Abstract

Medical imaging is a technique that allows us to visualize non surgically the internal structure of the human body in order to diagnose or treat medical conditions. It permits also monitoring of physical processes or functions of different organs inside the body. The medical imaging encompasses wide range of techniques based on different physical principles, including techniques using ionizing radiation. The quality of the images depends significantly on the quality of the used imaging detectors. There are many types of the detectors, from old analog devices (e.g. films) to fully digital detectors such as flat panels, that are the most widely used today. The newer technology is being developed and the techniques such as photon counting explored. However, the state of the art technology is the single photon counting, where the experimental detectors such as Medipix are able to count and process each individual photon.

This works studies the properties, features and applications of the newest detector from the Medipix family Timepix3 in different imaging modalities. Firstly, a design of a new hardware readout interface for Timepix3 is presented together with data acquisition software and new analysis and calibration algorithms. Then, different applications of Timepix3 detector were explored: very fast full spectral radiography - demonstrates a very fast measurement of "color" X-ray radiography. Single Photon Emission Tomography (SPECT) - benefited from using Timepix3 detector with suppression of unwanted signal, high resolution and energy sensitivity. The Positron Emission Tomography (PET) applications exploited the timing properties of Timepix3 to find coincidence gammas from positron annihilation as well as energy properties that helped to suppress massively the unwanted signal (by two orders of magnitude). Finally, application of the Compton camera concept has been studied. A multilayer and a miniaturized single layer Compton cameras designs are presented. The main advantage of these cameras is the possibility to avoid collimator in SPECT imaging and increase vastly sensitivity of the method. We have also proved other advantages of these cameras: times better resolution compared to the conventional gamma cameras, small dimensions (USB flash stick size), and weight (only 15 g).

This work also demonstrates that the use of single photon counting detectors such as Timepix3 significantly improved the quality of images in medical imaging and could even open in the future new imaging modalities and applications that were not possible before.

Keywords: Medical Imaging, Medipix, Timepix3, SPECT, PET, Compton camera