Bolometer pulse analysis using optimal filter

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Introduction

Cryogenic bolometers are extensively used in neutrinoless double beta decay (NDBD) search or dark matter search owing to its excellent energy resolution and easy upscalability. An experiment to study NDBD in ^{124}Sn [1] has been initiated in India. The India based Tin detector (*TIN.TIN*), an array of cryogenic bolometer employed with NTD Ge sensors will be used for this purpose. NTD Ge sensors have been developed indigenously by irradiating Ge wafers at Dhruva reactor BARC,Mumbai [2]. Using this sensor a cryogenic bolometer made with sapphire absorber is being tested to study systematic effects on a cryogenic bolometer.

Pulse analysis of the bolometer signal plays an important role in determining the best resolution achievable from a bolometer detector. Optimal filtering technique is commonly used for analyzing bolometer pulses. A pulse analysis program is developed to analyze the test sapphire bolometer pulse and the results are presented.

Bolometer Setup

A sapphire test bolometer is used for the present study. It consists of a 0.4 mm thick sapphire plate of area 20 mm × 20 mm, which acts as the absorber. Two NTD Ge sensors and a heater element are strongly coupled to the sapphire bolometer with the help of a thin layer of low temperature araldite. The heater element is developed by evaporating a 200 nm thick Au meander on a Si substrate. The sapphire plate is connected to the gold plated Cu heat bath using tiny dots of araldite (Dia. $\sim$ 1 mm, Thickness $\sim$ 0.1mm), which provide a weak thermal link. The readout and the DAQ system is described in Ref. [3] and the same data is used in this paper for optimal filter based analysis.

Analysis framework

A C++ and ROOT based program is formulated to implement the optimal filtering technique [4]. At first 100 identical pulses of energy 2 MeV, stable baseline and pileup free pulses are sorted out. Each of these pulses are then divided into two parts having same number of samples, one for the baseline (N) and the other for the pulse (C). An average FFT spectrum is calculated for both C and N using FFTW library in ROOT as C(f) and N(f). Now, N(f) is subtracted from C(f), which essentially removes all the frequency component present in the baseline data from the pulse and results in a nearly ideal signal template S(f). An example of FFT for C, N and S is shown in Fig. 1. The signal bandwidth is only about 2 kHz. Hence while calculating S, all the frequency component above 2 kHz is set to zero. The FFT of a pulse of unknown energy which needs to be filtered is weighted with W(f) and the time domain signal is retrieved with a inverse FFT calculation, where the W (f) is calculated using the Eqn. 1, which enhances signal but suppresses the noise resulting in a better signal to noise ratio.

$$W = \frac{|S(f)|^2}{|C(f)|^2} \qquad (1)$$

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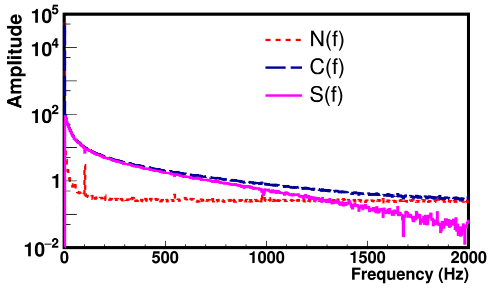

FIG. 1: FFT spectrum for N, C and S

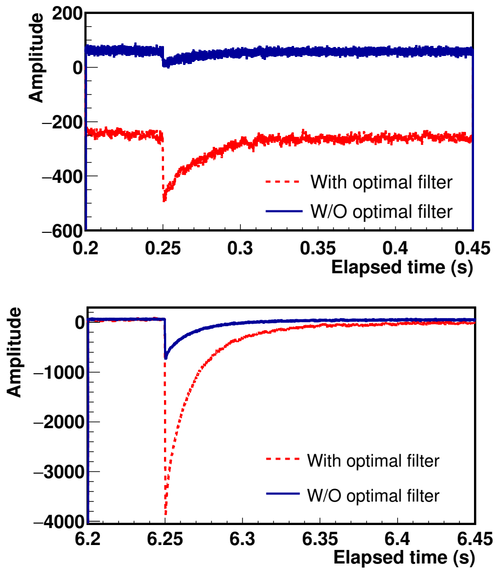

FIG. 2: An example of raw pulse and optimally filter red pulse for 300 keV (*top*) and 5 MeV (*bottom*) pulse.

An example of the raw pulse and the optimally filtered output pulse are shown in Fig. 2 for comparison. It is evident that the SNR is improved by a factor of ∼5 in the filtered pulse.

Results and Discussions

The pulse height vs energy is calibrated using a second order polynomial. The calibrated energy histogram is shown in Fig. 3. The energy resolution (σ) obtained at 2 MeV is 15±1 keV. It is found that if the opti-

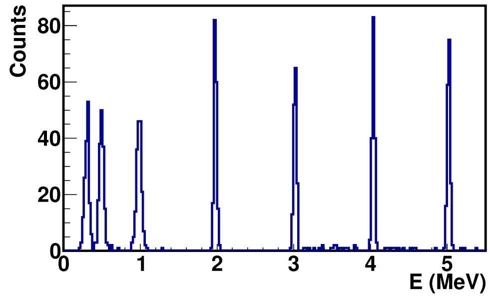

FIG. 3: Energy histogram of the optimally filtered pulses

mally filtered pulses are further processed using Savitzky-Golay filter based analysis technique as described in Ref. [3], the σ improves to 13±1 keV implying an improvement of ∼15%.

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