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Nuclear diagnostics and Magnetic Resonance Imaging

Week 1; Lecture 3; Section 1: The gamma camera; introduction

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Section 1

Introduction

Overview

Exploit γs produced in decay of radiotracer, so, detectors must:

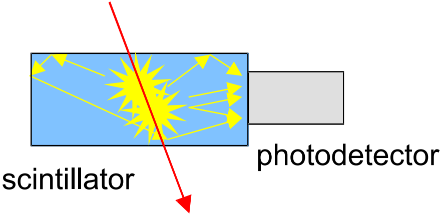
- Have good detection efficiency in range 80–300 keV
- Provide capability to measure γ energy:
  - To detect and reject γ that have undergone Compton scattering and so have lost pointing accuracy

"Gamma camera":

- Technique based on light production in a large-area crystal of sodium iodide (NaI)
- Scintillation light, produced by exciting atoms by absorption of radiation
- Light detection typically using 'photomultiplier tubes' (PMTs)

Generating scintillation light

Scintillation light is generated by relaxation of atomic electrons excited by ionising radiation.

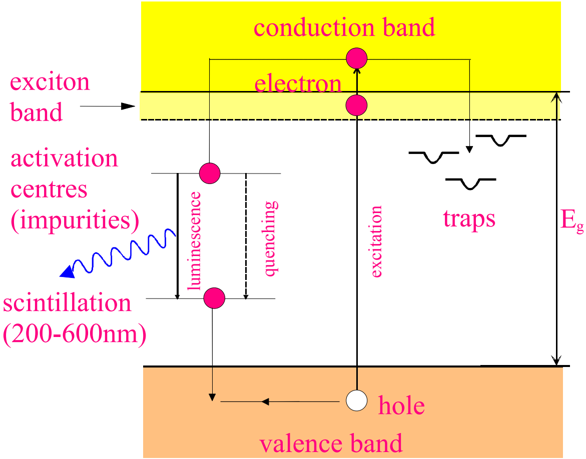


Properties of inorganic scintillators (e.g. NaI) include:

- Large range of Z and density; for medical application average and density Z of NaI and are favourable giving high probability that photon will be detected
- Large light yield; up to 40,000 photons per MeV
  - i.e. signal depends on energy of incident photon
- Single-decay times of from ns to μs

See for example Ambrosio, CERN Academic Training, April 2005

Generating scintillation light



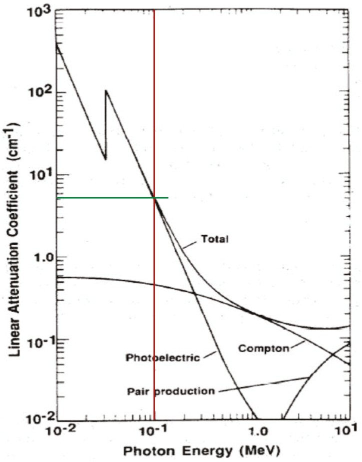
There can be more than one time constant:

- Fast recombination (ns–μs) from activation centres
- Delayed recombination due to trapping (μs–ms)
  - Traps arise due to dopants (wanted) and lattice imperfections (unwanted)

Chrystal preparation determines properties of scintillation light

See for example Ambrosio, CERN Academic Training, April 2005

Photon absorption in crystals



DOI: http://dx.doi.org/10.5772/intechopen.8550

Intensity, I, function of depth traversed, d:

$$I = I_0 \exp(-\mu d)$$

μ is the "Linear attenuation coefficient"

For NaI, at the energies we are interested in, penetration depth is a few mm

Detecting scintillation light

Photo-electric effect used to convert light into electronic signal that can be digitised

Detector requirements:

- High sensitivity; i.e. high "quantum efficiency", QE:

$$\mathrm{QE} = \frac{N_{\mathrm{pe}}}{N_\gamma}$$

  where N_{pe} is the number of photo-electrons generated by N_γ photons impinging on detector
- Low intrinsic noise
- Low gain fluctuations

See for example Gys, CERN Academic Training, April 2005

The photo-electric effect

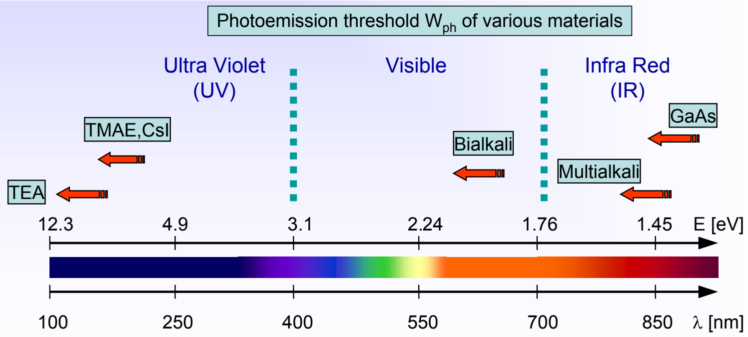
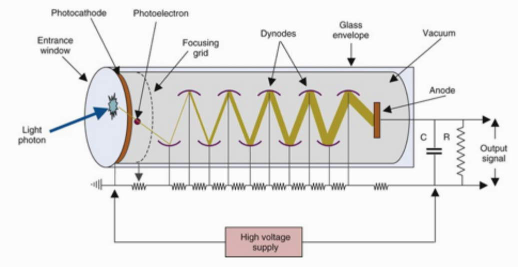
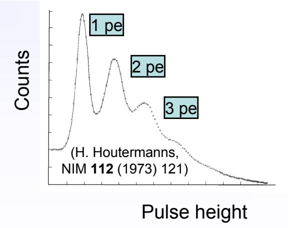


Photo-electric a 3-step process:

- Excite electrons in photocathode photon
- Excited electrons diffuse through material, losing some energy
- Electrons reaching surface with energy sufficient to escape may be detected

The photo-multiplier tube





- Photo-emission from photo-cathode
- Secondary emission from subsequent dynodes
- Dynode gain, $g_i = \frac{N_e^{\rm sec}}{N_e^{prim}}$, usually between $g_i = 3$ and $g_i = 50$
- Total gain $\mathcal{G} = \Pi_1^{N_{\rm dynode}} g_i$

See for example Gys, CERN Academic Training, April 2005