Development of Silicon Carbide based sensors for in-line and real-time X-ray beam profile monitoring applications

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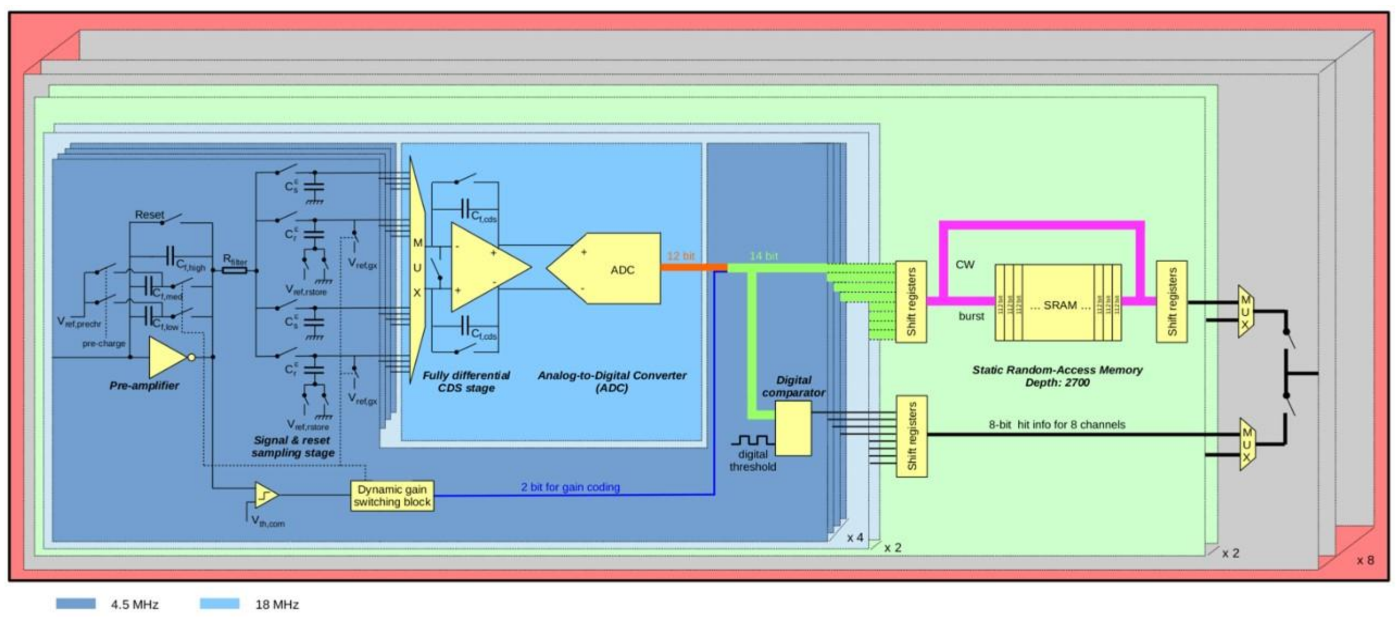
Introduction

Current commercially available in-line X-ray monitors use 2x2 pixel-arrays to detect the beam position but **fail in providing any information about beam profiles**. This information would be extremely useful in several applications such as spectroscopic measurements where, thanks to the increased brightness and coherence of the next generation X-ray beams, it will be for example possible to collect fast XAS (x-ray absorption spectroscopy) data by synchronously quickly rotating the monochromator and, at the same time, changing the undulator gap. In order to ensure a stable focused x-ray beam on the sample while the optical elements are moving these measurements will require a feedback not only of the beam position but also of its 2D profile. In more general terms, **beam profile monitoring would significantly improve the overall stability of various types of long-term imaging and/or spectroscopic experiments compensating mechanical systematic drifts or instabilities.**

Gotthard2 readout system



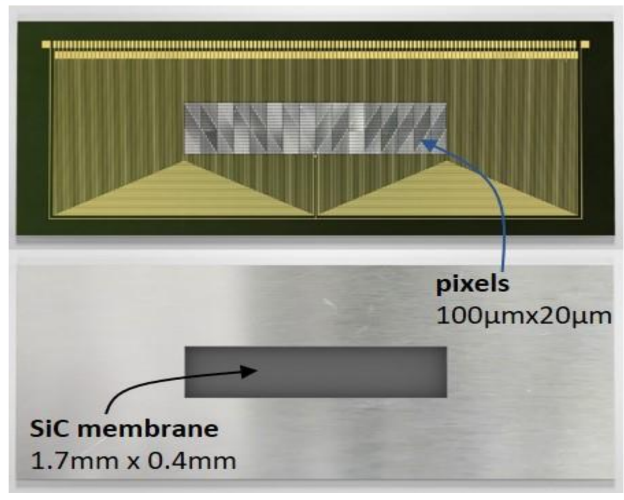
Simplified block diagram of the GOTTHARD-II chip [1]. Thanks to its on-chip ADCs (Analogue-to-Digital Converter), it provides 4.5 MHz frame rate allowing for real time analysis of the X-ray beam profile

Comparison of materials for X-ray in-line realtime monitoring

Single crystal diamond	Polycrystalline diamond	*4H Silicon Carbide*
• Small samples (<1cm²)	• 3' wafer available	• 6' "true electronics level" material
• Thick (low transparency)	• Thin (high transparency)	• Thin (high transparency)
• Uniform response	• Non-uniformities	• Uniform response
• Very fast dynamics (ns)	• Slow dynamics (~ms)	• Very fast dynamics (<µs)
• Low current signal	• Lowest current signal	• Highest current signal
• Requires bias	• Requires bias	• Zero bias operation

