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Microelectronic Single-Photon 3D Imaging Arrays for low-light high-speed Safety and Security Applications

MiSPiA Project 257646

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SEVENTH FRAMEWORK PROGRAMME

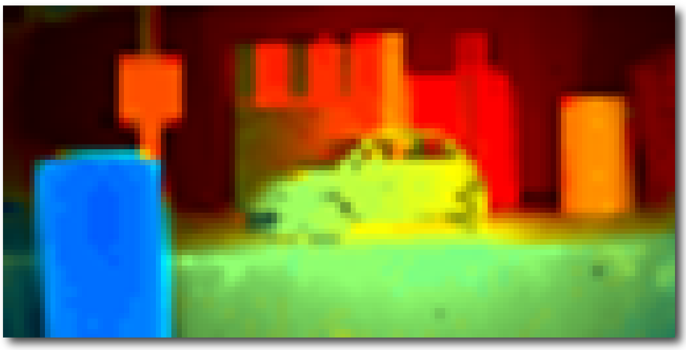
PARTNERS

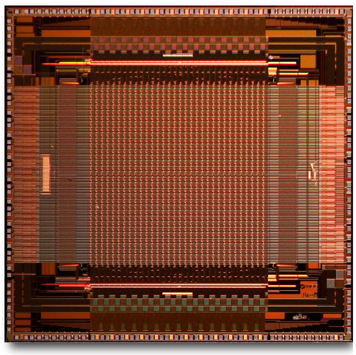
INTRODUCTION

MiSPiA aims to develop advanced microelectronic SPAD array chips able not only to count single photons ("single-photoncounting"), but also to accurately tag them with their arrival time ("single-photon timing") and so provide a full image ("single-photon imaging") of the object under investigation. Therefore, MiSPiA aims to conceive, develop and fabricate photonic and microelectronic technologies for cost-effective manufacturing of very fast, highly sensitive, two-dimensional (2D) and three-dimensional (3D) SPAD cameras running at higher speed than standard video-rate.

Results at the end of the project

- a set of new state-of-the-art CMOS SPAD detectors and arrays (Objective 1), with Dark-Counting Rate DCR<80cps at 5V excess bias for 30µm SPADs at room-temperature; Photon Detection Efficiency PDE of 55% at 400nm, >30% in the 300-600nm range, 10% at 750nm and still 5% at 850nm; Time-of-Flight (TOF) precision better than $40ps_{FWHM}$; SPAD diameters up to 500µm (never reported so far). MiSPiA SPADs are best-in-class not only among CMOS SPADs, but also impressively compare with leading-edge custom-process (both planar and reach-through) SPADs.
- a set of 3D ranging chips for "direct TOF" and photon-timing (Objective 2) with best-detection performance so far reported, based on smart-pixels with 30µm SPADs and in-pixel time-to-digital converters (TDCs) for TOF measurement of individual single photons: both linear arrays and 1048 pixels imagers, acquiring 2D images and 3D movies at 100,000fps with 5cm single-shot depth-precision while 0.9mm at 200fps, with 6bit photon-counting dynamics and <100cps/pixel noise, 10bit photon-timing with $212ps_{rms}$ resolution and 320 ns full-scale range.





- a set of 3D ranging chips for "indirect TOF" and photon-counting (Objective 2) with among the best cutting-edge performance among SPAD imagers, based on smart-pixels with 30µm SPADs and digital counters for phase-resolved detection of either pulsed-light (PL) or continuous-wave (CW) actively illuminate scenes: linear arrays or matrixes, 2048 pixels acquiring 2D images at 100,000fps and 3D maps movies at 33,000fps, with 9bit photon-counting dynamics and <100cps/pixel.
- two **compact and modular low-power fully-programmable active illuminators** (Object 3), to be coupled with 3D iTOF cameras for short-ranges up to 50m, based on commercially-available LEDs or solid-state lasers, able to switch between two operating mode, namely pulsed-light (PL) mode, with flashes lasting few hundreds of ns, or continuous-wave (CW) modulation, at MHz rates.
- one **reconfigurable user-friendly compact camera module** (Object 3) for 2D/3D acquisitions of pictures and movies by any (linear array or imager, iTOF or dTOF based) MiSPiA CMOS SPAD chip, to be remotely controlled by a remote pc through USB 2.0 link and a graphical user interface (gui). All signals, clock, and buses to/from the chip are managed by an on-board FPGA, able to store high-throughput streams of data into a SRAM.
- two different **cost-effective CMOS technologies for SPAD manufacturing**, in a robust and reliable 0.35µm node, to fabricate either fully-planar single-chip, front-illuminated CMOS **FrontSPAD** imagers (Objective 2) or advanced two-chip wafer-to-wafer bonded, back-illuminated SOI-based **BackSPAD** imagers (Objective 4). The FrontSPAD technology is completely validated and tested, and resulted in the development of previously listed products 1, 2 and 3.
- tests and characterization in short-range safety automotive scenarios (Object 6), under different experimental conditions, indoor and outdoor, in static and dynamic scenarios, in private driving test tracks and public every-day standard traffic conditions, in either daylight, twilight or night-time.