Monte Carlo Studies on Mammography System

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ABSTRACT

In order to understand and quantitatively analyze the physical phenomena and behavior of each component of mammography system during the breast imaging, we simulated mammography imaging using Monte Carlo simulation codes. MCNP4B code was used for our simulation purpose, and we investigated the effect of target material, anode angle, filtration, peak voltage and exposure on the image quality of mammograms. From the simulation results we expect that optimized operation condition of mammography system can be found.

Keywords: mammography, Monte Carlo simulation, MCNP4B

I. INTRODUCTION

Breast cancer is a major disease of women. Approximately 200,000 women were diagnosed with breast cancer in the U.S. in 2000 and 45,000 women died of this disease. In order to study the effect of each component of mammography system during the beast imaging, we simulated mammography imaging using Monte Carlo simulation codes. Digital radiography system can be separated into direct and indirect method. In direct method, X-ray emission by an object directly appear into an image that is further converted to electrical signal by a digital image device. Direct method can give high resolution of image because of its direct transmission to image device but needs exposure to higher dose than indirect method in human body. In the indirect method, X-ray emission by an object is first converted into light photons in the presence of phosphor. The resulting image is next converted to electrical signal by digital image device.[1,2]. X-ray mammography is the only imaging modality with a proven capability for detecting early-stage, breast cancer. Reliable x-ray mammography requires both excellent spatial resolution and high contrast.

II. MONTE CARLO SIMULATION PROGRAM

MCNP4B code is a general-purpose Monte Carlo radiation transport code that can numerically simulate neutron, photon and electron transport. The simulation calculated X-ray absorption distribution in MCNP code increasing CsI:Tl thickness and geometrical shape of phosphor calculated absorbed X-ray energy in each unit cell dividing 5000×4000×3μm size to calculate X-ray absorption distribution like in hexagon on Fig. 1 below. Phosphor used this simulation is CsI:Tl and assume to mono crystal. Moderate breast compression is assumed, hence the phantom breast thickness is 50mm. The simulation includes both Compton scattering and photoelectric absorption within the patient.

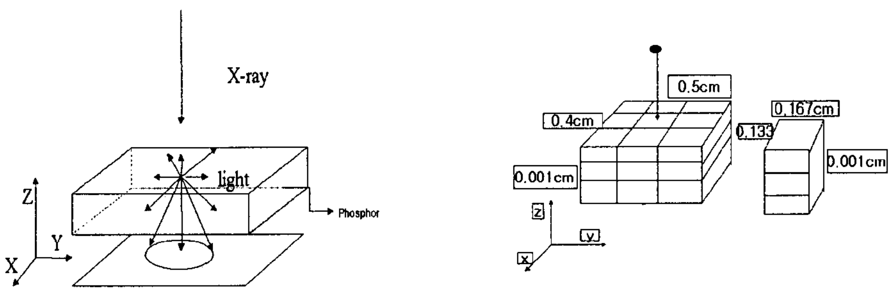

Fig. 1. Simulation geometry of Phosphor

III. SIMULATION METHODS

1. Diffusion of light in phosphor

X-ray image using phosphor has a large difference in the quality as a characteristic of phosphor. Important parameters that affected resolution of phosphor are type of phosphor, size of phosphor particle, thickness homogeneity of phosphor layer and phosphor thickness. Incident X-ray reacting with phosphor is released all direction which is absorbed in the responding spot, and increased diffusion as the thickness. Therefore as the thickness, the diffusion of light photon in phosphor is shown by PSF(Point Spread Function) below. [3,4]

$$P(z) = \int_{-Y}^{Y} \int_{-X}^{X} \frac{N_{opt}}{4\pi} \times \frac{z}{(x^2 + y^2 + z^2)^{3/2}} \, dx \, dy,$$

Where, P(z) is PSF, N_{opt} is light photon quantity produced in axis of x, y, z. X, Y are sampling pitch and x, y, z are position of the X-ray source.

2. Simulation method

Generally used tube voltage of mammography X-ray is 25~32 kVp. In this simulation, X-ray tube voltage is 30 kVp, the distance between phosphor and focus is 25.0 cm, the size of phosphor is 5000× 4000 μm, and simulated absorption and X-ray absorption distribution following every 10μm pitch by 10~120μm thickness. This simulation calculated X-ray absorption distribution in MCNP code increasing RM CsI(Tl) thickness and geometrical shape of phosphor calculated absorbed X-ray energy in each unit cell. Besides the source of X-ray was assumed that it is entered vertically in the middle of unit cell be in center of phosphor. In order to reduce statistical error, we setting 5,000,000 history of MCNP code. Besides we calculated light diffusion in absorption spot applicable at input of DETECT II code, Monte Carlo code simulating light transportation. We assumed that X-ray energy absorbed in unit cell is released in 4π direction creating a light in center of the cell. In simulation, we ignored that thought it is created a little light in the surrounding by fluorescence X-ray and rand of dispersion electron. Although real phosphor RM CsI(Tl) is fine power, geometry of phosphor in this simulation represented by homogeneous substance but it is possible to simulate dispersion and absorb a light in the fine power applicable absorption distance(AD) 400 μm , scattering distance(SD) 25μ m light in the inner phosphor.

