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Compton Backscattering from Broad Beam of Gamma Rays in Al and Zn

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The intensity distribution of Compton backscattered photons for a broad beam of gamma rays has been measured as a function of scatterer thickness for aluminium and zinc at incident photon energies of 279, 356 and 511 keV.

Key Words: Broad Beam, Compton backscattering, Build-up factor.

INTRODUCTION

The backscattering of photons is a problem of fundamental importance in the field of radiation shielding[1,2]. The quantities that characterize the reflection probability are called albedos or reflection factors. The study of Compton backscattering from a given material is a method to gain information about the characteristics of the material like electron density, cross-section and the likelihood of multiple scattering.

Measurement of photon flux incident to and emergent from a small area on the surface of a scatterer is difficult, because most of the photons incident on the area emerge from outside of area or captured in the scatterer. The broad beam geometry is free from such problems and has not any dead space of measurement. A small point isotropic source placed on the surface of a scatterer and a detector without a collimator moves on a hemisphere of sufficient large radii. In the present work, we have made preliminary measurements on intensity of Compton backscattered photons for Al and Zn at 279, 356 and 511 keV incident photon energies.

Theoretical consideration

In the present work, the theoretical relations of Maynord[3] and El-Ketab[4] have been used, which are associated with the calculation of the energy imparted when a beam of radiation is absorbed in a medium. Mathematically, it can be expressed as

$$I(x) = \int_0^x I_0 \, A \rho \, e^{-\mu x} \, dx \quad (1)$$

Where I(x) is the intensity of the photons accumulated at the depth x of the rectangular slab, x is the depth of the rectangular slab at which the interaction is assumed to occur, I_0 is the intensity of the backscattered photons at a thickness x = 0. ρ is the density of the material, A is the area of the rectangular volume of the scatterer and μ is the absorption coefficient of the scatterer at incident energy. The amount of the intensity that is backscattered from the thickness x is represented by

$$I(x) = I_o A \rho \int_0^x e^{-(\mu+\mu')x} dx \qquad (2)$$

Where μ' is the linear absorption coefficient of the backscattered photons.

Integrating equation (2), we get

$$I(x) = \frac{F I_o A \rho}{(\mu+\mu')}[1 - e^{-(\mu+\mu')x}] \qquad (3)$$

In this equation build up factor (F) contains the information about; (a) energies of the incident and the scattered photons; (b) the area, the thickness and the density of the scatterer and (c) the angle subtended between the source, the scatterer and the detector.

EXPERIMENTAL

The experimental set up used in the present work is shown in Fig. 1. Samples of aluminium and zinc of dimensions 8 mm × 4mm with varying thickness are irradiated with gamma rays of 279, 356 and 511 keV obtained from radioactive sources of ^{203}Hg, ^{133}Ba and ^{22}Na of strength about 1.0 μCi, respectively. The sources are placed at a distance

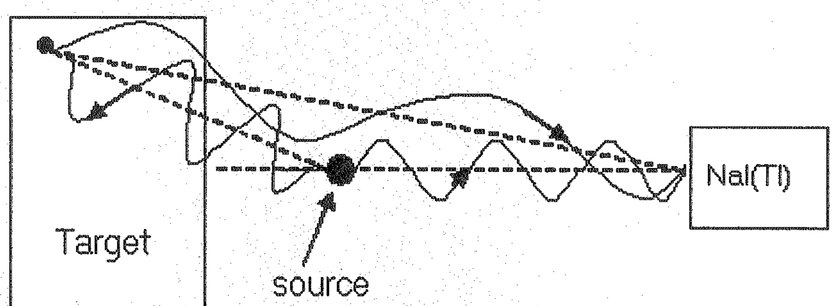

Fig. 1. Experimental arrangement showing backscattering of photons

of 0.5 cm from the front face of the scatterer and the distance of the detector from the sources is 8.5 cm. The photons backscattered from the scatterer are detected by a NaI(Tl) scintillation detector of dimensions 51 mm diameter and 51 mm thickness coupled to PC based plug in Multichannel analyzer. The experimental spectra are corrected for various correction factors.

RESULTS AND DISCUSSION

Photon backscattered spectra are taken with the source at a distance of 0.5 cm from the front face and at the centre of the scatterer. This procedure is repeated with and without the scatterer in position for 5 ks. The area under the backscattered and incident photon peaks is evaluated and corrected for self-absorption correction. The variation of intensity of backscattered photons as a function of thickness of scatterer for the area 8 × 4 mm of aluminium, and zinc has been measured. The build up factor as a function of thickness of the scatterer is calculated using equation 3 and plotted in Figs. 2 and 3.

