# Geant4 Modeling of X-ray Induced Charge Clouds for High-Precision Sub-pixel PSF measurement in HgCdTe based infrared detectors.

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## Abstract

In the context of dark matter studies via weak gravitational lensing and galaxy distortion measurements, modern space-borne astrophysics missions demand unprecedented performance from infrared (IR) detectors in under sampled imaging. This necessitates a rigorous understanding of the Point Spread Function (PSF) at the intra-pixel scale. However, traditional optical characterization techniques like spot scans or CSIG (Continuously Self Imaging Grating) are experimentally difficult to implement at cryogenic temperatures and processing the data resulting from these measurements is not straightforward.

This study focuses on HgCdTe photo-detectors with a cutoff wavelength of 2.1µm , with 15µm pixels based on P+/N photo-diodes. These detectors exhibit excellent noise performance, with dark currents of the order of a few electrons/pixel/s and read noise of approximately 20 electrons.

We therefore propose an innovative method to measure the spatial response of infrared detectors using X-ray photons. This approach overcomes the constraints associated with classical optics by bypassing its diffraction and cryogenic-coupling constraints. The interaction of X-ray photons with the semiconductor generates a high number of carriers in a spatially localized volume, forming a charge cloud. The characteristics of this cloud directly relate to the measurement precision as well as the choice of the X-ray source.

Consequently, simulation and theoretical calculations were made in order to determine the shape, dimensions and orientation of such a cloud and the impact of its various experimental parameters, such as the X-ray photons energy, the different materials used in the detector and its fixture, the various de-excitation effects such as fluorescence or auger electrons. We also simulated the individual electron cloud produced by the impact of a single X-ray. All those simulations were made using Geant4, a Monte-Carlo based simulation tool developed by CERN. This work will focus on those simulations, specifically that of the interaction between X-ray photons and the infrared detector.