Compton Scattering Pinhole Imaging Technology for Measuring and Diagnosing Dose Field Intensity Distribution of Intense Pulse Gamma Ray Beams

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Abstract—**In the intense pulsed gamma radiation environment (dose rate>1GGy (SI)/s, FWHM10-20ns), the damage of electronic devices and systems exhibits a strong dose rate effect. The dose field distribution of the intense pulse gamma-ray beam generated by the "Qiang guang 1"accelerator is an urgent problem to be solved. It is the premise of carrying out the experiment of high dose rate effect to obtain the distribution information of strong dose field accurately and quickly. In this paper, we present a method for the problem based on the Compton scattering method: placing a target near the exit and using a pinhole imaging system, the scattered gamma intensity distribution at the thin target is reconstructed, and then the intensity distribution of the dose field of the strong pulsed gamma ray beam at the thin target is given.**

Key words—Qiang guang 1; dose rate effect; pulse radiation; transfer matrix; reconstruction

I. INTRODUCTION

In the intense pulsed gamma radiation environment (dose rate>1GGy (SI)/s, FWHM10-20ns), the damage of electronic devices and systems exhibits a strong dose rate effect. The measurement of dose distribution of pulsed gamma radiation field, on the one hand, can provide accurate radiation field parameters for applications, and provide physical process diagnosis for the development of generation technology on the other hand. However, the existing diagnostic techniques cannot simultaneously solve problems such as occupancy effect space, long data acquisition period, detector saturation, severe electron and neutron interference, which restricts the development of the generation technology of intense pulsed gamma radiation environment and the improvement of the application level.

Fig. 1 is a schematic diagram for simulating and calculating the dose distribution of the typical gamma radiation field of the "Qiangguang-1" accelerator [1]. The intensity of the red region nearest to the accelerator can reach 10×10^{9} Gy(Si)/s, and the farthest to the blue region which satisfies the intense pulse effect experiment is 1×10^{9} Gy(Si)/s. The location shown in the black box is a cylindrical interior with a cross-section diameter of 9 cm and a length of about 40 cm from the end face of the beam exit of the accelerator to 43 cm.

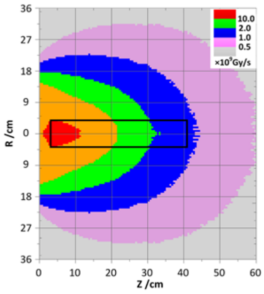

Fig. 1 Typical dose distribution diagram of γ field

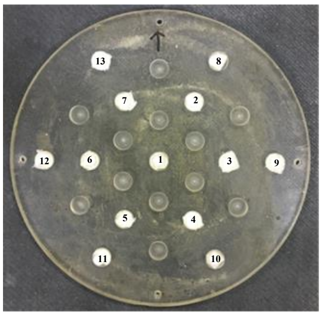

Fig. 2 Target Dose Plate Layout

Fig. 2 is target Dose Plate Layout. At present, the problems to be solved urgently in the measurement and diagnosis of intense pulsed radiation field:1. The repeatability of the radiation area produced by intense pulsed radiation is poor, and the location and intensity of the radiation area will change every time. In thousands of experiments, the intensity distribution of the pulsed radiation field is different each time [2]. 2. Because the radiation field on the target surface is asymmetrical, enough thermoluminescent dosimeters are needed to form an array to ensure the spatial resolution of the intensity distribution of the radiation field. Luminescent dosimeters need to be annealed to read data, which costs too much manpower and takes too long. 3. Thermoluminescent dosimeters are easy to break up in the measurement process, resulting in the loss of key data [3].

II. COMPTON SCATTERING

Figure.3 is Compton Scattering Diagram. Compton effect is a phenomenon that incident photons are scattered by inelastic collisions with extra nuclear electrons in matter atoms. When colliding, the incident photon transfers part of its energy to the electron, making it detached from the atom and become a recoil electron, while the energy and direction of motion of the scattered photon change.

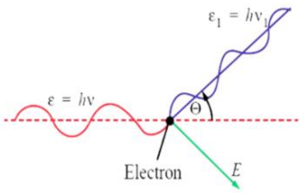

Figure. 3 Compton Scattering Diagram

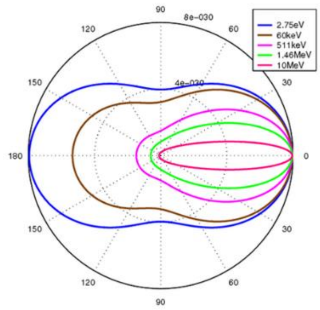

Figure. 4 Differential cross section of Compton scattering (original figure from [4])

The significance of the differential cross section of Compton scattering is that the probability that an incident gamma photon with an energy of $h\nu$ will be scattered into a unit solid angle in the direction of theta (cm^2/unit solid angle) after interacting with an electron outside the nucleus of an atom is as follows（Klein-Nishina）:

$$\frac{d\sigma(\theta)}{d\Omega} = Zr_0^{\,2}\left(\frac{1}{1+\alpha(1-\cos\theta)}\right)\left(1+\frac{\cos^2\theta}{2}\right)\left(1+\frac{\alpha^2(1-\cos\theta)}{(1+\cos^2\theta)[1+\alpha(1-\cos\theta)]}\right)$$

Figure.4 is differential cross section of Compton scattering. For photon beams with energy above 1kev, the emitted photons are mainly concentrated at the scattering angle of 0, and the larger the incident photon energy is, the smaller the scattering amplitude is.

