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Introduction

Breast cancer is one of the leading causes of death among Japanese women. This malignancy can be treated relatively easily when detected early. The highest incidence of breast cancer is observed among those in their thirties and forties. The high incidence among these age groups considerably affects our society because women in these generations usually play important roles in their families and working places.

Recently, imaging modalities such as X-ray mammography and/or ultrasonic echography have proven useful for the detection of breast cancer. However, these modalities provide only morphological information. On the other hand, younger women or women without a history of breastfeeding tend to develop mammary gland tumor. In some cases of X-ray mammography, a developing mammary gland produces shadows on mammography images, making detection of breast cancer difficult.

Positron emission tomography (PET) for whole-body diagnosis can provide functional information on cancerous tissues including the degree of malignancy, as reflected by the level of accumulation of a tracer, [^{18}F]fluoro-deoxyglucose. However, various problems still remain such as limited spatial resolution and motion artifacts due to respiration movement, as well as high costs for device installment and maintenance. In measuring events of the coincidences of positrons, a larger distance between detectors, as seen with PET scanners, for whole-body imaging limits spatial resolution. To compensate these weak points, we have started to develop a positron emission mammography (PEM) scanner dedicated for the local diagnosis of breast cancer.

The name of our project is "development of high resolution PEM equipment that shows the next generation breast cancer diagnosis", granted by the regional research and development resources utilization program from Japan science and technology agency (JST).

Basic concept and scintillator

The basic concept of PEM development consists of the compact radiation detectors, high-speed electronic circuit, and lower cost of equipment. Finally, the PEM scanner is expected to achieve a high spatial resolution of about 1 mm, which is a quarter of the resolution of conventional PET scanners. Regarding the radiological dose to be needed for examination would be low as much as 20 MBq, approximately one tenth of the dose of conventional PET scanners. Cost performance is also an important issue, and PEM can be developed with the costs of one fifth of the conventional PET scanner.

In our new scanner, a new crystal of praseodymium doped "lutetium aluminum garnet" (LuAG)[1)] is used as a novel scintillator in this project. Table 1 shows the summary of comparison of performances of different scintillators. This new scintillator has some advantages such as a short fluorescence lifetime, a low manufacturing cost and a high light output.

Image mapping system

The image mapping system is used for diagnosis of the crystal. The system consists of a personal computer, the core with amplifiers, analog-to-digital converters and the dark box for the scintillation measurement (Fig. 1). The system is set up in a personal computer rack. A flat panel photomultiplier tube (PMT), H8500, made by Hamamatsu photonics, is used for the scintillation mapping. The mapping method is based on the center of gravity calculation. The system has the gain correction function for the variety of the multi anode outputs from a flat panel PMT. The system can measure the energy spectrum of the scintillation.

PEM simulator

Presently, we are still in the process of developing a PEM scanner, and we will also fabricate a prototype PEM scanner for commercial use. This scanner will be used for detecting smaller tumors, and it will be cheaper and smaller than the conventional PET scanner. We are aiming for a spatial resolution of <1-2 mm, and the price will be 20% lower than that of the conventional PET scanner.

The PEM simulator is set up in a personal computer rack and a worktable and used for the diagnosis of the crystals and the PMTs. Last year, we developed several test devices and a PEM simulator. One of these devices is a block detector device. This device is constructed from a flat-panel photomultiplier tube (FP-PMT), an inorganic scintillator crystal array, an aluminum case and a signal processing circuit. The FP-PMT is a multianode PMT with 16×16 anodes and has positional sensitivity. The PEM simulator is a testing and an evaluating system of the PEM scanner. The simulator has four block detector devices, high voltage supply units for PMTs and signal processing units. The latter consists of an analog amplifier, an analog to digital converter, Field Programmable Gate Array (FPGA) devices and communication interface for PC (Fig. 2).

In summary, this project is now in progress steadily for developing the prototype PEM scanner. As the PEM simulator was developed with other scintillator, we are trying to optimize the performance after being equipped with the new LuAG scintillator. We will assemble and test larger size LuAG scintillator crystal block arrays. We will also develop additional softwares for image reconstruction, gantry control, patient registration and so on. Finally when this project is finished, we hope that a new possibility will be opened to the breast cancer diagnosis.

References

1) Ogino H., Yoshikawa A., Nikl M., et al., J. Crystal Growth **292** (2006) 239.

Table 1. The performance comparison of the scintillators. Pr:LuAG scintillator is better than another scintillators in a shorter fluorescence lifetime, a lower manufacturing cost and a higher light output.

	Pr:LuAG	BGO	GSO	LSO
Scintillation w.l. (nm)	310~370	480	440	420
Light Yield (ratio BGO)	320	100	200	400~500
Scintillation decay time (ns)	**20**	300	56	41
Manufacturing cost (yen / cm^3)	**2,500**	2,000	4,000	5,000
Density (g / cm^3)	6.7	7.13	6.8	7.4
Melt point (deg)	1,970	1,050	1,950	2,150
Advantages	**high yield, short FLT**	low cost	proven to be better than BGO	**high yield, high density**
Disadvantages	short wave length, segregation	low yield, long FLT	cleavage (crack and processing difficulty)	segregation, manufacturing difficulty

*abbreviations: FLT= fluorescence lifetime

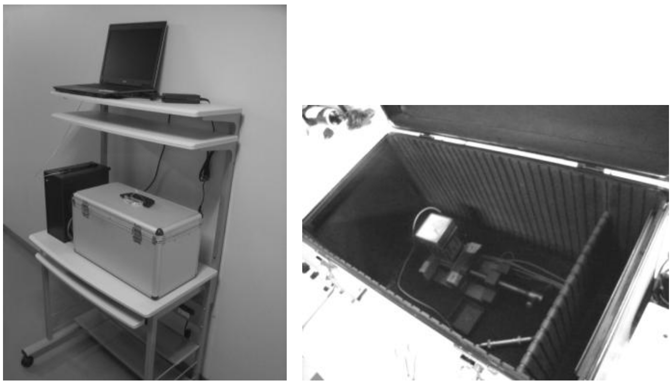

Figure 1. Left is the image mapping system consists of a personal compulter, the core with amplifires, analog to digtal converts and so on, and the dark box for the scintillation measurement. Right is inside the dark box.

Figure 2. Left is the PEM simulator. The PEM simulator is a subset of the PEM scanner and used for the diagnosis of the crystals and the PMTs. Right is a close up of the detector units.