Avalanche pixelated sensors and dedicated read-out electronics for time resolved experiments

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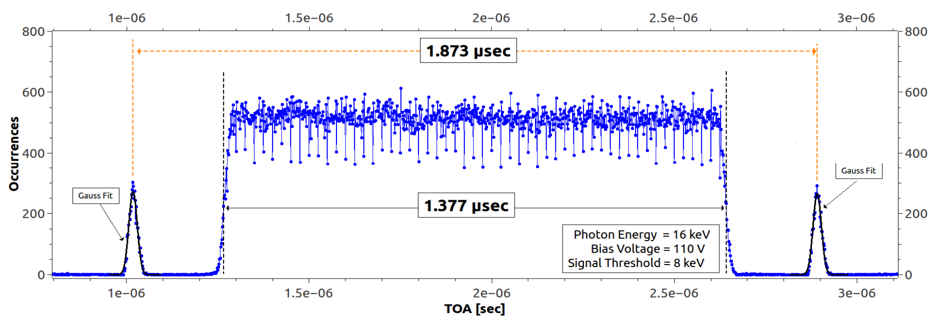
Introduction

In the past decade hybrid pixel detectors revolutionized many Photon Science experiments such as crystallography experiments. Photon Science time resolved experiments still demand faster and faster detectors capable of accessing the microsecond or nanosecond time scales. This demand cannot be efficiently satisfied by presently available detector systems and read-out schemes. Timepix3, the latest read-out chip released by the Medipix3 collaboration goes in this direction by using a data driven sparse read-out. However the dead time is still a major drawback with the presently available technology. In addition this technology is not optimal for photon energies smaller than 4 keV. Avalanche pixel sensors could address very effectively both issues.

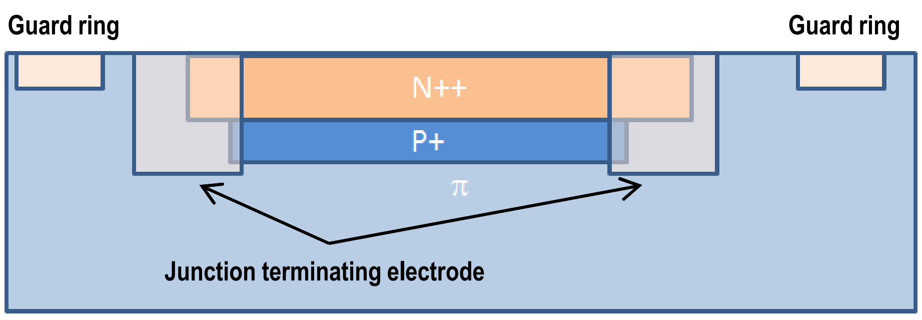
The Idea/Concept

Recent developments in High Energy Physics led to the fabrication of avalanche structures in high resistivity silicon that is normally used to build hybrid pixel detectors. The idea is to apply this new developments to detector systems for Photon Science to further improve their performance. Large area avalanche pixelated sensors with a pixel size similar to Medipix (55 μm) should be developed. Issues such as gain change at the boundary of the pixels should be addressed. The detector group at Diamond has started investigating the fabrication of this sort of sensors in collaboration with the University of Glasgow and Micron Semiconductor (see Neil Moffat contribution at IWORID). In order to build a complete system another crucial step is the development of dedicated front-end electronics that should have a bandwidth large enough to take full advantage of the speed of the signal delivered by an avalanche sensor and adjustable gain to compensate for the avalanche gain variation between pixel and pixel.

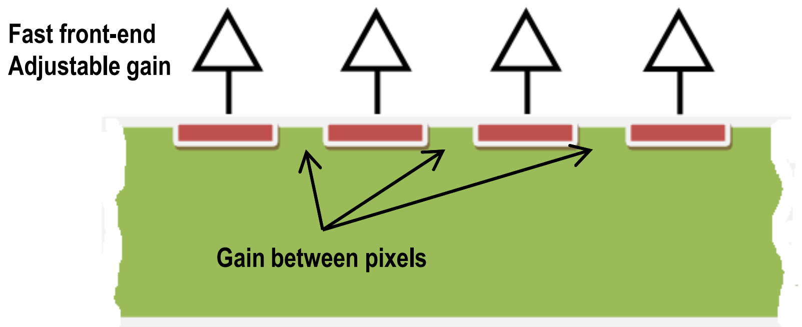


Beam test of Timepix3 at Diamond Light Source. Timepix3 enable to resolve the isolated X-ray flashes with a time resolution of 8 ns r.m.s. One of the major contribution to the dead time is the relatively limited speed of the signal generated by the standard sensors.

Avalanche test sensors fabricated by Micron Semiconductor under assembly at Diamond Light Source for the first tests with radioactive sources.



Avalanche test sensor schematic under study by a collaboration between the University of Glasgow, Micron Semiconductor, and Diamond Light Source. The P+ region is the multiplication region. The junction terminating electrode helps in reducing the electric field at the edges.



Two crucial points to be understood, improved, and further developed. The change in gain between pixels and a fast front-end electronics with adjustable gain.

Potential Impact

The potential impact of an avalanche pixelated detector systems can hardly be understated. Hybrid pixel technology proved to be a major technological leap in Photon Science. However there are still applications where this technology has not given its best and avalanche pixelated sensors would help in broadening the range of application of such a technology.

One application is in time resolved experiments where data driven sparse read-out scheme can vastly improve the efficiency of experiment but they have their limitation in the speed of the signal delivered by the sensor. Avalanche sensors would enable to reduce the dead time due to the signal speed.

The other noteworthy application is the use of hybrid technology in the photon energy range 1 keV – 4 keV. The front-end electronics of the present systems work close to the noise edge when the detectors are operated in this energy range. If the sensor provides gain it would enable the front-end electronics to work in a much more comfortable range. The hybrid technology could then be extended and applied to experiments operating at low photon energy.