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Extreme High Count Rate Performance with a Silicon Drift Detector and ASIC Electronics

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Abstract: Extremely High Count-Rate Performance of Silicon Drift Detector (SDD), the Vortex®, has been achieved by integrating it with new front-end ASIC electronics and using a new pulse processing technology. The use of ASIC electronics produced a very low input capacitance that also significantly improved resolution at short peakingtimes.

1. Short Risetime

The Vortex® SDD system [1, 2] has been modified by replacing the standard JFET input electronics with an ASIC (CUBE), developed by XGLab S.R.L., Milan, Italy, and by use of new pulse processing technologies: the "Xspress3" developed by Quantum Detectors, Harwell Oxford, UK, and the "FalconX" developed by XIALLC, Hayward, CA, USA. With the new ASIC technology a very short signal rise time is achieved, further enhancing the existing high countrate capability of the Vortex® system. The output signal from the ASIC preamplifier is a step wave with its height proportional to the energy of the incident photon (~1.5 mV per 1 keV photon energy), as shown in Fig. 1.

A Vortex® ASIC unit was evaluated and compared with a similar unit equipped with a JFET by Dr. Cédric Cohen [3] at the European Synchrotron Radiation Facility (ESRF). An average rise time of 22 ns was observed as shown by the signal rise time distribution in Fig. 2.

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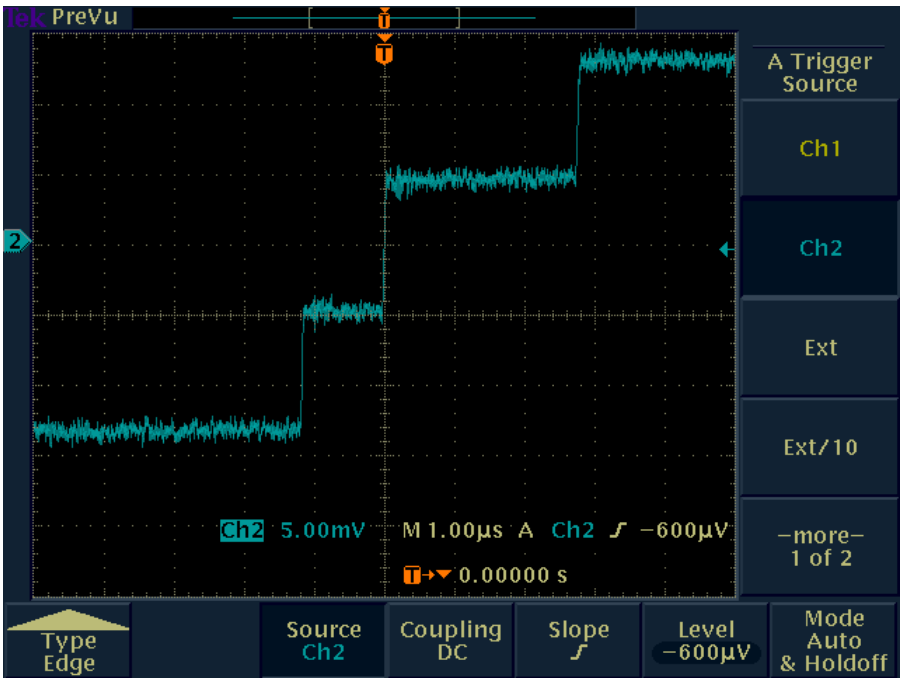

Fig. 1. ^{55}Fe oscilloscope trace of preamplifier output step pulses, including noise. Height of the steps is proportional to the x-ray energy (5.9 keV). Average signal rise time is 22 ns.

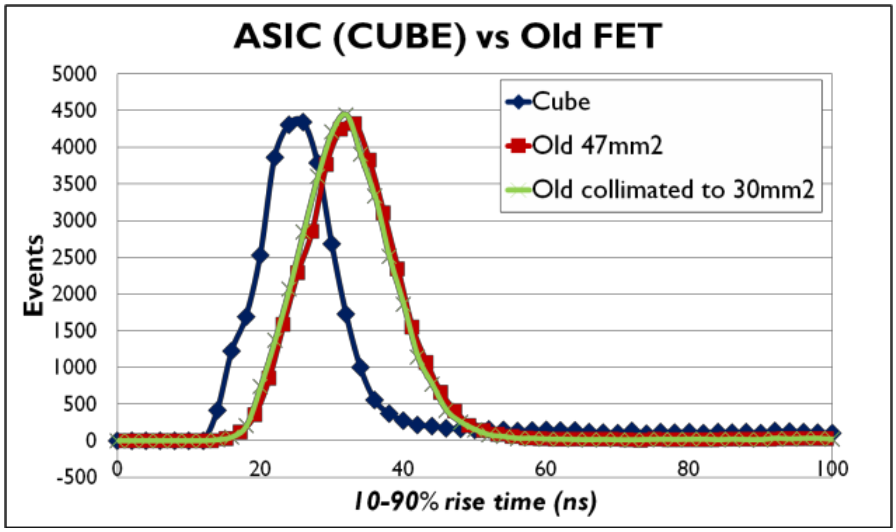

Fig. 2. Vortex® ASIC rise time (10-90%) histogram, collected at ESRF (35000 accumulated trigers). The Cube data was collected from the Vortex with Cube ASIC electronics. The other data (Old and Old collimated) are data collected from a Vortex with JFET electronics.

