

Use of CsI(Na) in High Count Rate Applications

INTRODUCTION

CsI(Na) offers better energy resolution and higher stopping power than Na(Tl). It is much more tolerant to mechanical and thermal shock, making it a more robust system core to use in rough environments. CsI(Na) emits its scintillation light over a period of a few microseconds, which is too short for most commercial spectrometers. Hence, the CsI output is typically fed into a charge integrating preamplifier with a 50 μ s decay constant. The convolution of the CsI scintillator decay time and the preamplifier decay time creates a poorly defined mix of characteristic times, which renders the traditional pole/zero cancellation and baseline restorer stage of an analog spectrometer useless. Hence, it is commonly assumed that CsI cannot be used in applications with input count rates exceeding 50kcps. In this application note we will show that with a digital spectrometer it is possible to use CsI(Na) at input count rates exceeding 250kcps.

We used a 1 inch long, 1 inch diameter CsI(Na) crystal manufactured by PhotoPeak Inc [1]. It was coupled to a 1 1/8" diameter photomultiplier (PMT) with a bi-alkali photocathode. The PMT output was fed to a current-to-voltage converter, which preserved the speed and shape of the CsI scintillation pulses. Its output in turn was sent to the Polaris, an all-digital spectrometer.

ALGORITHMS

First, we evaluated the performance of the CsI(Na) crystal by acquiring waveforms from the PMT using the Polaris and integrating these numerically over varying periods of time. Figure 1 shows the CsI scintillator light pulse intensity averaged over a 1000 events. Figure 2 shows the energy resolutions obtained as a function of the integration time. For the three curves the energies at which the energy resolutions were measured are 662keV (137-Cs), 1332.5keV (60-Co) and 2614keV (208-Tl).

It can be appreciated from figures 1 and 2 that a non-negligible fraction of the scintillation light is emitted beyond 5 μ s after the gamma absorption. At input count rates exceeding 100kcps the scintillation pulses will pile up considerably. A digital spectrometer can process such pileups if it is given a model of the scintillator light output function.

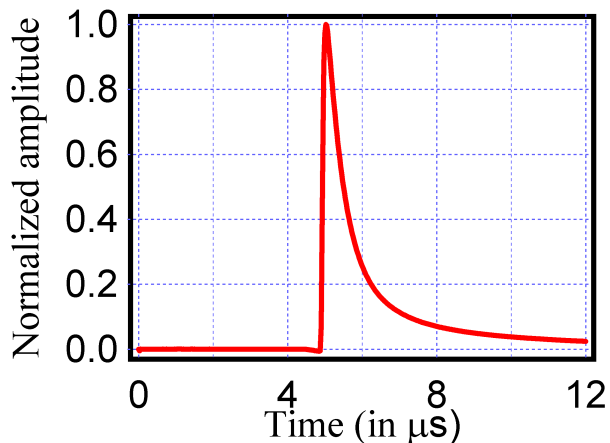


Figure 1: CsI(Na) scintillator light output, averaged over 1000 events.

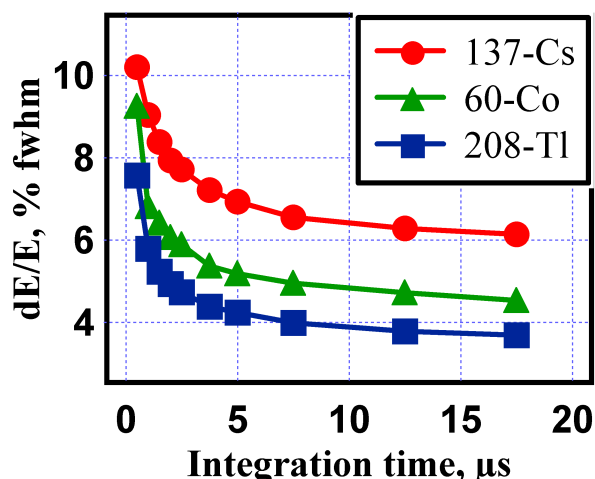


Figure 2: CsI(Na) energy resolution as a function of integration time for 137-Cs, 60-Co and 208-Tl sources.

From the average of 1000 waveforms, shown in figure 1, we created a doubly exponential model of the CsI(Na) light output. We found that the scintillation light was best described by a short component with a 550ns decay time and a long component with a 4 μ s decay time. Taking these two components into account, we reprogrammed the Polaris to use a special digital filter characterized by a filter peaking time, to which we refer in figures 3,4,5.

