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GAS MICROSTRIP X-RAY DETECTORS FOR APPLICATION IN SYNCHROTRON RADIATION EXPERIMENTS

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Abstract

The Gas Microstrip Detector (GMSD) has counting rate capabilities several orders of magnitude higher than conventional wire proportional counters while providing the same (or better) energy resolution for x-rays. In addition the geometric flexibility provided by the lithographic process combined with the self-supporting properties of the substrate offers many exciting possibilities for x-ray detectors for applications on synchrotron beam lines. Using experience obtained in designing detectors for Particle Physics we have developed a variety of detectors and their associated fast, low-noise front-end electronics for use on SR sources. These include a detector for wide angle x-ray scattering (WAXS) studies which has fan geometry and an x-ray detector which can acquire soft (E_x<4keV) XAFS data at rates of several MHz. These detectors are described and results of tests carried out at Daresbury Laboratory presented.

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1. Introduction

The intense beams of x-rays from Synchrotron Radiation Sources (SRS) require detectors which are capable of very high counting rates. This must be combined with energy resolution for application in studies such as X-ray Absorption Fine Structure (XAFS) and with position sensitivity for small and wide angle scattering experiments (SAXS/WAXS). The Gas Microstrip Detector (GMSD) [1] has been developed over many years at various centres for application in the harsh environment of future collider experiments in Particle Physics (see for example [2]) and meets many of the demands of x-ray counting in SRS beams. Operation has been demonstrated at count rate densities of up to 1MHz/mm^2 of plate [3] with useful counter lifetimes corresponding to months of continuous running at these rates [4]. Careful study of the of the GMSD [5] has shown that its high rate capability is combined with a flexibility of design and operation not normally met with in gas counters which suits it well for counting/imaging applications in the x-ray energy region up to (and beyond) 10keV.

2. A GMSD counter for Emission XAFS

This application called for a detector with energy sensitivity capable of counting the fluorescent x-rays emitted by a sample under irradiation by the SRS beam on station 3.4 at Daresbury Laboratory (DL). A detector was fabricated based on a plate of S8900 glass lithographed with a pattern of 10µm wide anodes interleaved with 90µm wide cathodes on a repeat pitch of 300µm. The strips were bussed in groups of twenty with the cathode and anode connections brought out to pads to which pressure connections could be made. Four groups of twenty strips formed independent, active counting areas of 12mm x 6mm, each instrumented with preamplifier, shaping amplifier (CR-RC time constant selectable), discriminator and counter. Figure 1 shows the plate mounted and ready for insertion in the stainless steel containment vessel. The gap between the plate and the 50µm thick (20mm diameter) beryllium window (13mm) formed the active volume of the detector which was operated with a flowing gas mixture of 50%helium + 50% isobutane supplied by a mass flow gas mixing system. An internal EHT bias chain placed the window at earth potential providing a drift potential of 2100V and an anode-cathode potential of ≈700V. This gave an operating gas gain of just over 1000.

3. Experimental XAFS Data

Laboratory tests showed that the counter had the x-ray energy (E) resolution expected in the region between 1keV and 6keV: measured as $\sigma = 0.187E^{1/2} - 0.061$ keV. On station 3.4 at the SRS XAFS curves were taken across the K edges of silicon, sulphur and phosphorus. The lower curve in figure 2 shows the scan across the K edge of phosphorus in a phosphate sample. The curve represents the sum of the four counting channels and data is acquired at rates up to 5MHz. The deadtime of the counting system was assessed by stopping down the beam and measuring the observed rates at the first and second peaks of the XAFS scan and plotting them against the beam monitor current. Over most of the range, the response curve of each channel fitted well to the simple deadtime formula for counting above a discriminator with a time constant of 0.2µs. (This is equivalent to a 50ns time constant in the four channels summed). Figure 3 shows that the corrected counting rates are linear with the beam monitor current up to (corrected) rates of 6MHz. The highest rate points may represent the breakdown of the simple deadtime model or may be an artefact of the method used to attenuate the beam. The effect of the deadtime correction on the XAFS scan is shown in the upper curve in figure 2.

