NETWORKED PHOTONIC COMPONENTS FOR BIOMEDICAL IMAGING

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FULLY NETWORKED, DIGITAL COMPONENTS FOR PHOTON-STARVED BIOMEDICAL IMAGING SYSTEMS

Conceptual design of a possible SPADnet full pre-clinical PET implementation.

Vision & Aim

SPADnet aims to develop a new generation of smart, large area networked image sensors, based on a conventional CMOS fabrication technology (the same as used for microchips or sensors in cellphone cameras, for example), for photon-starved biomedical applications. SPADnet will build ring-assembly modules for Positron Emission Tomography (PET) medical imaging, and carry out performance tests in a PET system evaluation testbed.

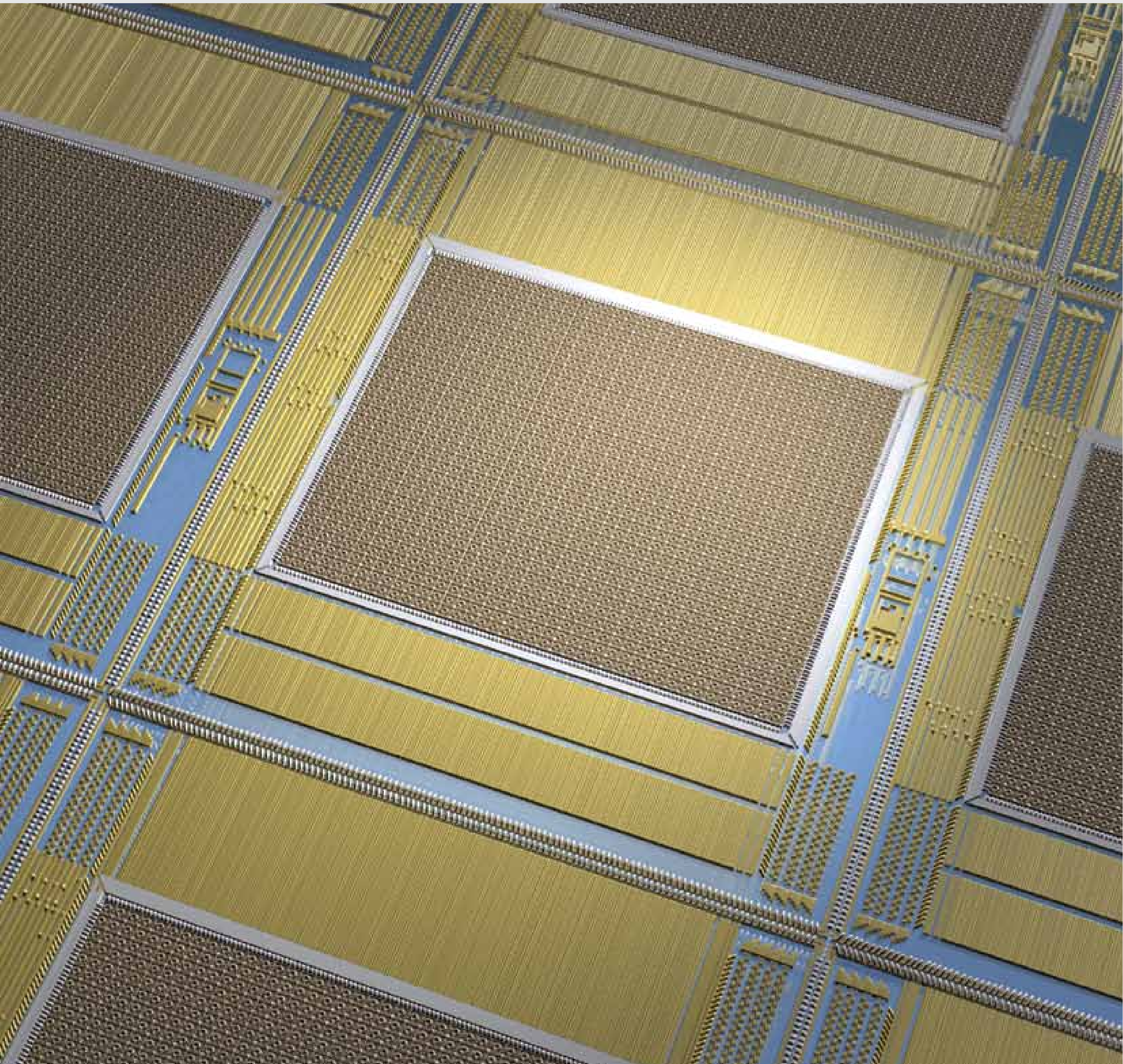
While suited to applications offering repetitive measurement techniques, existing sensors are not well adapted to single-shot, rare events often occurring in diagnostic tools based on specific radiation detection, PET, SPECT, gamma cameras, and other minimally-invasive / point of care tools. In addition, the relatively small field-of-view of existing sensors is a limiting factor.