Table 1. Physic characteristic of phosphor using diagnosis X-ray

Type	Z	K-edge (keV)	ρ (g/cm³)	λ (nm)	Index of refraction	W(eV)	Γ (light /keV)
CaWO4	74	69.5	6.06	480±100	2.25	33	30
Gd2O2S:Tb	64	50.2	7.34	550±20	2.3	17	60
CsI:Na	55/35	36/33	4.51	415±50	1.84	25	40
CsI:T1	55/35	36/33	4.51	560±80	1.79	18	55

IV. RESULTS AND DISCUSSION

Figure. 3 shows X-ray energy spectrum of 30kVp, when used of W, Mo, Rh target material.

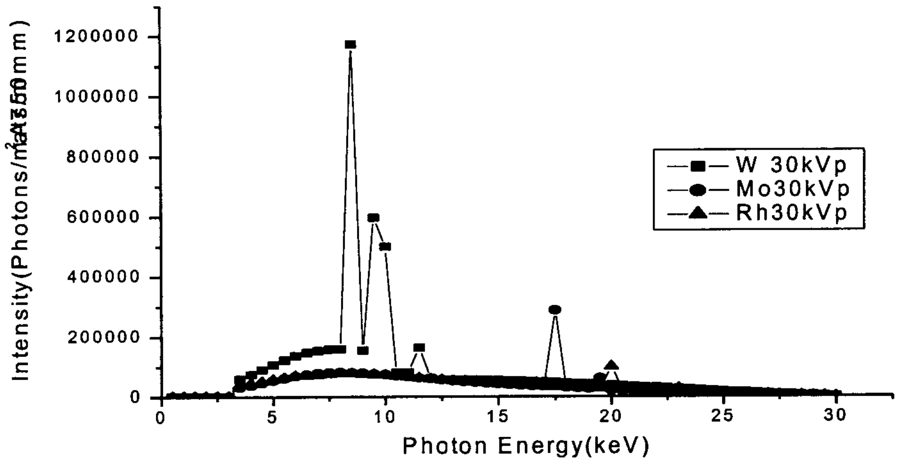

Fig. 3. X-ray energy spectrum

To prove X-ray absorption and diffusion calculated by MCNP and DETECT II code compared reference value. For the incident bremsstrahlung X-ray with the mean energy of 30keV, the detection efficiencies in unit of energy and percentage are presented as a function of metal thickness for three cases of phosphor thickness, such as 10~120μm, Figure. 4.

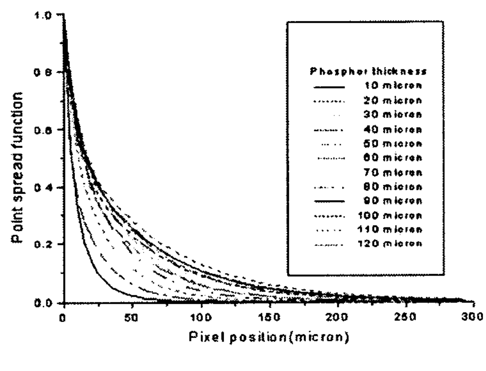

Fig. 4. PSF as phosphor thickness

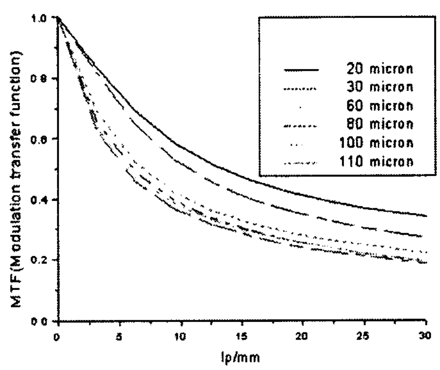

Fig. 5. MTF of Phosphor

Figure. 5 shows MTF at 30keV of X-ray energy. Using Monte Carlo simulation, we estimated the spatial resolution as well as detection efficiency for various combinations of metal plate/phosphor screen as a X-ray detector. Phosphor thickness was the most important criteria for obtaining good resolution image when creating indirect intra-oral X-ray image sensor. Once proved experimentally, we will study FOP, CCD which transfer light photon.

V. ACKNOWLEDGEMENTS

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