Nuclear instrument techniques to improve the diagnosis of breast cancer by using plastic scintillator and wavelength shifters

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Introduction

Breast cancer is the common and the second most leading cause of death among women in both developing and developed countries [1]. Breast cancer is always caused by a genetic abnormality. However, only 5-10% of cancers are due to an abnormality inherited from the parents. While, 85-90% of breast cancers are due to genetic abnormalities that happen as a result of the aging process [2].

Hence, medical imaging plays an important role for breast cancer screening, for classifying and examine indistinct breast abnormalities, as well as for defining the extent of breast tumors. Evaluating response to therapy constitutes an additional important role of imaging [3]. Therefore, imaging via different modalities represents an essential, life-long component for patients with breast cancer, from initial diagnosis throughout the evolution of the disease [3]. One of the most widespread modalities currently available is the so-called Positron Emission Mammography (PEM) [4]. It is a dedicated and well recognized technique to diagnose breast cancer. The main benefits of PEM include higher spatial resolution, improved geometric sensitivity with reduced attenuation, shorter imaging time, and the possibility of reducing the radiopharmaceutical dose compared to whole-body PET [5]. However, the commercially available PEM scanners have moderate specificity and sensitivity and thus lead to a lot of negative biopsies. Our aim is to design, construct and establish the characteristic performance of the Mammo-PET based on a novel idea with plastic scintillator and wavelength shifter (WLS) [6].

Plastic scintillators will allow us to reach a superior time-of-flight (TOF) resolution and a high spatial acceptance at a moderate price. The scanner will consist of plastic scintillator strips where at both of their ends a read-out signals is carried out by silicon photomultipliers [7–11]. This idea does not gives sufficient resolution along the strips, therefore WLS will be used in order to improve the axial and spatial resolutions [12].

WLS is like a plastic scintillator which absorbs photons at higher wavelengths and for each photon re-emits light isotropically at lower energies, providing useful modes for light collection. Fig. 1 shows the principle of measuring the axial coordinate of the gamma quantum interaction point in a plastic scintillator bar using an array of WLS strips. It is possible to measure the axial coordinate of a gamma quanta interaction point in a plastic scintillator strips via the detection of scintillation photons escaping from the scintillator placed perpendicular with respect to an array of wavelength-shifting strips as in Fig 1.

Materials and Methods

We propose to build a PEM with these new techniques based on plastic scintillator strips and WLS, called Mammo-PET. The detector system will consist of two modules of plastic scintillators, having the WLS placed orthogonally on its side. Each scintillator bar is attached at both ends with Silicon Photomultipliers for the signal readout. Our idea is to improve sensitivity and specificity to obtain the better time information and spatial resolution, reaching the order of 1 mm. The combined use of plastic scintillators, which have superior timing properties, with the WLS strips can provide an economic and precise

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scanner with significant improvement in spatial resolution and efficiency for the detection of breast cancer. Systematically, this will be done by preparing a simulation program based on the Monte Carlo method for optimizing the geometry and materials of the Mammo-PET prototype. The next step will be to construct this prototype by using the above geometry and materials, and perform hardware commissioning and calibration, by taking the detector system into operation. We also intend to prepare the image reconstruction procedure for double module Mammo-PET and perform measurements with radioactive sources and phantoms for testing the device and focusing on its imaging capabilities. Furthermore, we will work on data analysis and on the determination of the imaging characteristics prototype for specificity, sensitivity, point spread function(PSF) and signal to noise ratio (SNR). After these steps to improve the sensitivity and specificity, the Mammo-PET will be an effective system for the detection and diagnosis of breast cancer.

Conclusions

Mammo-PET is a new device based on old PEM, but with increased sensitivity and specificity. This improvement will be possible by the employment of plastic scintillators combined with WLS strips.

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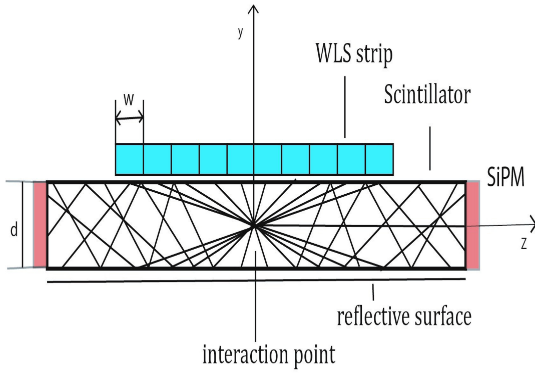

FIG. 1: A schematic view of the interaction of light inside a plastic scintillator with WLS strips. Here w (d) is the WLS strip (plastic scintillator) thickness, while the black lines represent the light trajectories inside the plastic scintillator.

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