16th International Workshop on Low Temperature Detectors
20–24 July 2015

Optimization of metallic magnetic calorimeters with embedded Ho-163

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The analysis of the calorimetrically measured electron capture spectrum of Ho-163 offers an attractive possibility to investigate the value of the electron neutrino mass in the sub-eV range. The ECHo collaboration plans to reach this sensitivity by using large arrays of metallic magnetic calorimeters (MMCs) read out using microwave SQUID multiplexing. The embedding of the source in each detector will be done using ion-implantation.

With a first prototype of MMC having the Ho-163 source implanted in the absorber, we performed the first high energy resolution measurement of the electron capture spectrum. At an operating temperature of 25 mK, the achieved energy resolution was ΔE_{FWHM} = 7.6 eV, defined by the fit of the k-alpha line of Mn-55 at E = 5.9 keV from an external Fe-55 source, and the signal rise-time was τ = 130 ns.

The best energy resolution achieved by MMCs developed for soft x-rays spectroscopy is presently ΔE_{FWHM} = 1.6 eV at 5.9 keV and the typical risetime, limited by electron spin interaction, is below 90 ns at 20 mK. Our goal is to reach this performance on single pixels with implanted Ho-163 and then demonstrate that they hold also in multiplexed detector arrays. Our approach in ECHo is to constantly investigate methods to improve the energy resolution to reduce the smearing of the data at the endpoint region of the spectrum and speed up the signal rise to reduce the background due to unresolved pileup events.

The optimal activity per pixel will be defined considering the limits coming from the allowed unresolved pileup fraction and the requirement that the additional heat capacity due to the magnetic moment of Ho ions is negligible with respect to the total detector heat capacity.

We discuss the design and fabrication of optimized detectors to be used in the first stage of the ECHo experiment, ECHo-1k, which will be able to reach a sensitivity on the electron neutrino mass below 10 eV/c2 with one year measuring time. In ECHo-1k a total activity of the order of 1000 Bq will be ion implanted in about 100 detectors. These detectors will be divided into arrays fabricated on silicon substrate together with an integrated on-chip microwave SQUID multiplexer.

We present preliminary results obtained with standard MMCs developed for soft x-ray spectroscopy, maXs-20, where the Ho-163 ion-implantation was performed using a high purity Ho-163 source produced by advanced chemical and mass separation. With these measurements we aim at determining an upper limit for the background level due to source contamination and provide a refined description of the calorimetrically measured spectrum.

We outline how the present production of MMC arrays, including the micro-fabrication steps and the ion-implantation processes, can be upgraded for the development of a large scale experiment where an activity of the order of 1MBq will be embedded in more than 10000 detectors.