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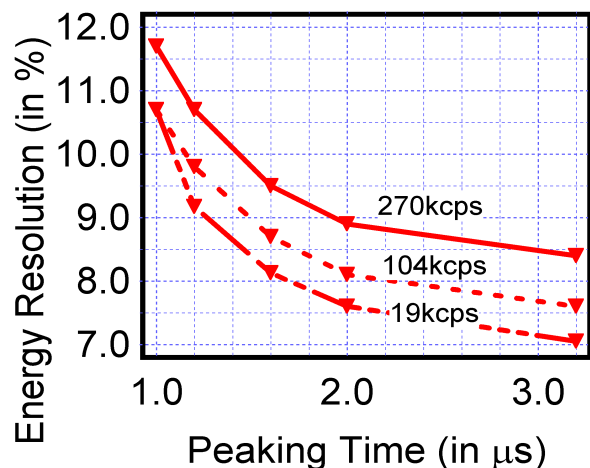


Figure 3: Energy resolution versus peaking time at different input count rates -- 137-Cs Source.

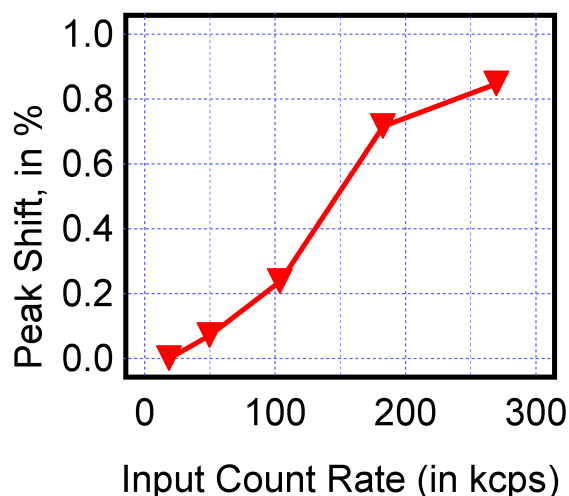


Figure 4: Peak Position shift with count rate -- Measurements made at 3.2μs peaking time.

RESULTS

The algorithm was tested at different input count rates, ranging from 19 kcps to 270 kcps using a 1mCi 137Cs source (fig. 4). The energy peak shifts by less than 1% over the entire range, which reflects good system linearity (fig. 4).

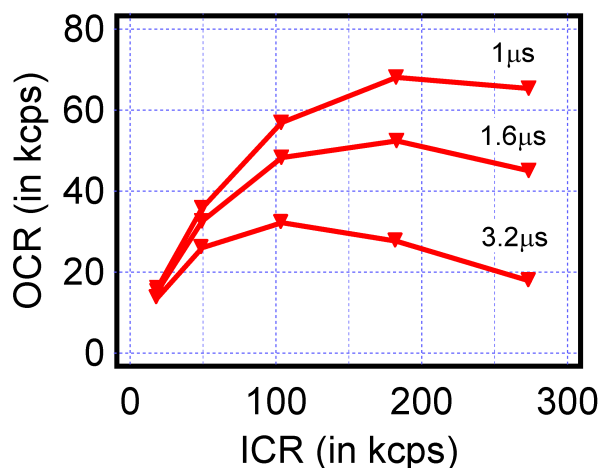


Figure 5: Output Count Rate (OCR) versus Input Count Rate (ICR) at various peaking times.

The energy resolution deteriorates only gradually as the input count rate is increased to 270kcps. The main reason for the loss in resolution are undetected pileups of the between large and small energy gammas. In this case, the 33keV Ba K-alpha X-rays presented the biggest problem.

The throughput rate is determined by the dead time given by the length of the digital energy filter, which is $S_g+S_0+S_1$. The resulting output count rate (OCR) vs. input count rate (ICR) characteristic is shown in figure 5.

CONCLUSIONS

We have shown that the Polaris spectrometer can be used to operate CsI(Na) at input count rates of 270kcps with good linearity and energy resolution.

The digital algorithm reconstructs the energy taking into account the presence of a fast and a slow component in the scintillation light, making it customizable for other types of doubly decaying scintillators as well. It also demonstrates the Polaris flexibility to deal with non-common pulse shapes. Instead of changing the hardware, we enhance the software.

References:

[1] PhotoPeak, Inc., Chagrin Falls, OH, phone 440-543-1197, www.photopeak.com

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