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Modelization and design of Geiger-APD for applications in astrophysics and biology

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Nowadays, there are two devices to detect low luminous flux: the PhotoMultiplier Tube -PMT- and the Avalanche Photodiodes polarized in Geiger mode -Geiger–APD-. The PMT is a detector designed in the sixties, combining many advantages but also suffering disadvantages such as its large size, expensive cost, heavy weight, sensitivity to magnetic fields and most importantly its very difficult integration for imaging pixels.
Our consortium CESR-LAAS in Toulouse has developed a generic technology for Geiger–APD and SiPM. The Geiger–APD is designed to detect very low luminous flux and compares well to PMT with many additional advantages. The work presented here consists in the study of modeling and design of a matrix of pixels with high sensitivity for application areas such as space observations, medical imaging and biology.
In this paper, we describe the model which has been used to design these devices. In the first part, we present the model for avalanche mechanism able to take into account electrical and thermal aspects. In the second part, we give the complete model including Noise evaluation and Photon generation for the basic devices which provides the response of the Geiger–APD to an incident photon: current, voltage and gain. This model is investigated by Simplorer using VHDL-AMS language, and simulated in Matlab. So, this model provides a new approach for modeling Geiger–APD Microsystems, while enabling noise extraction through experimental measurements for modeling of luminous flux as a function of this noise. The last part elaborates on the study of a novel design, with the ambition in the long term, to develop multiple applications in astrophysics (in particular in the field of Cerenkov high energy astronomy), biology, optical sensing, and mostly, imaging systems.