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Experimental investigation of the incidence angle dependence of bremsstrahlung yield induced by 10–25 keV electrons in a thick tungsten target

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INTRODUCTION & AIM

Electron interactions with matter produce various atomic processes such as ionization, excitation, electron backscattering, and X-ray emission[1]. The non-characteristic X-rays, called bremsstrahlung radiation, are generated due to the Coulomb interaction between incident electrons and the nuclei of the target atoms. In thick targets, electrons undergo multiple scattering and continuous energy loss, making the bremsstrahlung process complex. Its intensity and angular distribution depend on the electron energy, target material, and experimental geometry. Understanding thick-target bremsstrahlung is important for applications in X-ray source development, radiation shielding, detector calibration, and basic studies of electron–matter interactions[2].

In the present work, bremsstrahlung radiation from a thick tungsten target bombarded by 10–25 keV electrons is experimentally studied. The aim is to investigate the variation of bremsstrahlung yield with electron energy and emission geometry. Measurements were carried out using an orthogonal beam–detector arrangement with a Si-PIN detector, and the experimental results were compared with Monte Carlo simulations using the PENELOPE code to analyze the angular dependence of the photon yield[3].

EXPERIMENT

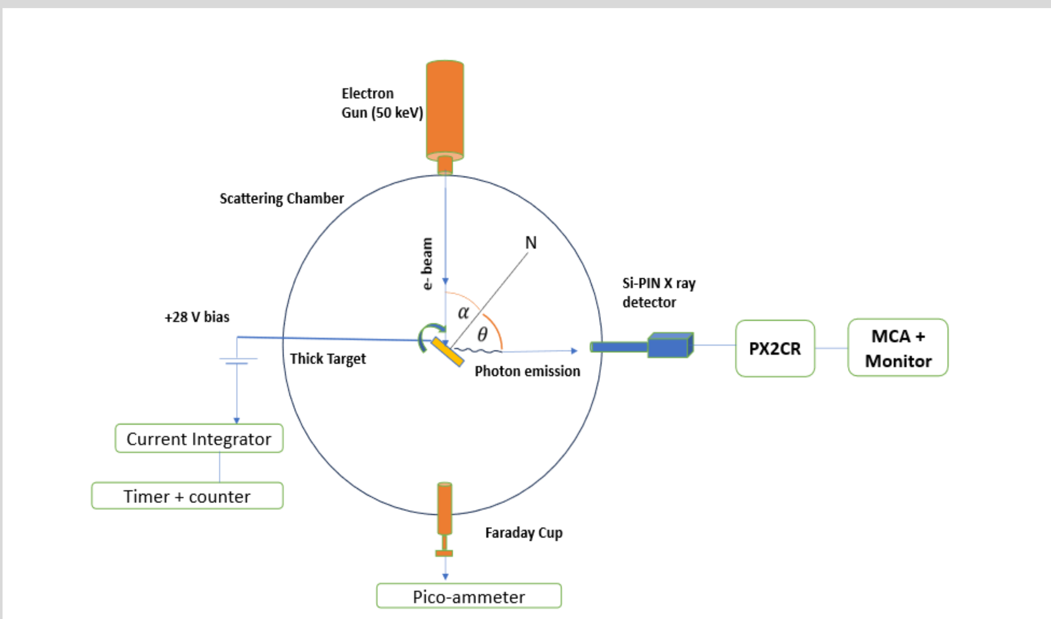

Fig.1: Schematic diagram of the experimental setup

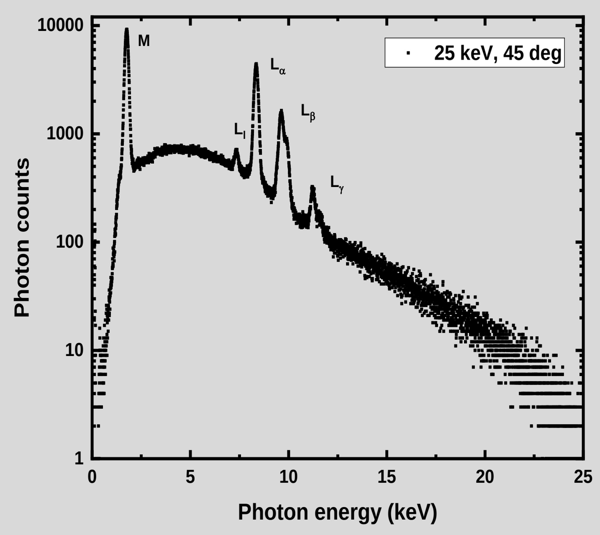

Fig.2: Raw x-ray spectrum of thick W produced by bombardment of 25 keV electrons at incidence angle 45˚.

Experimental conditions and instrument used

- Chamber pressure was kept below 3×10^{-6} Torr during experiment.
- An electron beam of specific energy was bombarded at the target to produce x-rays.
- The collision of electron with thick W target produced x-rays was detected by XR-100 CR Si(PIN) x-ray detector (mounted at 90° with respect to e-beam axis).
- Rotation of target changes incidence angle as well as detection angle since both are complementary of each other.
- Signal received from the x-ray detector was further amplified by PX2CR.
- Data acquisition was done using a Multi Channel Analyzer.

