APPLICATION OF X-BAND LINAC FOR MATERIAL RECOGNITION WITH TWO FOLD SCINTILLATOR DETECTOR

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Abstract

950 keV X-band Linac has the merits of compact system, and it does not need the radiation safety manager on-site in the public space. Therefore the system we have developed is suitable for the more safe circumstance in airport. Dual energy X-ray concept is introduced for material recognition with Linac these days, because it produces high energy X-ray which is available in case the target is thick and high atomic number material. We suggest the two fold scintillator detector concept to induce dual energy X-ray effect. The design of the two fold scintillator is decided by MCNP simulation with two scintillator code, CsI and $CdWO_4$. The material recognition is confirmed using aluminium, iron and lead metal in conditions such as various thicknesses and containers.

INTRODUCTION

The compact size of X-ray Linac promises the feasibility in the various fields such as non-destructive test, and medical treatment, baggage inspection system [1, 2]. Smaller size and higher energy X-ray are the direction of Linac development for the application in our normal life. In the point of view, X-band Linac shows us the new possibilities. For example the baggage inspection system in an airport uses the X-ray tube normally, which has the accelerating energy up to 500 keV. That means with the low energy, the range of inspection is limited to the low atomic number materials. Therefore we introduced the Linac as a X-ray source which produce the higher energy than X-ray tube. 950 keV X-band Linac is best based on compact size and maximum energy that is relevant in the public space such as an airport.

As the detector part, we developed 2-fold scintillator to induce the dual energy X-ray effect. It has two scintillators, CsI and $CdWO_4$, in the 2-fold configuration such as Fig. 1. CsI scintillator placed in front of $CdWO_4$ has thin thickness to absorb inside the low energy X-ray which means we can expect low energy X-ray image from CsI scintillator. $CdWO_4$ is thicker than CsI and placed after CsI. Therefore it absorbs the high energy X-ray which remains after CsI. One of features in the structure of 2-fold scintillator is it can take two images during one-time X-ray irradiation. Because many people concern the high energy X-ray irradiaition from Linac, one-time irradiation is promise us more safe and simple inspection system.

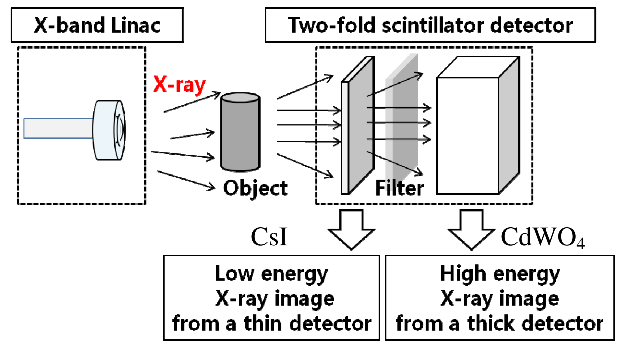


Figure 1: Dual energy X-ray concept with two-fold scintillator detector.

In the research, we suggested iron and lead for the target materials to prove the ability of material recognition in our system. High atomic number material such as lead cannot be distinguished using X-ray tube, because low energy X-ray from X-ray tube cannot penetrate the lead easily in certain thickness range, which does not give the information to the detector after lead target. With our results, we want to show the possibility of the material recognition in an atomic number range from 13, iron to 82, lead.

EXPERIMENT

950 keV X-band Linac

Table 1: Specifications of 950 keV X-ray Source

Resonant frequency	X-band 9.4 GHz
RF source	250 kW magnetron
Cavity type	On-axis coupling
Shunt impedance	~ 70 MW/m
Gun type	Thermionic, Diode, 20 keV
Tube length	~ 30 cm

Table 1 is the features of 950 keV X-band Linac that we have developed for the on-site inspection system. The size of an accelerating tube and magnetron is small. That leads to the compact size of whole system. [3].

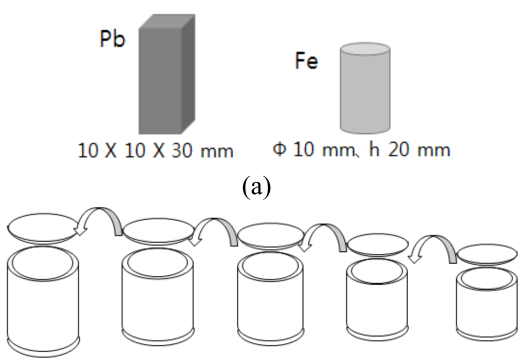
Two-fold Scintillator Detector

We found out the CsI has low detection efficiency and energy deposit rate compared to the $CdWO_4$. Therefore

CsI is engaged to low energy X-ray absorber, because if we use $CdWO_4$ for low energy X-ray absorber, high energy X-ray can be absorbed also somehow. It is nessassery to keep the low energy absorber low detection efficiency. Otherwise $CdWO_4$ is engaged to high energy X-ray absorber [4].

