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Technique for Recovering Pile-up Events from Microcalorimeter Data

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We report here a novel technique for processing microcalorimeter data that offers improved live-time over conventional optimal filtering techniques without loss of resolution. Conventional optimal filtering techniques [1] require pulses produced by individual photons in a single pixel to be separated by the time-domain length of an optimized Wiener filter (typically many times the thermal time constant of the detectors in order to achieve the desired spectral resolution for the filter). Consequently, pile-up events (the condition where two or more photons are detected within a filter length) are unrecoverable and may reduce detector live-time by a significant fraction, depending on the photon detection rate. Moreover, attempts to reduce the frequency of these pile-up events by shortening the filter length result in a degradation of resolution, since shorter filters are less effective at removing noise. In response to this problem, we have developed a technique that can process much more closely spaced pulses with a full-length filter. Separate filters optimized for pulse amplitude and pulse arrival time are constructed from the averaged signal and noise spectral densities, with the usual assumption that the noise is stationary during the pulse. These filters are applied to the entire pixel data stream. For an isolated pulse, the zero crossing of the arrival time filter output gives the best estimate of the arrival time, and the amplitude filter output at this time gives the best estimate of the pulse amplitude; there is no additional information in any of the other points. There is a substantial amount of ringing at times up to the filter length away from the pulse, but this is entirely deterministic given the amplitude and arrival time. This allows us to treat pile-up events as the sum of isolated pulses. That is, for a pile-up event containing N overlapped pulses, we just need to solve for the set of N arrival times and N amplitudes that give exactly the 2N observed filter outputs at these arrival times. Preliminary results of the application of this technique to data from the most recent sounding rocket flight of the X-ray Quantum Calorimeter will be presented.

1. A. E. Szymkowiak, R. L. Kelley, S. H. Moseley, and C. K. Stahle. "Signal processing for microcalorimeters." J. Low Temp. Phys. 93. pp. 281-285, 1993.