SPADnet's prime objective is to develop a scalable photonic component for large format, rare-event imaging. The core of the component will be an array of SPADs (Single-Photon Avalanche Diodes, very sensitive light detectors, capable of detecting and timing a single quantum of light), implemented in a conventional CMOS technology. This will enable the integration in a mainstream technology, capable of volume production, of the single-photon sensing part, as well as the related electronics, rather than having to use dedicated fabrication processes. Furthermore, the sensors will be faster and cheaper than existing devices, and compatible with the use in strong magnetic fields, a prerequisite for the integration of PET scanners with MRI machines (a current industry trend).

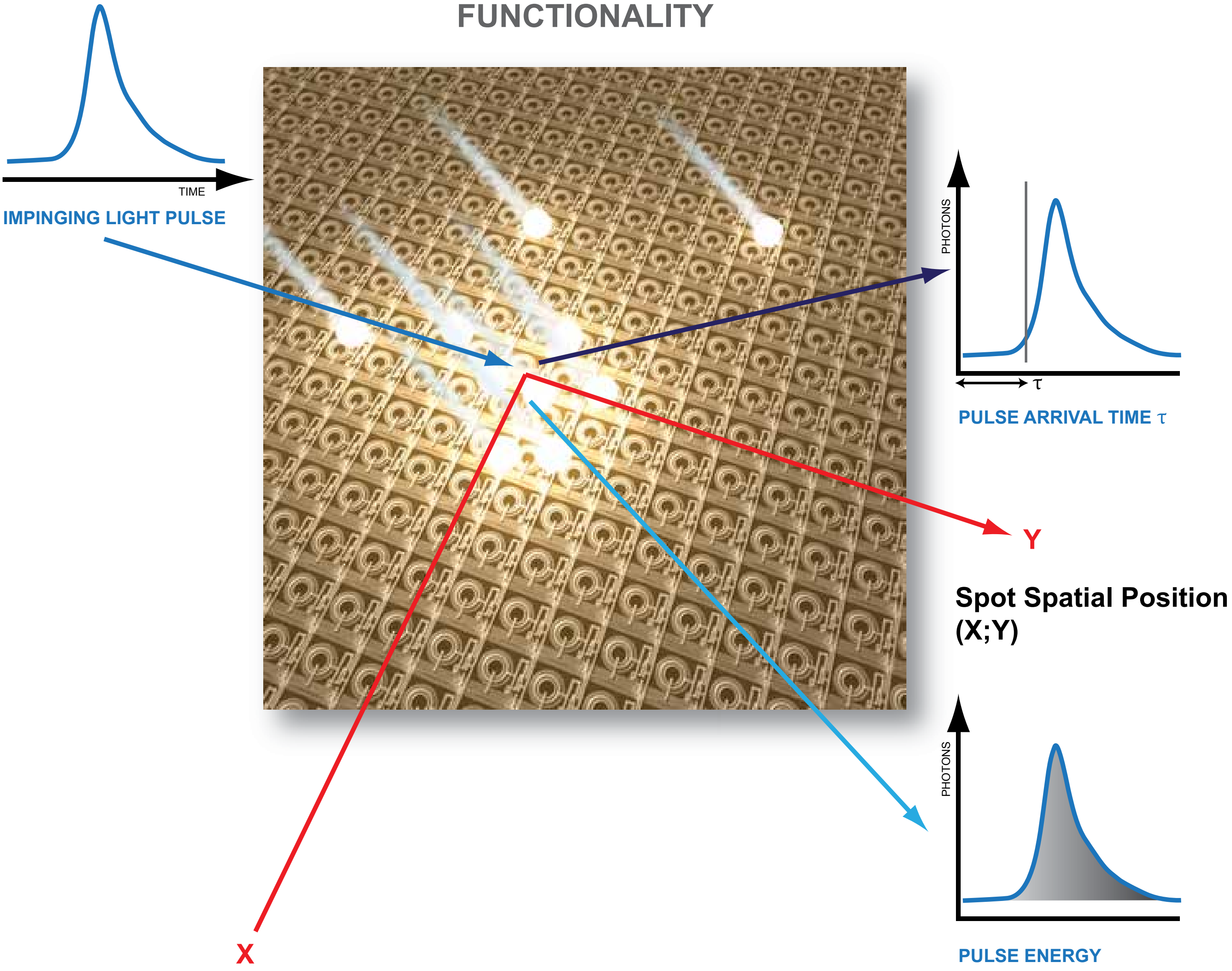
Large formats will be achieved by tessellating several tens of dies in abutment style, using innovative three-dimensional packaging techniques based on through silicon vias (TSVs), which allow the implementation of vertical interconnections in a silicon substrate, rather than horizontal ones as in conventional assembly processes.