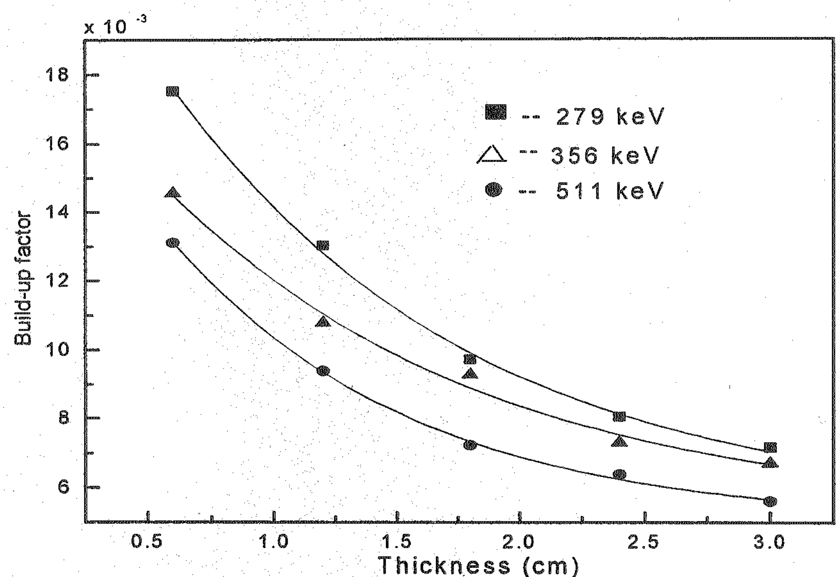

Fig. 2. Variation of build-up fator with thickness at different energies of zinc

The backscattered intensity of photons increases with the thickness of the scatterer and a stage is reached when this intensity starts saturating. This saturation thickness for high-energy incident photons is small as compared to small energy incident photons. This is due to the fact that high-energy incident photons penetrate more into the scatterer and backscattered photons of low energy have to travel a long path to reach at the detector. Hence, the increase in number of scattered photons with scatterer thickness is compensated by the attenuation of backscattered photons during their return path.

The build up factor decreases exponentially with thickness for aluminum and zinc. The build up factor for high energy photons saturate at lower thicknesses as compared to low energy photons in the case of aluminium, while for zinc the build up factor decreases continuously with the increase of the thickness of the scatterer used in the experiment .

In conclusion, the intensity of backscattered photons increases with scatterer thickness, but the build up factor decreases exponentially. Also the build up factor decreases with the increase of atomic number and incident photon energy. The experiment is in progress for different dimensions of the scatterer at various incident photon energies.

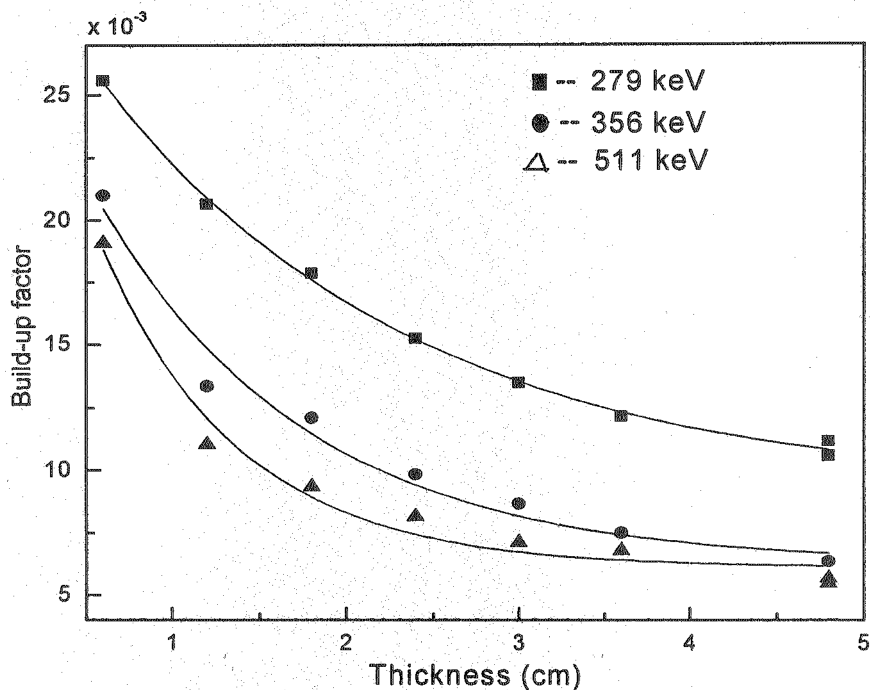

Fig. 3. Variation of build-up fator with thickness at different energies of Aluminium

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