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Constructive and Technological Aspects of the Development of Cryostats for HPGe Detectors with Electric Cooling

O.Yakovlev (1,2), V.Malgin (1), V.Gostilo (1), Y.Viba (2)
(1) Baltic Scientific Instruments, Riga, Latvia (o.jakovlev@bsi.lv / Fax: +371 67382620), (2) Riga Technical University

Abstract

The use of miniature Stirling electric coolers (EC) has made possible the application of high purity germanium (HPGe) detectors in spectrometers intended for space projects, field operations and mobile radiation monitoring systems for remote radiation monitoring, among other applications. The development of spectrometer systems requires mechanical, thermal and vacuum solutions to be applied during the design and manufacturing phases of the cryostats for HPGe detectors. These solutions determine the efficiency of the detector cooling, the time taken to cool down the detector, the level of mechanical vibrations, which impact the energy resolution of the detector, especially at low gamma-ray energies, the reliability and its operational life.

1. Introduction

Due to their excellent energy resolution and high efficiency for detecting gamma radiation, HPGe detectors stand out among all types of radiation detectors as ideal candidates for applications in precision gamma spectroscopy [1]. However, HPGe detectors must be cooled down to temperatures between 80K and 100K, which has limited their use in space projects. The development of compact electric coolers (EC) has opened up opportunities for the development of a wide range of nuclear physics devices based on HPGe detectors, including space applications [2,3]. However, the Stirling ECs create additional mechanical vibrations, which negatively impact the detector's characteristics. The present paper deals with constructive and technological aspects in the development of cryostats for HPGe detectors with Stirling ECs.

2. Mechanical Design

HPGe detectors are operated in cryostats, which must remove heat from the detector promptly and effectively, so that it can operate at its optimal temperature. Furthermore, the cryostats should permit continuous operation and multiple thermal cycles. A simplified design of a cryostat is shown in Fig. 1. The radiation reaches the HPGe detector through the input window, which can be made of aluminum (500 μm), carbon (700 μm), or beryllium (200 μm). The detector is placed in a custom-designed holder that fixes the detector by means of supporting rings made from composite materials with low thermal conductivity, while removing heat through a cold finger with elastic inserts. A modal analysis of the spatial oscillations in the detector unit was made using the SolidWorks simulation framework. The parameters of the elastic supporting rings, which remove the resonance oscillations of the detector caused by the EC operation frequency harmonics were defined in this model.

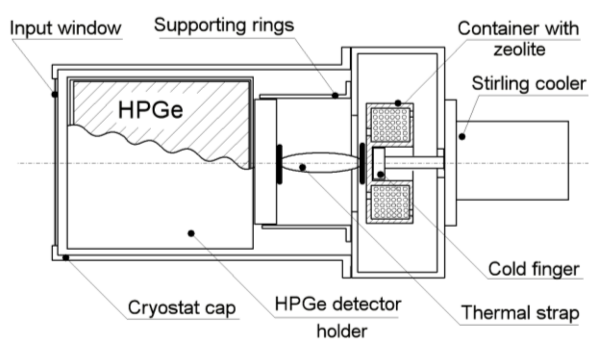

Fig.1. Simplified design of HPGe detector cryostat

3. Thermal Solutions

To increase the EC lifetime, special attention during the cryostat design process was given to the manner of achieving the most effective heat removal from the electric cooler case. Additional heat removal was provided for the surfaces in the EC case that are most prone to heating during operation. To reduce the contact resistance of heat removing connections, special thermo compounds were used, such as, for example, MUNG I (INTIVAC Corp.), which has a thermal conductance of up to 18.2 W/(m·K). Using this compound, the maximum temperature of the EC parts does not exceed 32^{o}C, even when the EC is operating at maximum power during the initial detector cool-down phase. When operating at pressures below 10^{-4} mbar, infrared radiation becomes the dominant heat transfer process, and to reduce this radiative heat transfer, heat screens were used in the cryostats. Through the application of multilayer insulation material (Coolcat2 NW), typical heat losses have been reduced to 0.2 W for chamber volumes up to 0.85 dm^3 at a detector operating temperature of 90K.

4. Vacuum Solutions

The Viton elastomer seals were replaced by Conflat CF gaskets or Wills rings to reduce the leakage rate of external gases into the cryostat. Hermetic electrical connectors were welded into the cryostat case.

Getters are placed in the cryostat (see Fig.1) to maintain a sufficiently high vacuum by absorbing remaining gases. The sorption properties of various types of getters were studied. The best results were obtained with nonvolatile SAES getters, which allow multiple regeneration cycles, and also with disposable baric getters.

To reduce the release of gas from the crystalline lattice of the metal components of the cryostat, the optimal annealing mode and technological preparation were defined for the cryostats with HPGe detectors.

5. Summary and Conclusions

In the development of gamma spectrometer cryostats, the main design effort was focused on reducing heat losses and optimizing the parameters of the detector pendant. The improved thermal design has favorably affected the lifetime of the electric cooler and decreased the typical energy consumption of the spectrometer. The success of the experiments presented here will be defined by the reliability and durability of HPGe detectors, especially in long-term space missions (Fig. 2).

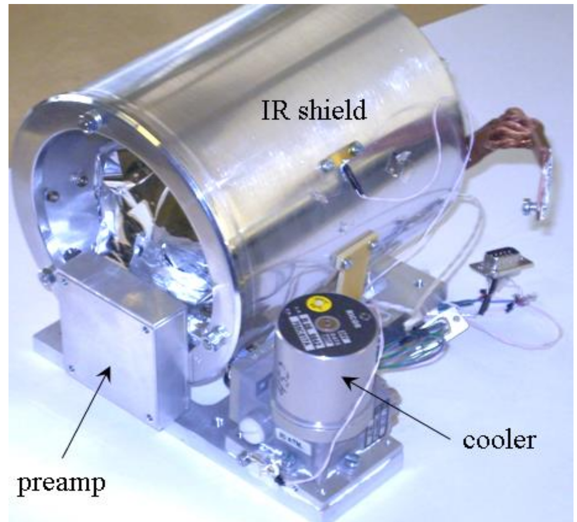

Fig.2. Miniature HPGe Gamma-Spectrometer for space applications with rotary cooler Ricor K508 [3]

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