Pulse pile-up does not have to ruin everything: using microcalorimeters at high count rate

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Microcalorimeters can measure x-ray and gamma-ray photon energies with very high energy resolution and high collection efficiency. Spectrometers made from microcalorimeter arrays have numerous potential applications, including the measurement of chemical and electronic properties of materials at synchrotron light sources; nuclear materials analysis; neutrino mass estimation in beta-decay endpoint measurements; studies of exotic atoms containing pions and kaons; and x-ray astronomy. To reach the full potential of microcalorimeters for most applications, each sensor must be capable of measuring hundreds or even thousands of photon energies per second.

Current "optimal filtering" approaches to achieving the best possible energy resolution, however, work only for photons well isolated in time. This requirement conflicts directly with the need for high photon rates. We describe a new analysis procedure to permit fitting for the pulse height of all photons, even in the presence of heavy pulse pile-up. In the limit of isolated pulses, the technique reduces to the standard optimal filtering with long records. We employ reasonable approximations to the noise covariance function in order to render multi-pulse fitting computationally viable even for very long data records. The technique is employed to analyze x-ray emission spectra at 600 eV and 6 keV at rates up to 270 counts per second in microcalorimeters having exponential signal decay times of approximately 1.2 ms. Very high

count rates are achieved with only a modest loss of resolution (the resolution increases by only 40% for 270 counts per second).

Head-to-head comparison with conventional optimal filtering, even with a range of record lengths, shows that the multi-pulse fitting technique performs significantly better. The general concept—a fit to a linear model with approximate accounting for the autocorrelation of the noise—is very flexible. We describe extensions to the idea that should better accommodate the nonlinear nature of microcalorimeter signals and that permit information learned about slowly varying quantities (such as near-DC offsets) to be propagated from one fit to the next. Approaches like this one will be required for future microcalorimeter arrays to make the most of their enormous potential.