ABSTRACT
A new class of silicon drift detectors (SDD), called “Vortex™”, with a large active area (~ 0.5 cm²), high-energy resolution (<150 eV FWHM) and high-count rate capability (>1 Mcps) has been developed for X-ray diffraction (XRD) and X-ray fluorescence (XRF) applications. The Vortex™ design allows for a relatively large active area while still maintaining a very low anode capacitance (~ 60 fF). This very small detector capacitance results in a reduction of the series-noise component and hence a reduction of the overall inherent electronic noise. The Vortex™ detector utilizes novel patent pending structures that have produced very low dark current (both bulk silicon dark current and surface dark current), high electric field, uniform charge collection, low noise and high-sensitivity to low energy X-rays. An energy resolution of 143 eV FWHM was measured at 5.9 keV, 6 µs peaking time; < 250 eV FWHM was achieved at 250 ns with commensurate output count rates of greater than 400 Kcps. The details of the detector performance as a function of amplifier peaking time and input count rates, and as compared to a comparable Si(Li) detector, are discussed.

INTRODUCTION
The development of charge coupled devices (CCD’s) for light-signal imaging, utilizing extremely low capacitance of the detector and readout circuitry, opened up a new chapter in possible nuclear detector designs. This also started a vigorous effort to develop silicon drift detectors for high-energy physics applications [1, 2]. Interest in the development of new structures for X-ray spectroscopy followed [3-6, 12-16]. The beauty of the drift detector design in this regard, is that, unlike traditional planar detectors, the SDD allows for a relatively large active area while still maintaining a very low capacitance (~60 fF) to achieve low noise. In order to take advantage of the low capacitance of the drift detector, the detector must be matched to a low capacitance input transistor. State-of-the-art low noise FETs (field effect transistors) for spectroscopy generally have a capacitance much larger than is optimal for use with the drift detector. In addition, standard techniques for coupling the FET to the drift detector anode typically add stray capacitance. Therefore, one approach has been to design low noise FETs, which can be integrated, or processed, directly on the detector substrate, thereby reducing the overall system capacitance [7-10]. However, it is difficult to achieve high a transconductance internal FET and anecdotal reports from several users of these detectors suggest that the preamplifier involving use of the internal FET may cause severe instability with count rate. Thus we have developed new patent pending techniques for the Vortex™ technology using highly optimized coupling of an external FET.
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VOlTEX DETECTOR

The electrical and mechanical packaging for the Vortex™ detector was designed to accommodate the detector, Peltier cooler platforms, heat exchange assemblies and utilized vertical assembly techniques for interconnecting the detector with the electronics to ensure minimum microphonics and noise. The Vortex™ detector housing is shown in Figure 1.

![Figure 1. A Photo of the outer housing of the Vortex™ detector. The coin in front of the detector window is a quarter.](image)

The detector is optimally coupled to a special low noise FET and a custom-designed low noise preamplifier. Tennelec TC 244 and Canberra 2026X amplifiers, a Nucleus PCA multi-channel analyzer, and XIA DXP-X10P were used to characterize the detector response to various radioisotope sources.

**Spectral Response**

An $^{55}\text{Fe}$ spectrum, obtained with the Vortex™ SDD detector is shown in Figure 2. An energy resolution of 143 eV FWHM was obtained for the 5.9 keV photopeak, at an amplifier peaking time of 6 $\mu$s.
Figure 2. An $^{55}$Fe spectrum obtained with a 0.5 cm$^2$ Vortex™ SDD at 6 µs peaking time.

**Count Rate Performance**

Energy resolution as a function of amplifier peaking time for both a cryogenically cooled 30 mm$^2$ Si(Li) detector and the Vortex™ detector is shown in Figure 3. The rapid degradation in resolution for the Si(Li) detector at shorter peaking times is due to the larger capacitance of the Si(Li) detector compared with the SDD detector.

Figure 3. Comparison of the energy resolution as a function of amplifier peaking time, for a 30 mm$^2$ Si(Li) and the 0.5 cm$^2$ SDD Vortex™ detector, in response to $^{55}$Fe.

Figures 4 and 5 show Cu spectra from a Vortex™ SDD and the Si(Li) detector, respectively collected at 1 µs peaking time. The resolution advantage of the SDD at the short time constant is clearly apparent.
Using an X-ray tube excitation makes it possible to test the performance of this special detection unit (Vortex™ SDD plus DPP MCA) under very severe count rate conditions. In particular, we were most concerned about the throughput, resolution and peak shift performances. In the test we used a Cu foil sample irradiated with varying X-ray fluxes. Spectra were acquired at different peaking times under various input count rates (ICR) and output count rates (OCR). Table 1 shows the results obtained.

Table 1. Cu Kα Resolution, Peak Shift vs. Throughput

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Note: The peak position and resolution were determined using Gaussian Peak Fitting method. Background correction was applied for resolution calculations.
CONCLUSIONS

The Vortex™ SDD has superior performance characteristics at high count rates and short amplifier shaping times compared with traditional Si(Li) and Ge detectors, and can be operated using only thermoelectric cooling, which enables compact and portable instrumentation. Energy resolutions of 143 eV FWHM at 6 µs peaking time and 250 eV FWHM at 250 ns peaking time (at 5.9 keV) makes the instrument ideal over a wide range of count rates for X-ray spectroscopy applications. The Vortex™ SDD package, as shown in Fig. 1 can be used for both XRD and XRF applications. The Vortex™ SDD can be mounted into the vacuum chamber of a scanning electron microscope or transmission electron microscope for standard chemical analysis or fast X-ray mapping applications [11]. In the very high count rate (> 1 Mcps) regime, with associated good energy resolution (<300 eV FWHM at Cu Kα 8.4 keV), the Vortex™ SDD is also ideal for X-ray diffraction applications.

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