2. Vortex® SDD and DPP

The Vortex® ASIC SDD was evaluated with the two most advanced digital pulse processors (DPPs): the

Xspress3 from Quantum Detectors and the FalconX, a product of XIA. The count rate results with the Xspress3 are presented in Fig. 3. With the Xspress3, an output count rate of 1.6 Mcps at 2 Mcps input count rate (20% DT) was achieved as presented in Fig. 3. The peak position stability of the Vortex® with the Xspress3 from zero to 3 Mcps is presented in Fig. 4.

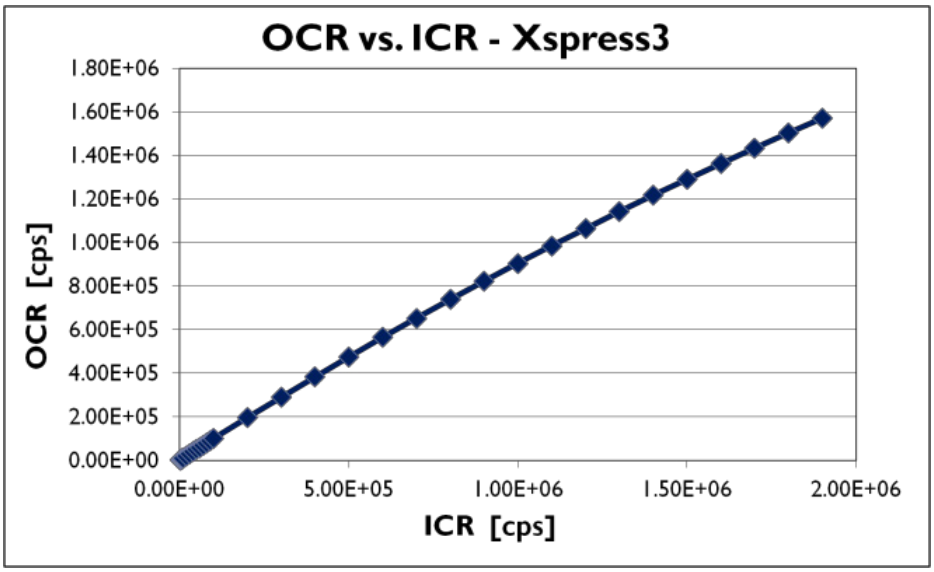

Fig. 3. The Vortex® SDD count rate performance with the Xspress3.

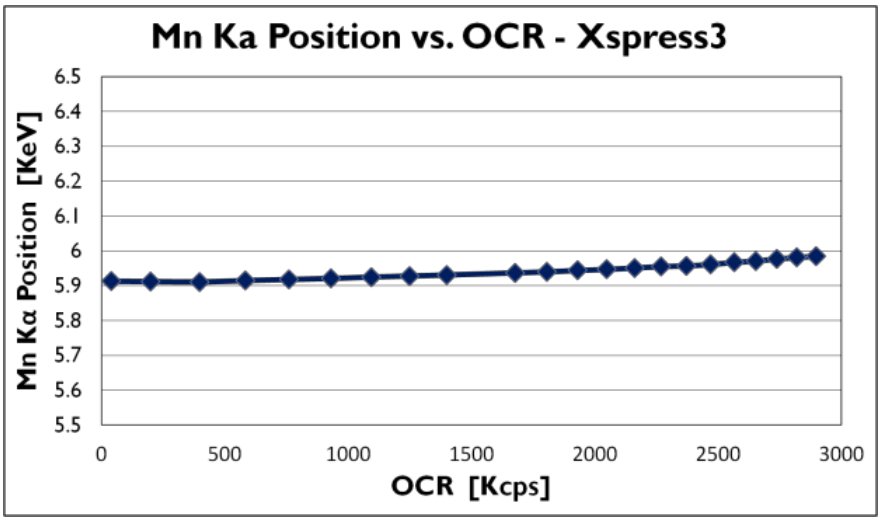

Fig. 4. Mn Kα peak position vs. OCR with Xspress3.

