Advanced Pulse Processing Techniques for Energy Dispersive X-ray Photon Science

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Abstract:

High throughput energy dispersive X-ray detection systems are used at advanced photon sources to rapidly analyse the structure, composition and function of both organic and inorganic samples. However, in many applications a high flux of incident radiation cannot be avoided, or may be desirable so that analysis can be performed in a reasonable time.

As the time between the arrivals decreases, characterization of all resultant signals becomes difficult. In particular, signal analysis is affected by a phenomenon known as pulse pile-up, whereby multiple detected incident photons arriving more or less simultaneously produce signals which sum together [1]. A failure to differentiate a large amplitude signal caused by a single X-ray photon events from the superposition of multiple photons can have a serious effect on the accuracy of subsequent spectroscopic analysis.

Historically, analogue pulse shaping circuitry (i.e. pulse shaping amplifiers, delay line circuits and discriminators) were used to analyse the output of radiation detectors. However, in modern pulse processing hardware, digital linear filters are used to produce trapezoidal pulse shapes with variable rise times and flat-top times [2]. Using such techniques, it is possible to design a filter that gives the best energy resolution. However, the practical requirement to operate at higher output count rates often precludes using a linear filter with optimal SNR [3]. There has been significant development in the optimal design, implementation and performance of digital pulse processing techniques, however, the approach to dealing with pulse pile-up remains the same. Generally, a fast timing channel is used to identify if a subsequent pulse has arrived within the impulse response time of the digital filter, and if this occurs, the subsequent pulse is excluded from spectrum analysis [3-5]. Although this approach improves the accuracy of the spectrum, the time required to collect sufficient statistics dramatically increases. In many applications as much as 80% of the information can be lost to the effects of dead-time and pulse pile-up [6].

This presentation details the design and application of advanced, real-time, model based detector signal processing algorithms to photon science at 3rd generation Synchrotrons. Particular challenges of implementing these techniques in modern day digital pulse processors are explored, performance results are presented. Some examples of use in Synchrotron science, and alternate applications in mineral processing, will also be presented.

[1] G.F. Knoll, Radiation Detection and Measurement, 3rd edition, Chapter 17, pp. 632–634, 658 and 659, John Wiley and Sons, New York 2000.
[2] A. Pullia, A. Geraci and G. Ripamonti, Quasi-optimum Gamma and X-Ray Spectroscopy Based on Real-Time Digital Techniques, Nucl. Inst. and Meth. A 439 (2000) 378–384.
[3] A. Georgiev and W. Gast, “Digital Pulse Processing in High Resolution, High Throughput Gamma-Ray Spectroscopy”, IEEE Trans. Nulc. Sci., vol. 40, no. 4, pp. 770-779, 1993.
[4] H. Koeman, “Discussion on Optimum Filtering in Nuclear Radiation Spectrometers”, Nucl. Instr. Method, vol 123, 1975, pp 161-167.
[5] G. Bertuccio, et al, “An optimum digital signal processing for radiation spectroscopy”, Nucl. Instr. Method. A, vol 353, 1994, pp 257-260.
[6] W. Skulski et al, “Digital pulse processing: new possibilities in nuclear spectroscopy”, Acta Physica Polonica B, vol. 31, no. 1, pp47- 57, 2000.