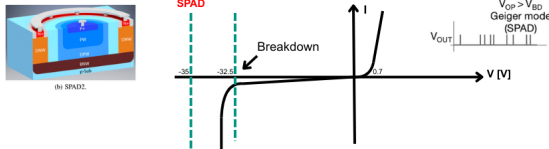


Non-uniformity characterization of a large-format time-resolved SPAD camera

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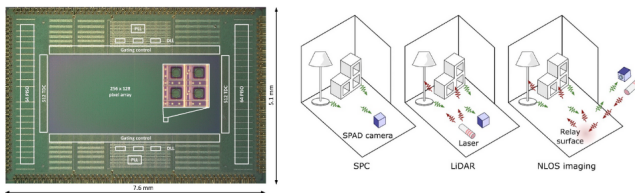
Introduction

SPAD sensor are peculiar photodiodes operating in Geiger mode.



When put together in arrays, highly sensitive and time-resolved cameras are created. Over the years these sensors' architecture has been studied and advanced in the literature, expanding the arrays and increasing their functionalities.

The Chameleon chip is a reconfigurable 256 x 128 SPAD sensor is proposed for single-photon counting (SPC), LiDAR, and non-line-of-sight (NLOS) imaging.



Objectives

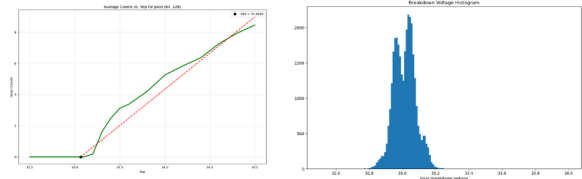
The aim of the proposed research is to understand how SPAD properties evolve from a single diode to a large array (~32K pixels), in particular we look at:

1. **DCR** (dark count rate)
2. **PDP** (photo-detection probability)
3. **Jitter**

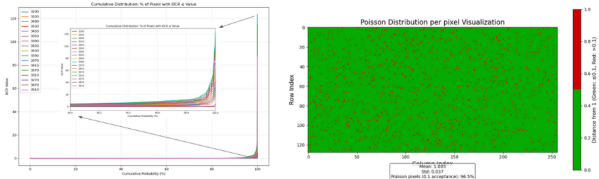
While these properties are well understood and characterized in the literature for single SPAD devices, their statistics over a large array are seldomly found, especially concerning sensitivity and timing.

Results

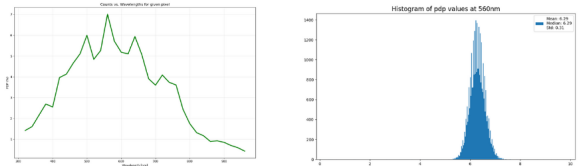
First of all we started by characterizing the breakdown voltage across the array.



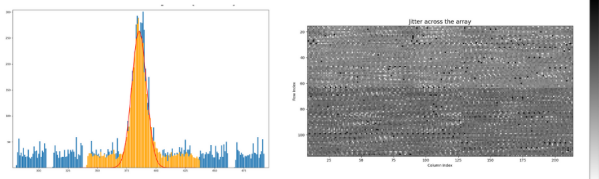
We then moved on to the DCR, running a Poisson ratio simulation to identify the hot pixels in the array.



The DCR showed very low values for most pixels, while high values for a few of them. Result confirmed in the Poisson ratio simulation with 3.5% falling outside a 0.1 epsilon from 1.

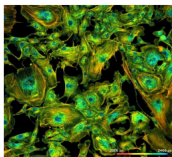


The PDP behavior was the one expected, peaking at around 560nm, with a median of 6.29%.



We can see a mean of 650 ps across the array, substantially bigger than what was recorded on the single SPAD [2], which makes us think that the ancillary electronics play a major role in this dimension.

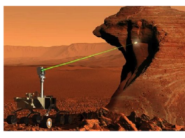
Applications



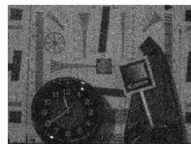
FLIM:
Fluorescence Lifetime Imaging Microscopy; SPAD arrays reveal cell dynamics at the nanoscale.



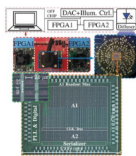
Biomedical:
Time-of-Flight PET scanners improve image resolution and reduce dose.



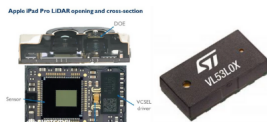
Scientific:
Raman spectroscopy with SPAD detectors used in planetary exploration (Mars rover).



Low-light imaging:
Single-photon sensitivity for extreme photon-starved conditions.



Security:
Quantum random number generators for secure cryptography.



Consumer:
LiDAR in smartphones and tablets for depth sensing, autofocus, and presence detection.

Acknowledgments

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References

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- [2] G. Gramuglia et al., "Engineering Breakdown Probability Profile for PDP and DCR Optimization in a SPAD Fabricated in a Standard 55 nm BCD Process."
- [3] T. Milanese et al., "A Reconfigurable 256x128 SPAD Imager with Gradient Gating for Single-Photon Counting, LiDAR, and Non-Line-of-Sight Imaging."
- [4] M. Fishburns, "Fundamental of CMOS Single-Photon Avalanche Diodes".