4. A GMSD counter for WAXS

The geometric flexibility of the GMSD permits a one-dimensionally sensitive WAXS detector to be fabricated in which the long anode strips (50mm) are made to point at the sample while the x-ray-induced electron clouds are drifted a short distance (< 10mm). (See reference [6] for a similar proposal.) Thus can high detection efficiency (≈40%) and high rate capability be combined with good (<1mm) spatial resolution. The prototype detector [7] consists of two S8900 plates with 10μm anodes pointing at the sample at a distance of 200mm from the front of the plate. Each plate subtends an angle of 15^o at the sample and consists of 128 strips ($\delta\theta=0.12^o$). The major gain variation along the strips is controlled to within 20% by grading the cathode strip width and reduced to an RMS value of 2.7% by means of a graded drift electrode [7]. An energy resolution of 15.3% FWHM for incident 5.9keV x-rays results. Each anode is read out by a preamplifier mounted on the detector mother board. Figure 4 shows the detector with the drift electrode removed. For data capture the preamplifier signals are fed into the 200 channel system developed at DL for the Multiwire Linear Detector [8].

5. Experimental WAXS Data

The rate performance of the WAXS detector was characterised using a laboratory x-ray generator used at two anode current settings: 5mA and 60mA. The range of x-ray intensities required was achieved by means of combinations of 12.5μm thick copper foils which were (iteratively) calibrated at low rates (deadtime effects low) using the detector itself. Figure 5 shows the curves of data capture rates versus incident rates for the two modes of the data system: “PR” refers to the enabling of a simple pattern recognition algorithm which takes account of the diffusion spread in the counter, “NoPR” means that each strip of the counter is counted independently. Simple comparison with the simple deadtime model (counting above a threshold) is not possible because of the strong 100Hz modulation of the x-ray beam. This was measured to be ≈20% at 5mA and 100% at 60mA anode current. A montecarlo method was used to average the deadtime response over the current cycle. The results are seen in figure 5 where a deadtime of 0.55μs is fitted for each channel in the “NoPR” case and 0.95μs in the “PR” case. The WAXS detector was installed on station 8.2 at the Daresbury SRS and diffraction data taken on a series of samples. Figure 6 shows the scattering pattern observed on a polyethylene sample. The data in the main peak is accumulated at a total rate of ≈1.3MHz. When corrected for the system deadtime the (main) peak position does not change, the height increases by 20%, the area by 4% and the FWHM decreases by 8%. The experimental set-up for figure 6 did not permit the best spatial resolution of the detector to be realised (this is estimated to be ≈0.6mm [7]).The high rate of data acquisition is adequate for time resolved studies (there are ≈1300 counts in the peak in an exposure of 1ms) and a phase change experiment was performed by heating the polyethylene sample from 20^oC to 100^oC at the rate of 1^oC/minute and cooling down again. Data was acquired for 6 seconds of each minute allowing a complete characterisation of the structure changes. This work was performed in collaboration with Professor A Ryan of Sheffield University.

6. Conclusions

In prototype test it has been demonstrated that the GMSD offers excellent potential as a high rate x-ray energy spectrometer/counter (the XAFS detector) and as a high rate position/angle sensitive detector (the WAXS detector) in experiments on SR beamlines.

References

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Figure 1: A view of the internal structure of the soft x-ray XAFS detector