DATA ANALYSIS

Double Differential Bremsstrahlung Yield is measured as

$$\mathrm{DDBY}(\alpha, k, E_0) = \frac{N_B(\alpha,k,E_0)}{N_e \varepsilon(k) \Delta\Omega \Delta k}$$

where,

$\mathrm{DDBY}(\alpha, k, E_0)$= Double Differential Bremsstrahlung Yield of non-characteristic X-rays

$N_B(\alpha, k, E_0)$= Integrated Photon Counts of Bremsstrahlung photons of energy k

N_e= Total number of electrons incident on the target

$\varepsilon(k)$=Absolute efficiency of X-ray detector

$\Delta\Omega$(Solid angle)= 1.26×10^{-3} sr

Δk = Detector Resolution which is 210 eV at 5.9 keV

Experimentally determined DDBY was normalized with MC simulation at 45˚ incidence angle. So, normalized DDBY have been measured shown in the figures and compared with the MC simulation.

SIMULATION

For comparison with the experimental data, Monte Carlo simulations were performed using the PENEPMA code [4] based on the PENELOPE package, which simulates coupled electron–photon transport in matter. The code uses detailed models for photon interactions and a mixed (detailed and condensed) algorithm for electron transport. The simulations were carried out under the same geometrical and energy conditions as in the experiment, with appropriate cut-off and transport parameters. PENEPMA provides X-ray spectra in absolute units (per unit energy, solid angle, and incident electron). The bremsstrahlung yields were extracted from the simulated spectra in the same manner as from the experimental data, allowing a direct comparison of the energy and angular dependence of the photon yield.

