The Role of Signal Processing Electronics in X-ray Analytical Measurements

Objective

The following spectral features of a detection system are important for quantitative and economic analyses:

- peak resolution for discrimination of overlapping peaks
- statistical accuracy given by acquisition rate and time
- spectral line shapes for accurate analysis of neighboring peaks
- suppression of "spectral interference features" : pile-up, background, tailing and escape peaks, electronic noise, microphonics
- stability of the system with time and counting rate

In order to determine the effect of pulse processors on the X-ray spectra we compared several Si(Li) detectors and pulse processors and characterized their response.

Methods

The state of the art Si(Li) detector and analog signal processor from the detector manufacturer were selected as a reference for all figures except Figure 1 to compare to the CSX2 Digital X-ray Processor of Cambridge Scientific, Canada.

To compare their performances, the measurements were made in parallel. The preamplifier signal was split and supplied to the two processing units.

Conclusion

Different processors produced different spectra with the same detector. Overall the CSX2 processor provided better spectral performance because of the:

- Absence of spurious peaks and electronic artefacts (Figure 1)
- Reduction of tailing (Figure 1)
- Filtering electronic noise and the effect of mechanical vibrations (2, 3)
- Reduction of pile up intensity and distortion (Figure 4, 7)
- Increased throughput rate without significant reduction in resolution (5)
- Sustained line shape quality even at high input rates (Figure 4)

Note: electronic efficiency of the detection system is important for the following issues:

- distinguishing events from noise at low energies (Figure 6)
- challenges presented by the bucket effect and the ballistic deficit at high energies

Spurious Peaks & Tailing

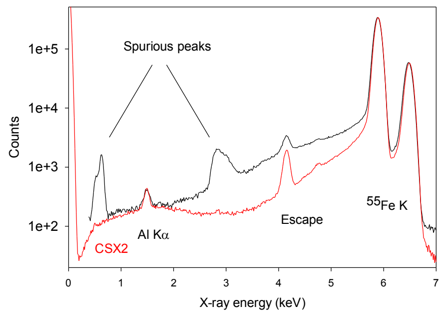

Figure 1: Electronic artifacts are visible in ths ^{55}Fe spectrum taken with a Si(Li) detector and its digital processor (—), while they are absent in the spectrum of the CSX2 processor (—). The CSX2 also greatly reduces the low energy tailing.

Electronic Noise

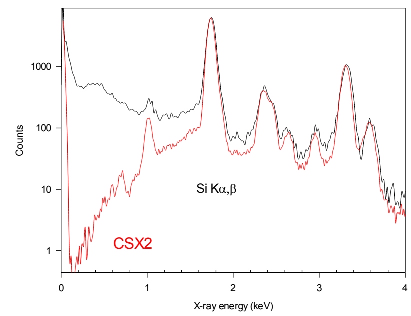

Figure 2: PIXE spectra taken by a Be window Si(Li) detector in "noisy" environment. The analog processor (—) shows significant noise and peak broadening. The CSX2 (—) reduced the electronic noise and shows the expected low energy drop off.

Microphonics

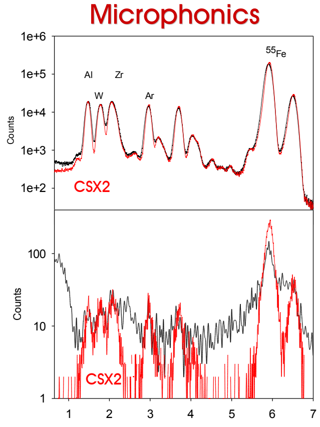

Figure 3a (top): Alloy spectra excited by 55Fe. Analog (—), CSX2 (—).

Figure3b (bottom): Same as 3a with microphonics present.

CSX2 Digital X-ray Processor

Line & Pile Up Shape at 200 kcps

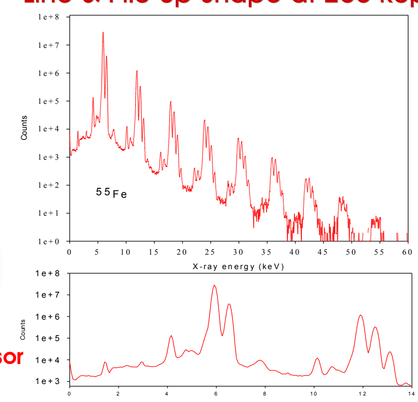

Figure 4: A CSX2 ^{55}Fe spectrum at 200,000 cps input rate. It shows no pile up peak distortion out to eight orders, and no parent peak distortion, as shown by the magnified view.

Performance

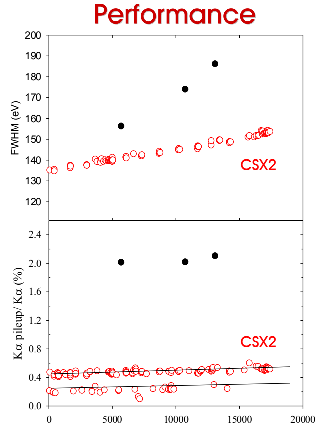

Figure 5: Performance evaluation with ^{55}Fe at 30,000 cps input rate: analog (•) and CSX2 (o). The CSX2 offers higher throughput with smaller resolution penalty and 5-10 times less pile up.

Low Energy Signals

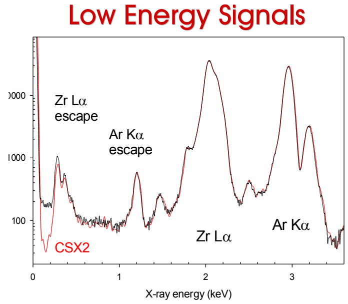

Figure 6: Low energy (at 300 eV) signal recognition.

Pile Up Peak Distortion

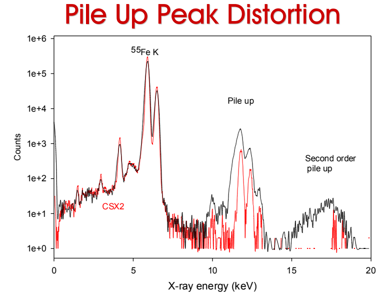

Figure 7: Pile up distortion is shown in these ^{55}Fe spectra taken at an input rate of 30,000 cps using the analog (—) and CSX2 (—). The CSX2 reduced pile up with no distortion.

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