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Advanced X-ray Detectors for Industrial and Environmental Applications

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Abstract

The new generation of X-ray free electron laser sources are capable of producing light beams with billion times higher peak brilliance than that of the best conventional X-ray sources. This advancement motivates the scientific community to push forward the detector technology to its limit, in order to design photon detectors which can cope with the extreme flux generated by the free electron laser sources. Sophisticated experiments like deciphering the atomic details of viruses, filming chemical reactions or investigating the extreme states of matter require detectors with high frame rate, good spatial resolution, high dynamic range and large active sensor area. The PERCIVAL monolithic active pixel sensor is being developed by an international group of scientists in collaboration to meet the aforementioned detector requirements within the energy range of 250 eV to 1 keV, with a quantum efficiency above 90%.

In this doctoral research work, Monte Carlo algorithm based Geant4 and finite element method based Synopsys Sentaurus TCAD toolkits have been used to simulate, respectively, the X-ray energy deposition and the charge sharing in PERCIVAL. Energy deposition per pixel and charge sharing between adjacent pixels at different energies have been investigated and presented.

Novel methods for industrial and environmental applications of some commercially available X-ray detectors have been demonstrated. Quality inspection of paperboards by resolving the layer thicknesses and by investigating orientation of the cellulose fibres have been performed using spectroscopic and phase-contrast X-ray imaging. It was found that, using phase-contrast imaging it is possible to set burn-out like quality index on paperboards non-destructively. X-ray fluoroscopic measurements have been conducted in order to detect Cr in water. This method can be used to detect Cr and other toxic elements in leachate in landfills and other waste dumping sites.

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