Target

The reason we provide iron and lead samples is that our goal in the research is to distinguish light metal from heavy metal (Fig. 2 a). Each of them represents the light metal and the heavy metal. They are placed in the cylinder concealments made of polyethylene and polyvinyl chloride. Small size of concealment is put inside of bigger one for five steps of the thickness. Each of concealment has 5 mm thickness (Fig. 2 b). Therefore it is 10 mm when X-ray goes through the concealment, front and back parts of it. When the step goes up, X-ray has to go through thicker concealment 10 mm more.



(b)

Figure 2: Target samples (a) and concealment (b).

Line sensor controller generates 10 Hz pulses which go to line sensor and 950 keV X-band Linac (Fig. 3). While the target goes by in front of line sensor in a proper velocity, X-ray from Linac in 10 Hz goes through the target and reaches the 2-fold scintillator.

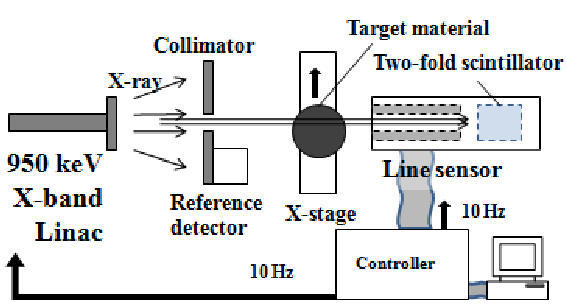


Figure 3: Experimental setup.

RESULTS AND CONCLUSION

We obtain the reconstructed images for iron and lead inside of the concealments according to the every step of increasing thickness of the concealment from 10 to 50 mm. In the polyethylene container, Fe and Pb show in the atomic number difference between experimental value and theoretical value of 3 ~ 10 for Fe, 2 ~ 5 for Pb. In the polyvinyl chloride container, Fe and Pb have the difference of 9 ~ 12 atomic number for Fe, 1 ~ 3 for Pb. The difference between experimental value and theoretical value is getting bigger as the thickness of container is thicker and density of composed material is higher (Table 2).

Table 2: The Difference of Atomic Number for Each Metal Between Experimental and Theoretical Values in Each Container

Polyethylene container

Thickness of container	Fe (26)	Pb (82)
5	3.41	2.35
10	4.76	2.58
15	4.06	3.22
20	7.02	3.31
25	9.99	4.34

Polyvinyl chloride container

Thickness of container	Fe (26)	Pb (82)
5	9.09	2.86
10	11.53	2.71
15	9.64	1.58
20	9.33	1.86
25	10.7	2.14

DISCUSSION

We found out several problems on the image (Fig. 4). First of all, when we look at the CsI image there is certain pattern every 4 channel. The candidate for this problem is cross talk between 4 channels, because every 4 channel of CsI is set. To solve the problem, 4 channels of CsI is separated into one channel.

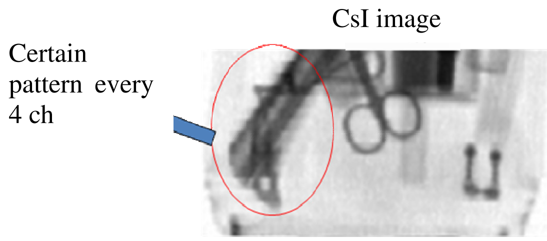


Figure 4: Problem on the CsI image.

Another problem is the size of photodiode (Fig. 5). Now the one channel of photodiode express 2 mm object on the image. It is not relevant as custom inspection system. The new one reduces the photodiode until 1 mm.

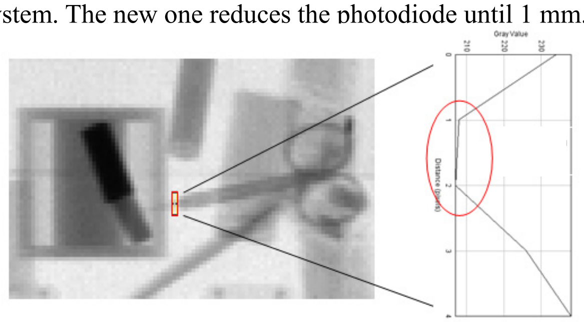


Figure 5: 2 channels (red circle) express 4 mm on the scissors.

The third problem is the scattered X-ray (Fig. 6). Two collimators in front of 2-fold scintillator can be adjusted the window width until 2 mm.

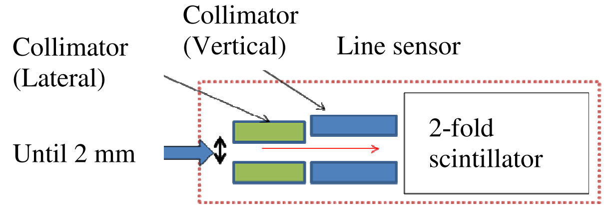


Figure 6: Suppression of scattered X-ray.

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