A pulse height analysis technique for cryogenic bolometers

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Introduction

Cryogenic bolometer is widely used for rare event searches like neutrinoless double beta decay (NDBD) or dark matter searches mainly due to its unprecedented energy resolution and scalability. In India, Tin based cryogenic bolometer is being developed to study NDBD in ^{124}Sn [1]. Unlike other particle detectors eg. Scintillator detector, HPGe detector etc., the response time of a bolometric detector is comparatively slow. The rise time of a large mass (∼100 g) bolometer is ∼10 ms and decay time ∼ 0.1 s − 1 s. A pulse analysis program is needed to extract the best possible energy resolution of the detector. In this paper, an off-line pulse shape analysis technique developed for cryogenic bolometer is discussed.

Experimental Setup

Low temperature measurements were carried out in a custom designed high cooling power Cryogen Free Dilution Refrigerator (CFDR) [2], kept inside a Faraday cage. A sapphire bolometer (20 mm × 20 mm × 0.4 mm) consisting of two indigenously made NTD Ge thermistors [3] (3 mm × 6 mm × 1 mm) and a heater mounted using a thin layer of fast setting Araldite, is weakly coupled to the CFDR mixing chamber stage. A schematic of the readout electronics is shown in Fig. 1. The data acquisition system consists of a Multi-function I/O Module NI PXI-6281 housed on a high performance, high bandwidth chassis NI PXIe 1082. The PXI-6281 has two single ended 16 bit DAC output channels and 8 differential 18 bit ADC input channels. The chassis is interfaced with the PC via a high-speed optical fiber. The NTD Ge sensor was optimally biased with a DC voltage of 400 mV from one of the DAC output. The other DAC output is used to power the heater in pulsed mode (200 μs wide square wave pulse @ 2 Hz). Both positive and negative heater pulses were used to avoid any error due to zero offset. The sensor output voltage is amplified with a gain of 60 dB using a commercially available differential voltage amplifier from FEMTO and the amplifier output is recorded using an ADC input channel with a sampling rate of 50 kS/s.

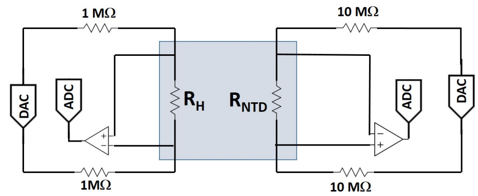

FIG. 1: The electronics readout.

Pulse shape analysis

A ROOT based C++ program is developed for off-line pulse shape analysis of the bolometer signal. The program consists of two parts. In the first part, smoothened signal (S0), first derivative (S1) and second derivative (S2) of the digitally sampled raw pulse (S) are derived by applying Savitzky-Golay technique [4] as illustrated in Fig. 2. In the second part, when S1 crosses a certain preset threshold, various

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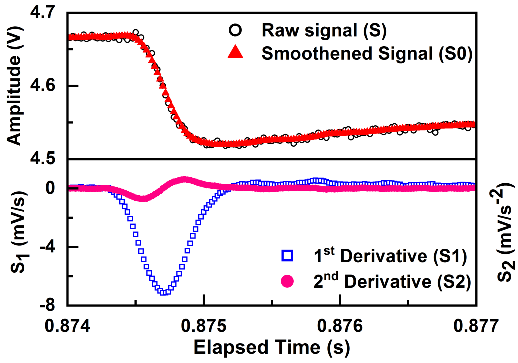

FIG. 2: An example of the pulse processing.

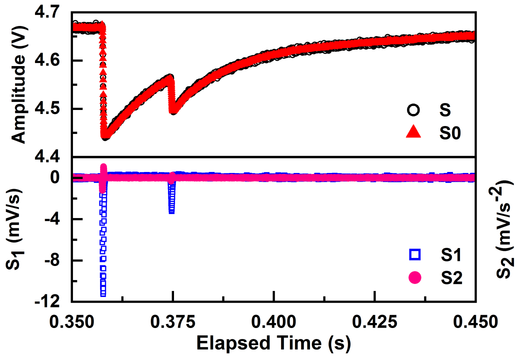

FIG. 3: An example of the pileup rejection.

pulse shape parameters as listed in Table 1, are extracted. The time t_0 defines the arrival time of the pulse and t_r is a major of the rise time, t_p and t_d are the peaking time and decay time of the pulse, respectively. These are used

TABLE I: Different pulse shape parameters

Parameter	Definition
t_0	Time when S1 crosses the threshold
t_1	Time when S1 is maximum & S2≥0
t_2	Time when S0 is maximum & S1≥0
t_3	S0 decays 63 % from the maximum
t_r	t_1-t_0
t_p	t_2 - t_0
t_d	t_3-t_2
ΔS1	Value of S1 at time t = t_1

to filter out spurious pulses. Since the pulse height (ΔS1) is extracted from the derivative of the signal, it is unaffected by any slow baseline variations. Further, the pileup pulses are well separated in S1 yielding efficient pileup rejection (see Fig. 3).

Results and Discussions

An example of energy spectra for thermal pulses with equivalent energy of 0.3 - 5 MeV at 20 mK base temperature is shown in Fig. 4. The energy resolution (σ) obtained is 22 keV at 5 MeV and is found to be independent of the energy as expected. However, the observed value is higher than that expected from thermodynamic fluctuation.

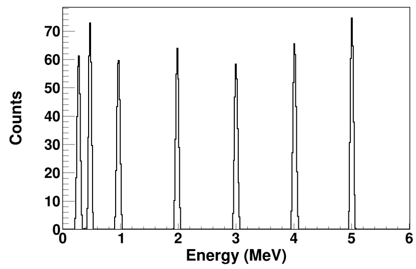

FIG. 4: The energy spectrum for thermal pulses

The algorithm can be extended to generate pulse height histogram from the area under S1 curve. This will take into account the variation in the rise time. The technique can be applied to pulses generated due to radiation like α- particles, muons etc. Some of these results and possible improvements will be presented.

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