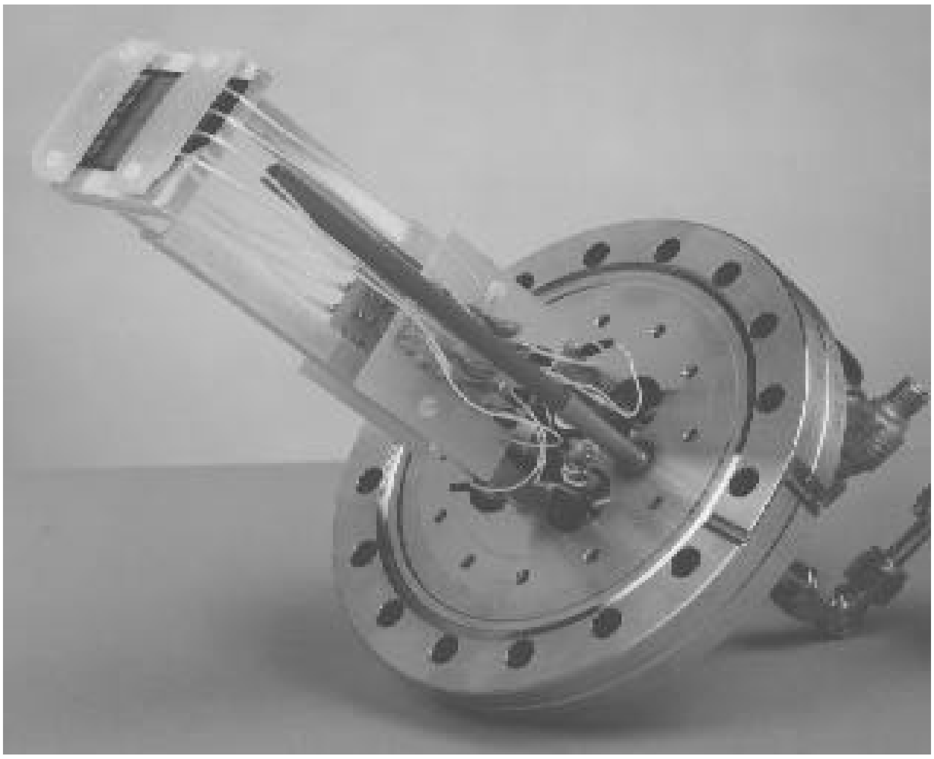

FIGURE 2: Emission XAFS scans with and without deadtime correction

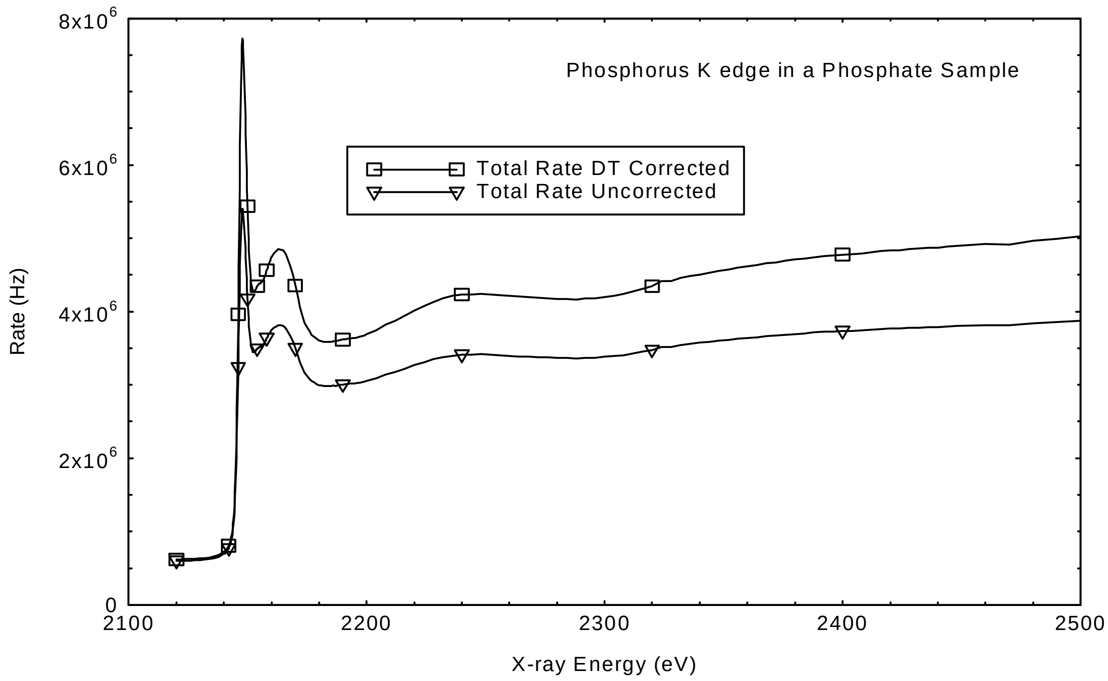

FIGURE 3: Deadtime corrected rates for the first two peaks of Fig.2