III. EXPERIMENTAL SETUPS

Fig.5 is a schematic diagram of a diagnostic system for spatial distribution of intense pulsed γ field based on scattering method. The average energy of the intense pulsed gamma radiation photons from the front-end diode of the high-current accelerator is 1.1MeV, and the equivalent dose coefficient is 4.33pGycm^2. The gamma photon flux corresponding to the dose rate of 1×10^9Gy(Si)/s is calculated to be about 2.31×10^{20}cm^{-2}s^{-1}. A thin target with suitable material and thickness is arranged at the distance of 3-5cm from the beam exit surface. The gamma photons scatter from the thin target to the beam direction and pass through the shielded collimator. Thick pinholes in the IP (Image Plate) imaging board deposit energy and form latent image. The gamma photon flux decreases by 3 to 4 orders of magnitude, about 2.31 x 10^{16} cm^{-2}s^{-1}. It is suitable for measurement and diagnosis with IP imaging board [5].

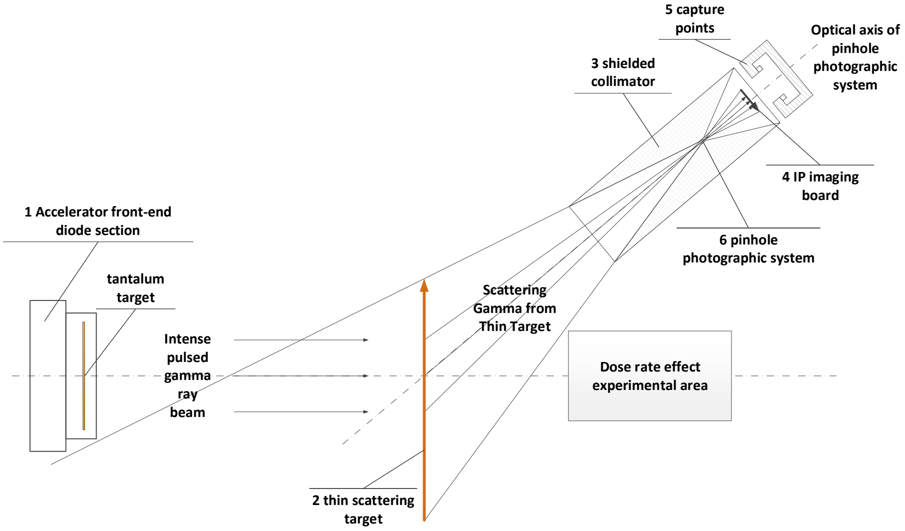

Fig. 5 Schematic diagram of a diagnostic system for spatial distribution of intense pulsed γ

IV. RESULTS AND ANALYSES

It is the imaging result of IP plate after simulating the scattering of different shapes of source by thin target. (Annular Source, Planar Source, Plane Target).

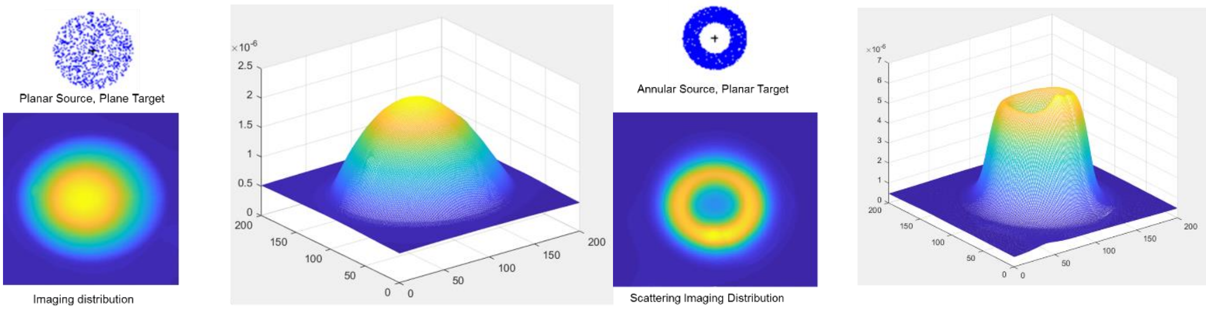

Fig. 6 Planar Source Plane Target Annular Source, Plane Target

IV. CONCLUSION

In the dynamic range of IP imaging plate, the off-axis intensity distribution gray image of thin target scattering gamma can be measured, and the dose field intensity distribution at the thin scattering target can be calculated by using the appropriate reconstruction method.

Because the intensity distribution of the scattered gamma dose field at the thin target is consistent with the dose field intensity distribution of the strong pulse γ radiation field, the dose field distribution of the strong pulse γ radiation field can be given.

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