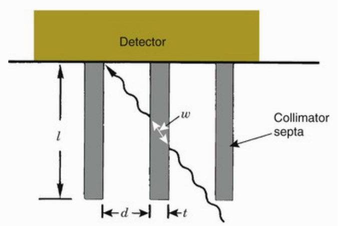
- High probability of absorption in moderate thickness of material

Four main types:

- Parallel, pin-hole, converging, diverging

Parallel-hole collimator





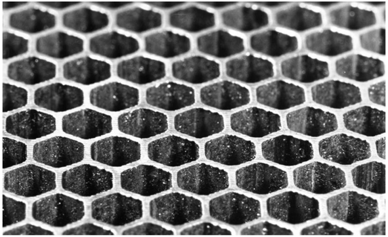
Magnification, M, given by:
$$M = \frac{I}{O} = 1$$

γ incidence minimizing material shown. Hence: $t = \frac{2dw}{l - w}$

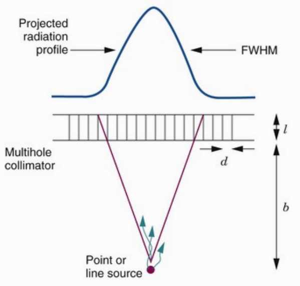
Specify, septal penetration $\lesssim 5\%$; i.e., for medium with linear attenuation coefficient, μ, $\ln \frac{I}{I_0} \lesssim \ln(0.05) = -\mu w \approx 3$:

$$t \gtrsim \frac{6d}{\mu l - 3} \approx 3\,\mathrm{mm\ for\ Pb\ collimator\ and}\ E_\gamma = 140\,\mathrm{MeV}$$

Parallel-hole collimator: contribution to resolution



Example: hexagonal holes to maximise area of detector exposed



Resolution, $\delta r_{\rm col}$, is FWHM spread of radiation from point source.

$$\delta r_{\rm col} \approx d \frac{l + b}{l}$$

Independent of t

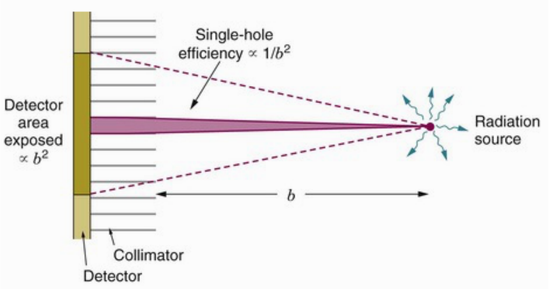
Parallel-hole collimator: geometrical efficiency

Geometric efficiency, g, defined as fraction of emitted γs that are transmitted by collimator
Example, for square-hole collimator:

$$g = \frac{d^4}{12 l^2 (d+t)^2}$$

Independent of b, because:

- Efficiency for a particular hole falls as $\frac{1}{b^2}$, but
- Number of holes illuminated groups as b^2



Parallel-hole collimator: summary

Collimator Type	Recommended Max. Energy (keV)	Efficiency, g	Resolution R_{coll} (FWHM at 10 cm)
Low-energy, high-resolution	150	1.84×10^{-4}	7.4 mm
Low-energy, general-purpose	150	2.68×10^{-4}	9.1 mm
Low-energy, high-sensitivity	150	5.74×10^{-4}	13.2 mm
Medium-energy, high-sensitivity	400	1.72×10^{-4}	13.4 mm

Diverging collimator

Focal point typically 40–50 cm behind collimator

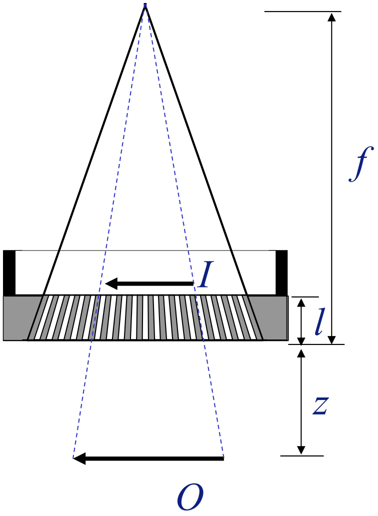
Large field of view

Reduced image that is not inverted

Image size depends on distance (z) leading to distortion

Magnification:

$$M = \frac{I}{O} = \frac{f - l}{f + z} < 1$$



Converging collimator

Focal point typically 40–50 cm in front of collimator

Reduced field of view

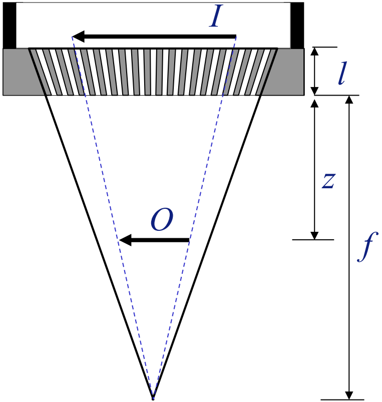
Magnified image that is:

- Not inverted if $z < f$
- Inverted if $z > f$

Image size depends on distance (z) leading to distortion

Magnification:

$$M = \frac{I}{O} = \frac{f+l}{f-z} > 1$$



Pinhole collimator

Pinhole size $\sim$ mm

Field of view depends on z

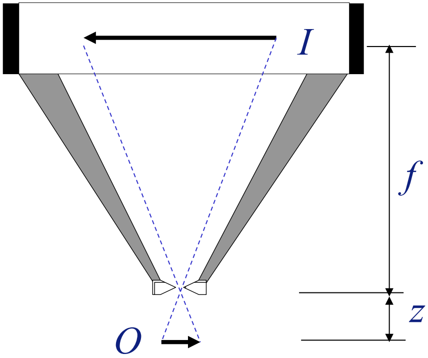
Image is:

- Magnified and inverted if $z < f$
- Reduced and inverted if $z > f$

Image size depends on distance (z) leading to distortion

Magnification:

$$M = \frac{I}{O} = \frac{f+I}{f-z} > 1$$



Summary of section 3

Collimator geometry is chosen based on application.

Contribution to overall resolution of gamma camera and its efficiency depend on collimator thickness and size of holes

Four types of collimator were considered:

- Parallel-hole collimator:
- Diverging collimator: produces a reduced image (magnification, $M < 1$)
- Converging collimator: produces a magnified image (magnification, $M > 1$)
- Pin-hold collimator: produces a magnified image (magnification, $M > 1$)