The count rate results with the FalconX are presented in Fig. 5. With the FalconX an output count rate of 1.8 Mcps at 3 Mcps input count rate (40% DT) was achieved as presented in Fig. 5. The peak position stability of the Vortex® with the FalconX from zero to 3 Mcps is presented in Fig. 6. With both advanced

processors, the Xspress3 and the FalconX, an energy resolution of less than 200 eV was achieved with a 2 Mcps input count rate. At low count rates, the SDD resolution is 130 eV.

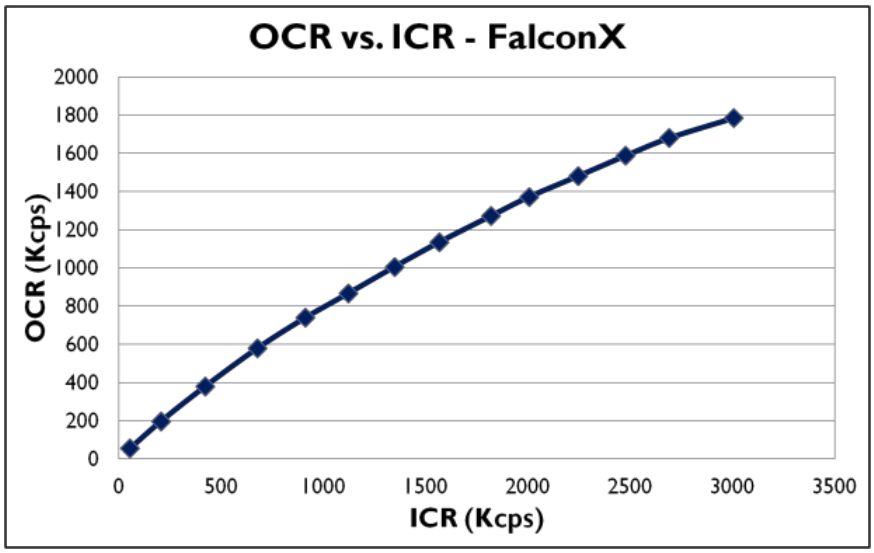

Fig. 5. The Vortex SDD count rate performance with the FalconX.

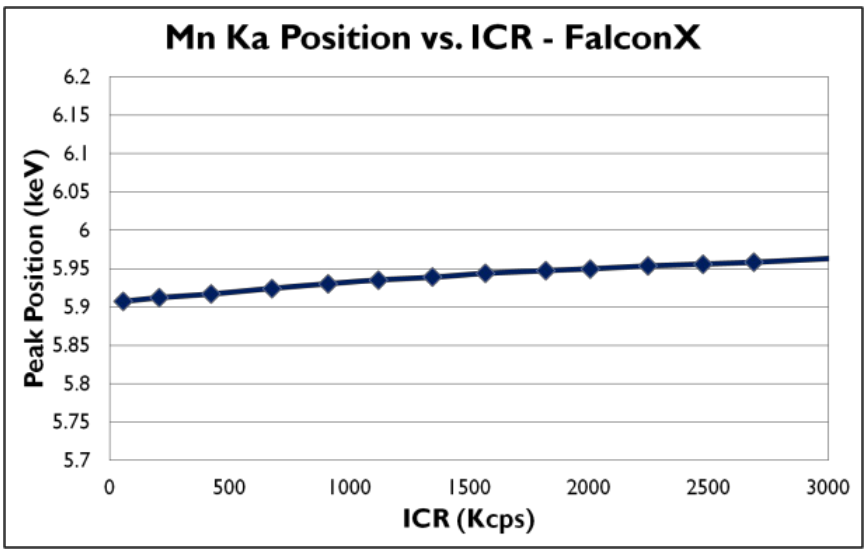

Fig. 6. Mn Kα peak position vs. OCR with FalconX.

3. Implementing Asic into Multi-Element Detectors

For some synchrotron applications, a single SDD unit is not adaquate to meet the high count rate requirement.

To significantly improve the high count rate performance of the Vortex® single SDD, a multi-element 4-channel SDD [4], the Vortex® ME-4, equiped with ASIC electronics, was developed and is already in use

in many synchrotron facilities throughout the world. The Vortex® ASIC ME-4 is shown in Fig. 7.

Several different multi-channel Vortex® SDDs were developed for specific synchrotron applications. All of them are equipped with the ASIC electronics described above. One of these unique designs, which is already in use at the Brookhaven National Laboratory (BNL), is the Vortex® ME-3 [4], which is a focal design detector with a narrow tube to enable close access to a sample in a limited chamber space. The special design enables the collection of a spectrum with maximum efficiency from a sample located at the focal point. The Vortex® ASIC ME-3 is shown in Fig. 8.

