PET imaging in breast cancer diagnostics

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***Resumo* – Apresenta-se um equipamento de imagem por tomografia de emissão de positrões. O detector baseia-se em cristais de LYSO acoplados opticamente a fotodíodos de avalanche (APD) lidos por um sistema electrónico de baixo ruído. Um sistema de aquisição de dados dedicado é utilizada para seleccionar coincidências com elevada eficiência, grande banda-passante e reduzido tempo morto. Um manipulador especializado permite realizar exames da glandula mamária e da axila.**

***Abstract* - A scanner for positron emission mammography is described. The detector is based on pixelized LYSO crystals optically coupled to avalanche photodiodes (APD) and readout by a fast low-noise electronic system. A dedicated digital trigger and data acquisition system is used for on-line selection of coincidence events with high efficiency, large bandwidth and small dead-time. A specialized gantry allows to perform exams of the breast and of the axilla.**

I. INTRODUCTION

Positron emission tomography (PET) has been proposed as a complementary technique to X–ray mammography in the diagnosis and treatment monitoring of breast cancer. In the recent years, a significant progress has been made in the development of compact systems, specially designed for breast imaging known as positron emission mammography (PEM) cameras [1], [2]. Belonging to this new generation of scanners is the Clear-PEM scanner under development by the PEM Consortium in the framework of the Crystal Clear Collaboration at CERN [3], [4].

The detector is based on pixelized LYSO:Ce crystals optically coupled on both extremities to avalanche photodiodes (APD) and readout by a fast low–noise electronic system. A dedicated digital trigger and data acquisition system is used for on-line selection of coincidence events with high efficiency, large bandwidth and small dead-time. The scanner consists of two compact and planar detector heads with adequate dimensions for breast and axilla imaging. A dedicated gantry is being built to allow the rotation of the detector heads in breast exams as well as to permit exams of the axilla region. The Clear–PEM scanner is developed with three main guidelines: low random background; high sensitivity; and spatial resolution of the order of 2 mm. The first requirement arises from the fact that the scanner must cope with a large single photon rate. In order to increase the sensitivity the Clear–PEM imaging system allows to exploit Compton interactions in the detector. Finally, in order to deliver the required spatial resolution all over the field-of-view without compromising the sensitivity by restricting the angle of the accepted lines–of–response, the detector is able to measure the depth-of-interaction (DoI) of the incoming photons [4].

II. THE CLEAR-PEM SCANNER

A. Detector System

The Clear–PEM scanner consists of two parallel detector heads covering a $16.2 \times 14.1\ cm^2$ Field–of–View (FoV). Each head holds 96 detector modules with a packing fraction of about 52%. In total there are 12288 electronics readout channels. Modules are composed of a $2 \times 2 \times 20\ mm^3$ LYSO:Ce 32 crystal array optically coupled on each side to a 32– pixel Hamamatsu S8550–01 avalanche photodiodes (APDs) array. Twenty four modules are grouped in a mechanical structure called supermodule with about $4 \times 14\ cm^2$. Each detector head is formed by four supermodules side by side. The Clear–PEM scanner is mounted on a dedicated robotic gantry that controls the detector heads positions for the breast examinations. During the exam the patient lays in prone position with the breast hanging through an aperture in an imaging table and the two detector heads positioned in each side of the breast. The detector heads can rotate around the breast in order to collect data at several angular orientations for tomographic reconstruction.

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B. Data Acquisition System

In the front–end boards, S8550–01 APD arrays are connected to low noise amplifier and multiplexer ASICs. This ASIC performs the readout of one side of six modules (192 channels), amplification, sampling and storage in analogue memories at the system frequency up to 100 MHz, as well as the selection of two active channels (192:2 multiplexing) above a common threshold. Analogue dataframe composed of 10 samples are digitized in the front-end by 10-bit sampling ADCs, serialized in LVDS bit streams and transmitted to the off-detector system.

The off-detector DAQ system is housed in a 6U crate with two dedicated buses implemented in CompactPCI backplanes. Two types of electronic boards were developed: the Data Acquisition Boards (DAQ Boards) and the Trigger and Data Concentrator Board (TGR/DCC Board). DAQ boards are responsible for the initial phase of data reduction and pipeline data storage. Parallel algorithmic processing is used in order to minimize dead time while extracting the amplitude and time from the detector pulses. The algorithms are implemented in Xilinx Virtex-II FPGAs with 4 million gates [5], [6].

At each trigger the relevant dataframes are transmitted to the acquisition PC where raw data is re–processed for energy and time extraction [6]. From the extracted energy values, the crystal DoI coordinate z is estimated by the energy signal asymmetry between the top and bottom APD channels. For events with more than one active crystal in a detector head, reconstruction position algorithms are used to estimate the first interaction crystal [7].

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