This will in turn permit a drastic reduction of insensitive areas. The second key advantage will be represented by the ability to stamp the time and position of each photon impingement in a burst event, such as the light flashes generated by the impact of an X or gamma ray on the scintillator covering each chip. The concept of spatial oversampling is introduced, where a single measurement is partitioned into a myriad of simultaneous sub-measurements. The notable difference is that in space oversampling many SPADs will detect the same event independently, thus reducing each sensor's dead time on average by the number of detectors involved.

The proposed, new SPADnet pixel array (shown below) will represent a significant increase in processing and detection capacity.



SPAD SENSOR ARRAY AND ITS FUNCTIONALITY

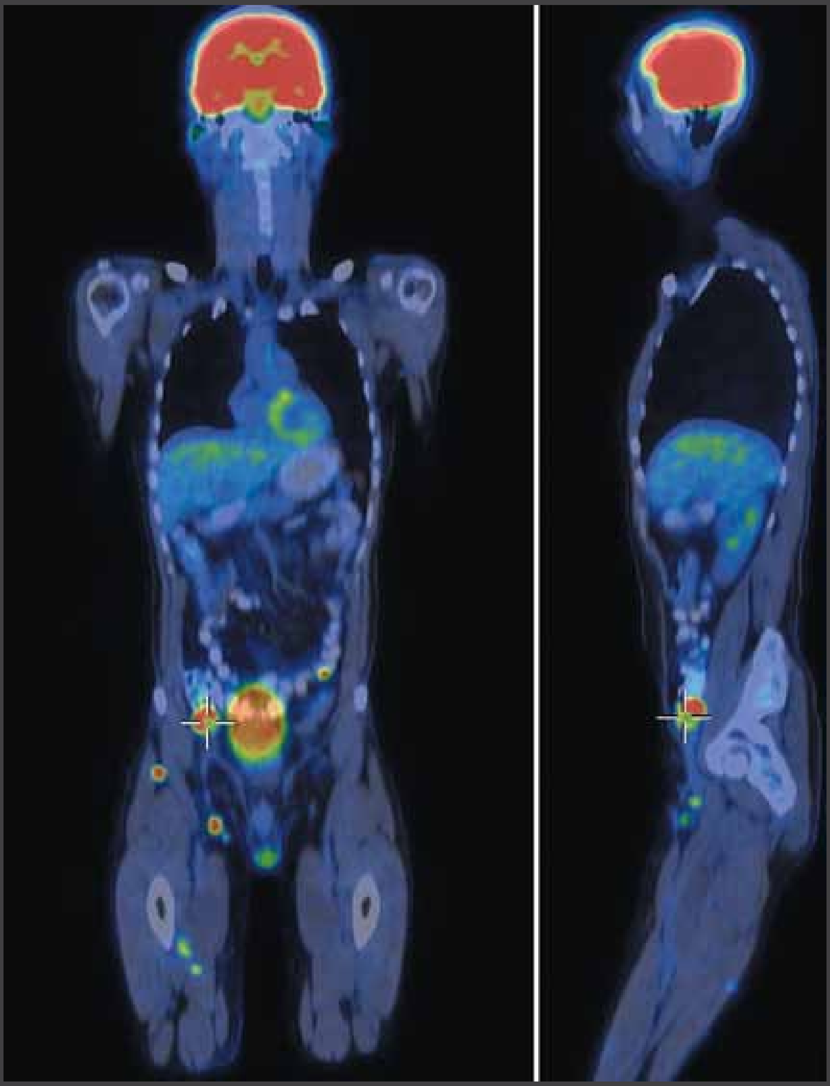


The decomposition of the large format imager to a network of independent arrays is key to managing massive data streams. In conventional sensors, such as PMTs (photomultiplier tubes) or SiPMs (silicon photomultipliers), the sensitive device produces a stream of analog electrical pulses, which are processed outside the sensor. The photonic component proposed in this project, on the contrary, generates streams of digital data which will have been precomputed in the sensor itself. Finally, the current state-of-the-art on inter-chip data exchange will be the basis for efficient data communication, in a true sensor network communication style.

Data packets will be routed in the network and will be handled on-demand. For example, coincidence mapping devices can be used in this context as “snoopers” (network traffic surveillants) on the data bus, thus considerably simplifying the architecture of systems such as PET.

WHY SPADNET MATTERS!