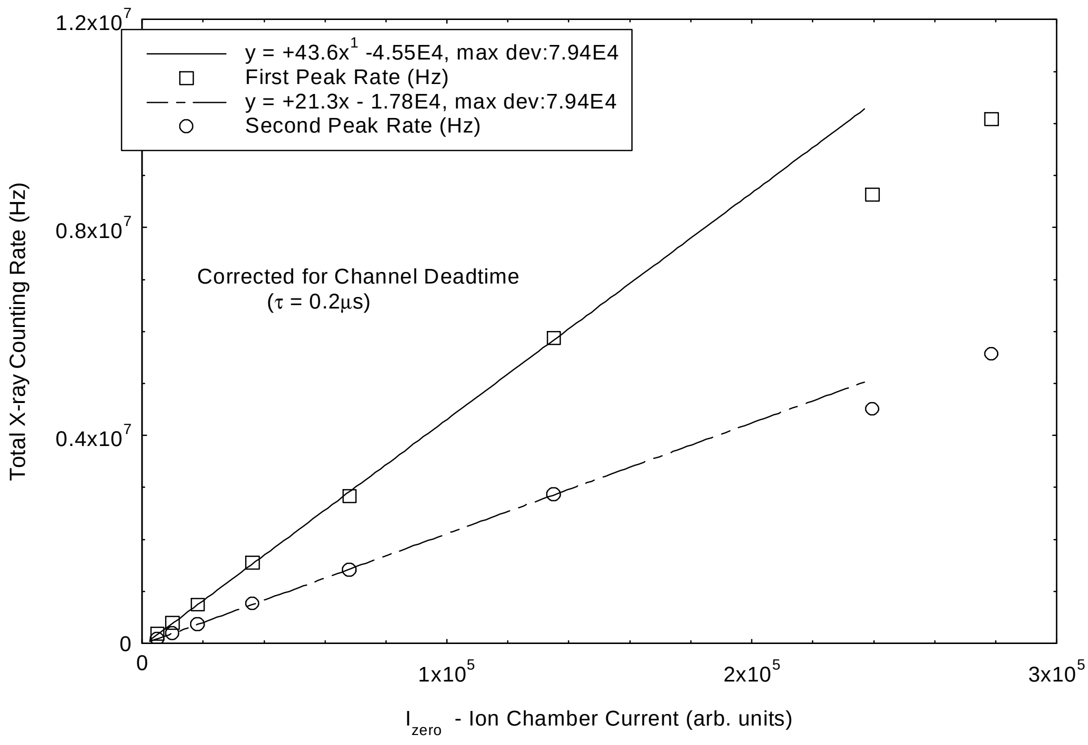

Figure 4: A plan view of the WAXS detector with the drift electrode removed

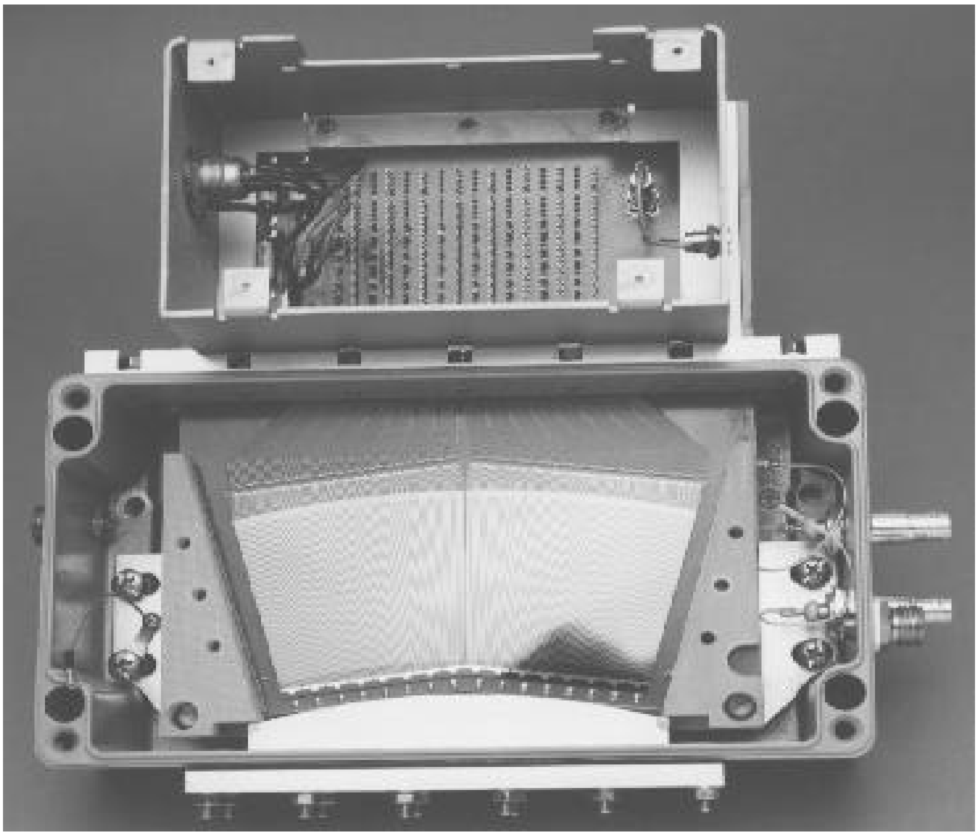

