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Multispectral Photon-Counting for Medical Imaging and Beam Characterization

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Next generation detection systems operating in multispectral mode have the potential to revolutionize diagnostic capabilities in medical imaging in terms of efficiency, image quality and lower patient dose.

We present our approach that utilizes direct conversion radiation detectors operating in Photon Counting (PC) mode.
Our strategy is to use several different detector technologies including thick silicon, high-Z semiconductor materials (CdTe/CdZnTe) and silicon enhanced by scintillator (SiS) material together with pixel Read-Out Chips (ROC) running in PC mode. Due to our involvement in high energy physics, in particular in the CMS Tracker at CERN, we have access to existing solutions of ROCs that are capable of working in the PC mode.

The main focus lies on the utilization of CdTe. Due to its high quantum efficiency it outperforms silicon in terms of photon radiation absorption. Additionally, due to the large energy band gap, devices based on CdTe can be well operated at room temperature. However, CdTe crystals are, at present times, difficult to grow and are only available in small form-factors containing a variety of defects. Therefore, we apply a thorough quality assurance that enables us to choose the best crystals for detector fabrication.

After manufacturing first successful prototypes for the proof-of-concept, we are now focusing on the processing of the CdTe crystals and thick Si wafers at Micronova Nanofabrication Centre in Espoo. Processed sensors will then be flip-chip bonded with the ROCs, which is a critical step in the detector production. Due to the intrinsic material properties of CdTe, bump bonding has to be done at lower temperatures compared to silicon sensors, thus usual materials cannot be used. A feasible approach is to employ indium based bumps that allow bonding at low temperatures.

In addition to detector development, other crucial tasks related to this project are: the evolution from single module to detector arrays and its electronic readout; the advanced data analysis and image reconstruction; and prototype testing to guarantee repeatability and long term stability.

This work is conducted within a consortium of Finnish research groups from Helsinki Institute of Physics, Aalto University, Lappeenranta-Lahti University of Technology LUT and Radiation and Nuclear Safety Authority (STUK) under the RADDESS program of Academy of Finland.

Figure 1. Photograph of processed CdTe crystal matching the pixel structures of the ROC (left) and rendering of the High Definition Interconnect PCB holding the detector array (right).

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