Positron emission tomography (PET) is a nuclear medicine imaging technique which produces a three-dimensional image or picture of functional processes in the body. It works by detecting pairs of gamma rays produced indirectly by a positron-emitting radionuclide. This tracer is introduced into the body through a biologically active molecule. Using these radionuclide data 3-dimensional images of the body can then be constructed by computer. 4-dimensional data (changes over time) can also be calculated.



PET technology has had a profound impact on modern medicine. It has been expanded as a method to assess the response to therapy, in particular cancer therapy, where the risk to the patient from a lack of information about the progress of a disease is much greater than the risk from the radiation exposure.

SPADnet offers the possibility of extracting much more clinical information than conventional PET technology, while reducing the exposure to radiation.

It should be able to accomplish this at significantly lower cost by exploiting detectors that operate in a photon-starved regime. A photon-starved regime means a regime of extremely low illumination, such as in many medical imaging systems, in particular those using radiotracers (“ordinary“ X-ray imaging, including CT imaging, is not necessarily photon starved *per se*, but might still profit from the proposed developments). In these regimes rare, single (light) bursts are the norm rather than the exception. In the case of PET, the proposed developments will potentially enable better quality images with lower doses of radiotracers. It should be noted that other biophotonic and biomedical applications are also photon-starved (e.g. those based on fluorescence lifetime imaging, which can also be tackled by the proposed sensor), and the same is true of applications in areas such as astronomy or particle physics.

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Web site:	***www.spadnet.eu***

Timeline:

Start Date:	*01/07/2010*
End Date:	*31/12/2013*

Budget:

Overall Cost:	*5.301.770 €*
Funding:	*3.700.000 €*

SEVENTH FRAMEWORK PROGRAMME