Only Silicon Carbide has both (*i*) crystal quality and (*ii*) availability of large samples to allows for pixelated systems with large active areas

First Silicon Carbide pixellated Devices



Two different layouts available:

1) large area sensor:

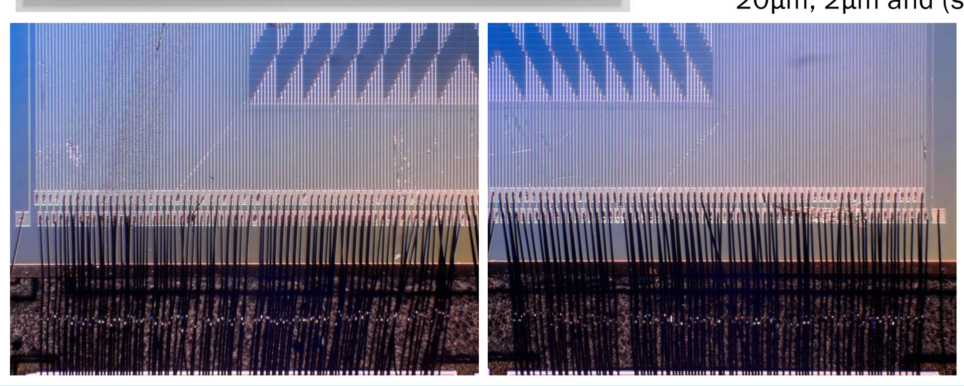
384µmx90µm pixel pitch, 6912µmx1620µm active area

2) small area/ high resolution:

106µmx26µm pixel pitch, 1908µmx468µm active area

Three different thicknesses available:

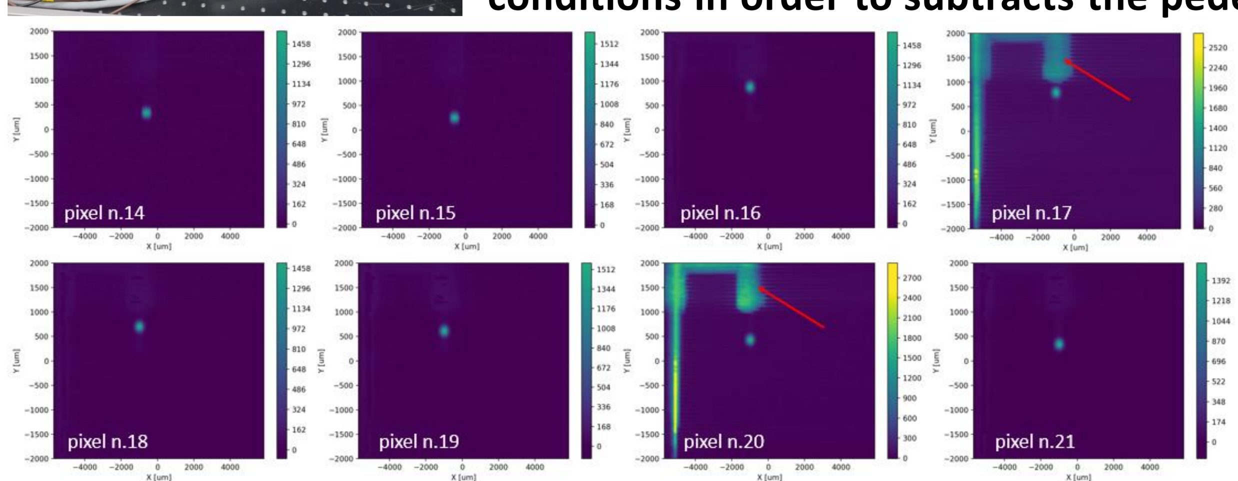
20µm, 2µm and (soon) 200nm active thicknesses



improvements in device quality and wire bonding necessary

Experimental setup and first tests

First tests on 20um detectors were carried out on a compact X-ray generator (@ SuperXAS) with a Mo anode where the beam is focused with polycapillary optics to a 50 µm at 20 mm from the optics. A 2D scan with a 150 µm step size on the X axis and 40 µm on the Y axis was performed, acquiring 1000 frames (frame rate 2.5 MHz, exp. time 100 ns) of the 256 pixels at each position of the scan in dark and under illumination conditions in order to subtracts the pedestal level from the data.



90 % of the wire bonded pixels are working.

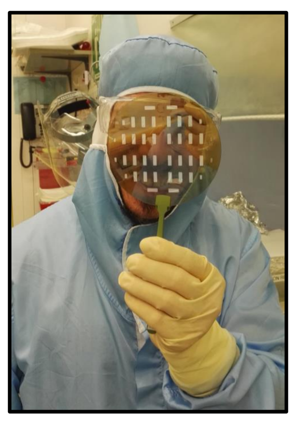
47 % of the pixels shows signal when the beam is on the fanout, which is not due to coupling.

This effect is still under study.

Xray lab source: spot size 69µmx61µm

Scalability

Demonstration of 4 inch wafer level fabrication of 2µ SiC membranes



Conclusions and outlook

- **Silicon Carbide based position monitors have been already demonstrated [2,3,4] and are now commercially available from SenSiC GmbH**
- **Thanks to the availability of large area high quality of Silicon Carbide samples, it is possible to fabricate pixelated detectors for beam monitoring**
- **Pixelated prototypes with sensor thicknesses of 20um have been realized and characterized with a focused X-ray lab source**
- **Fabrication of the sensors needs further improvements as only 50% of the pixels were properly wire-bonded and, of these, some showed anomalous signals from the metal routings.**
- **Further work will be devoted to improve fabrication and packaging steps to achieve proper pixels yield to allow for incorporation of these new monitoring systems in routing beamline control**

References

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