Fig. 7. The Vortex® ME-4, containing four 50 mm^2 SDDs, for synchrotron high count rate applications

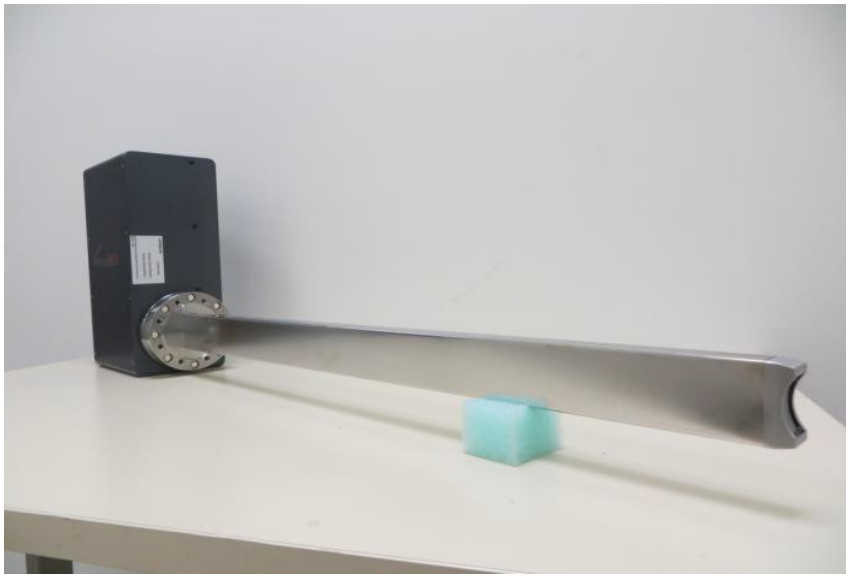

Fig. 8. The Vortex® ME-3, three 50 mm^2 SDDs, focal design: focal point at 30 mm.

A close look of the Vortex® ASIC ME-3's front end is shown in Fig. 9. The Advantage of the ME-3 focal design is presented in Fig. 10.

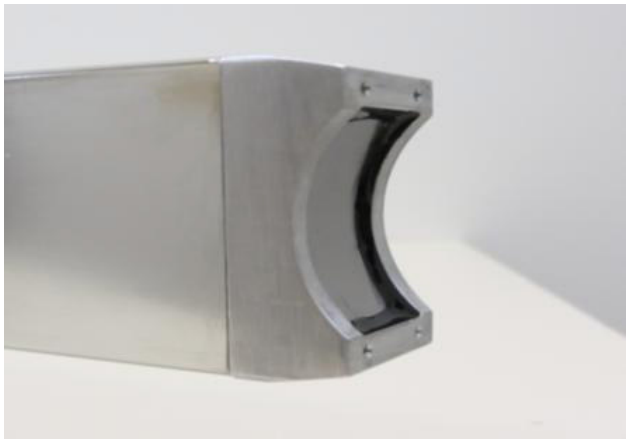

Fig. 9. The Vortex® ME-3 front end

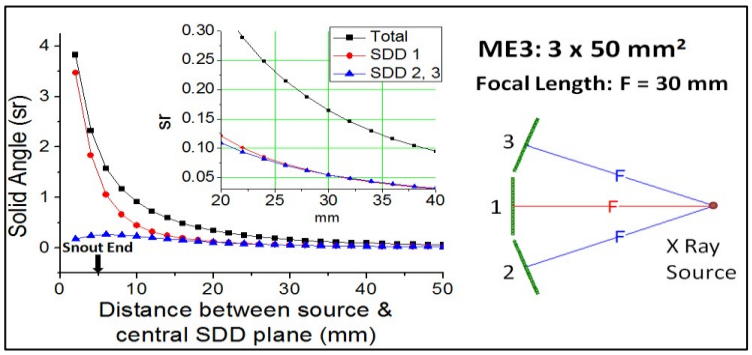

Fig. 10. The Vortex® ME-3, focal design for a sample at 30 mm from the SDD's front surface

4. Conclusions

- The following parameters of the detector were tested at ESRF: rise time, peak shift, energy resolution, and efficiency. The results of the tests comply with the technical specifications of the Vortex® datasheet.
- The ASIC preamplifier rise time duration is ~20% shorter compared to the previous preamplifier version, and offers the possibility of working at 100 ns processor peaking time without energy resolution degradation.
- The advanced digital processors "Xspress3" and "FalconX" enable customers to collect data at the extreme count rate of 3 Mcps with minimal shifts of peak position and minimal loss of resolution.
- The multi-element Vortex® ME-4 and ME-3 are products which directly address synchrotron high count-rate experiments by improved efficiency, resolution, peak position stability, and reliability.

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