RESULTS & DISCUSSION

Dependence of DDBY on angle of incidence at specific impact energy

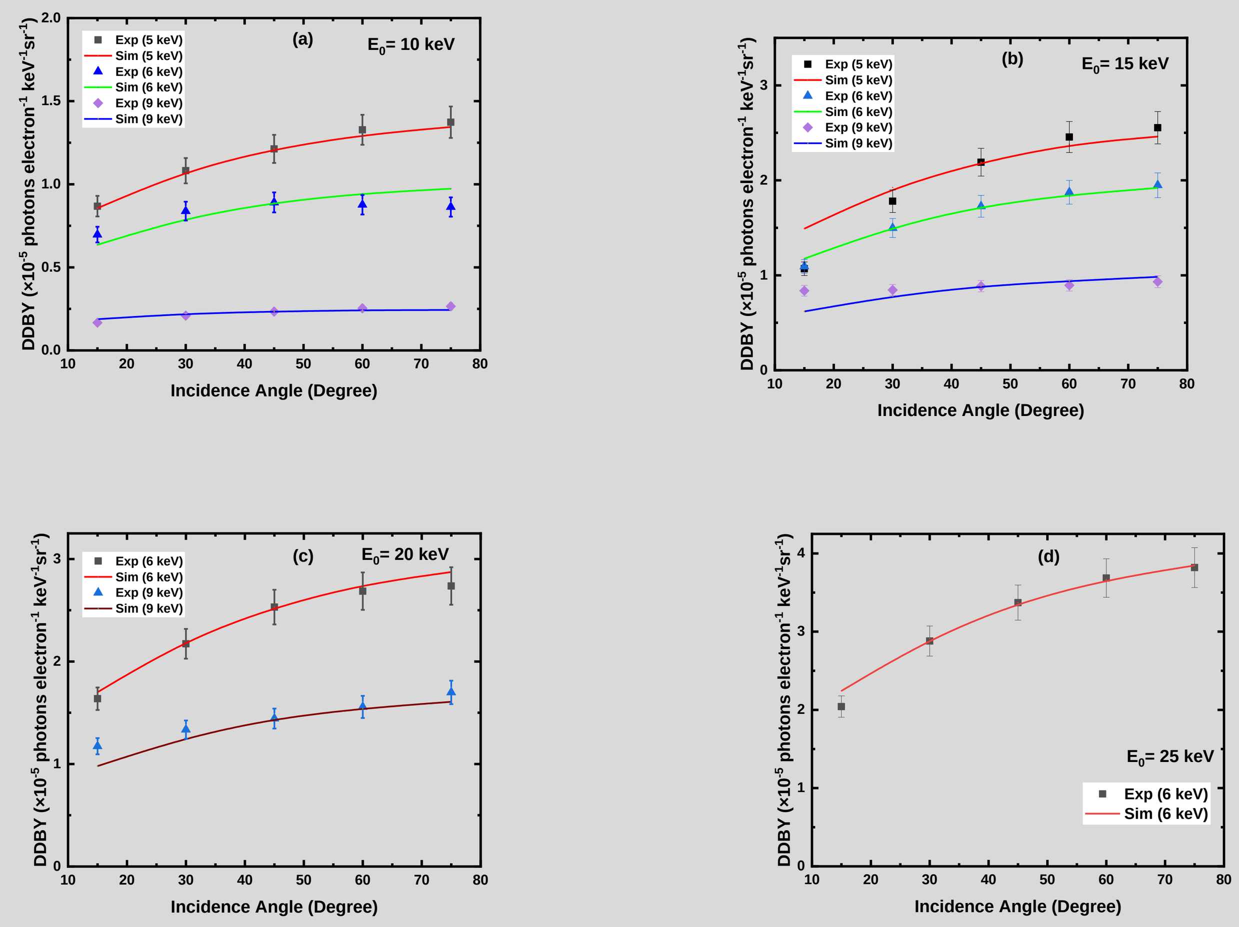

Fig.3(a-d) : Variation of DDBY (keV^{-1} electron^{-1}sr^{-1}) as a function of angle of incidence α at different photon energies (k) and impact energies (E_0)

Dependence of DDBY of photon of energy k on impact energy at specific angle of incidence

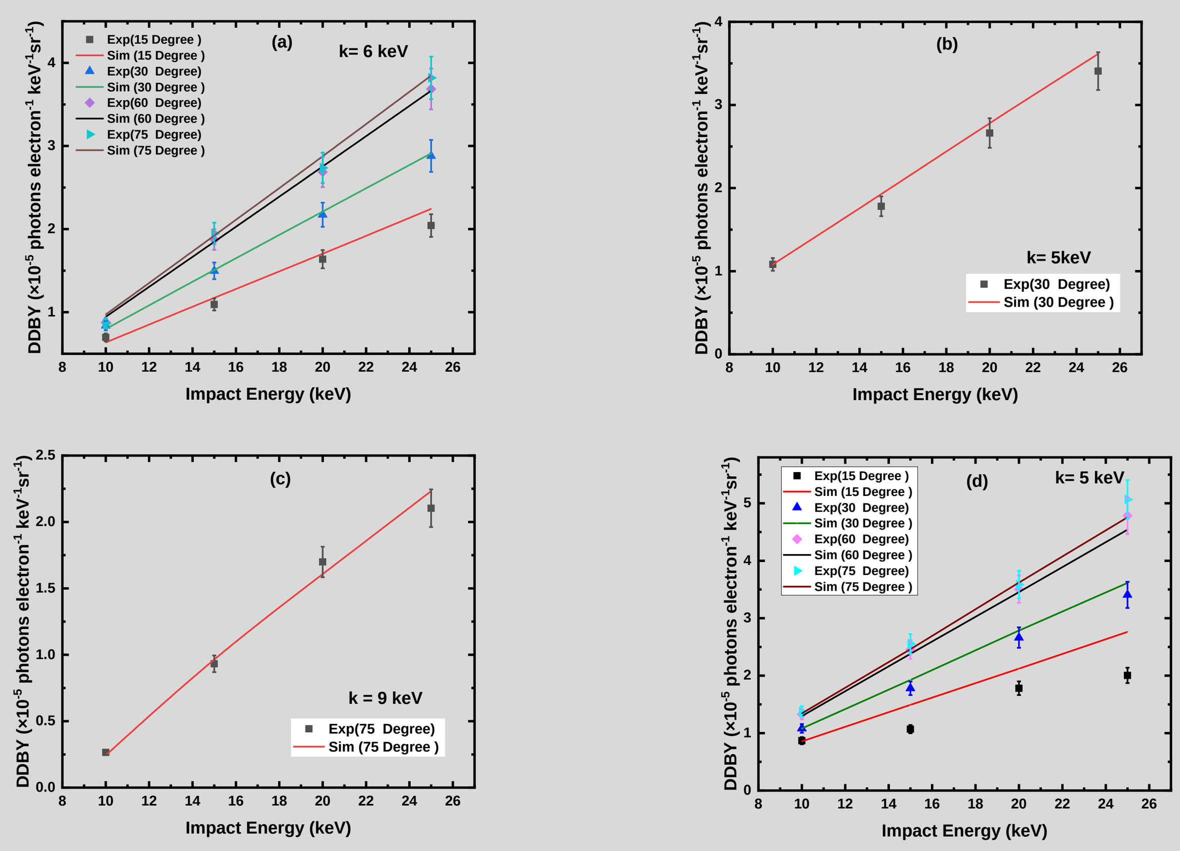

Fig. 4(a-d): Variation of DDBY (keV^{-1} electron^{-1}sr^{-1}) as a function of impact energy (E_0) at different angles of incidence α and photo energies (k)

CONCLUSION

- Bremsstrahlung yields were measured for a thick tungsten target irradiated by 10–25 keV electrons, for photon energies 5–9 keV and incidence angles from 15° to 75°.
- The photon yield increases with electron impact energy and shows a clear dependence on the angle of incidence and corresponding detection angle.
- Experimental results show good agreement with PENELOPE Monte Carlo simulations.
- Since tungsten is a high-Z material widely used in X-ray tubes and radiation shielding, these results are important for understanding and optimizing thick-target bremsstrahlung production in practical X-ray sources.

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