FIGURE 5: Data capture rate versus input rate for the WAXS detector

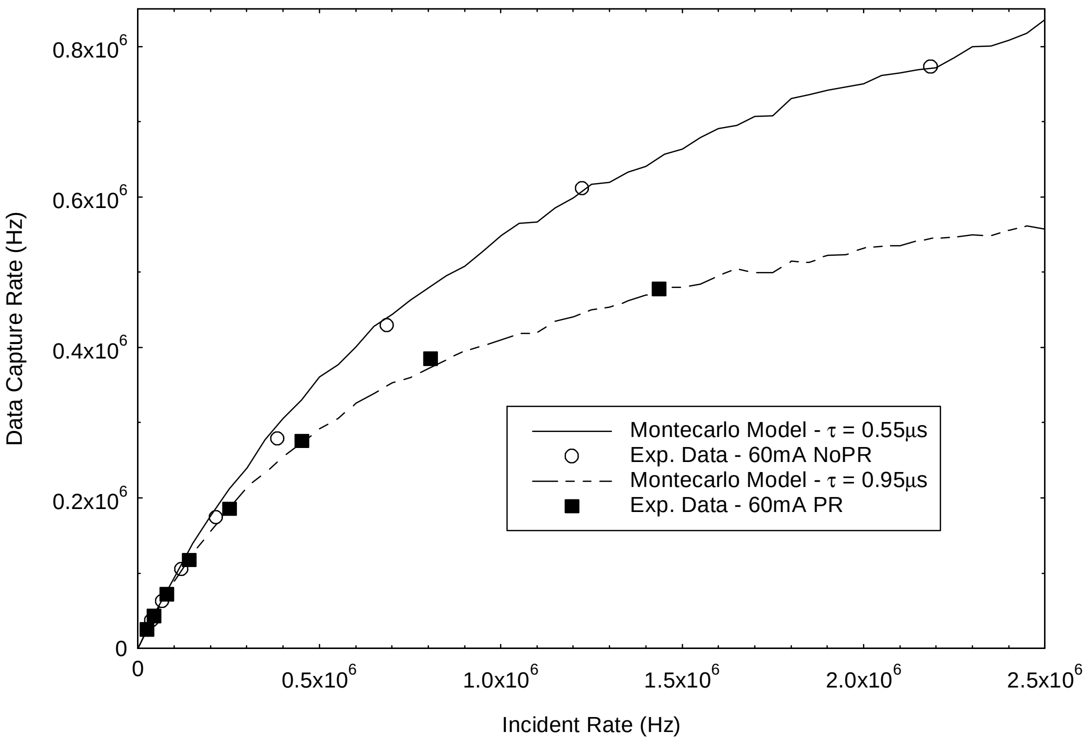

FIGURE 6: Scattering pattern measured from a polyethylene sample by the WAXS detector