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Special high-purity germanium photodiodes have been developed for the direct detection of vacuum ultraviolet scintillations in liquid helium. The photodiodes are immersed in the liquid helium, and scintillations are detected through one of the bare sides of the photodiodes. Test results with scintillation photons produced by $5.3\text{MeV} \alpha$ particles are presented. The use of these photodiodes as liquid helium scintillation detectors may offer substantial improvements over the alternate detection method requiring the use of wavelength shifters and photomultiplier tubes.

Introduction

Liquid helium scintillation counters are widely used in neutron polarimeters, and they have also found applications in various other physics experiments. However, detection of the helium scintillation light is difficult because it lies in the vacuum ultraviolet (VUV) with wavelengths in the range of 600-1000Å, a region where there are no suitable window materials with good transmission. The traditional detection method is to apply wavelength shifters on the inside wall of the liquid helium container to convert the VUV scintillations into visible light. This is then collected and transmitted through a window or light pipe to a photomultiplier tube. This method is also widely used with other gaseous and condensed noble gas scintillators which also emit in the VUV. Some of the major disadvantages of this method are: 

- Losses in the wavelength conversion and light collection processes and the low photocathode quantum efficiency of the photomultiplier often result in a large reduction in the number of photoelectrons emitted from the photocathode compared to the number of scintillation photons. This, in turn, gives rise to an increase in statistical fluctuations in the output signals, i.e., a decrease in resolution.
- Construction of the liquid helium dewar is often complicated by the need for close optical coupling and good thermal isolation between the scintillation volume and the photomultiplier tube.
- There are additional problems associated with photomultiplier tubes, e.g., instability, sensitivity to magnetic field and bulkiness.

Many of these problems can be alleviated by using a semiconductor photodiode as the scintillation detector. We have recently demonstrated the feasibility of using a high-purity germanium photodiode for the detection of liquid helium scintillations. The photodiode was immersed in the liquid helium to detect the VUV scintillations directly without using any wavelength shifters.

Germanium Photodiodes

Fabrication and operation of our germanium photodiodes is similar to that of high-purity germanium nuclear radiation detectors which are commonly used in gamma-ray and charged-particle spectroscopy. The scintillation light enters the photodiode through one of its bare sides (i.e., parallel to the diode junction). The use of high-purity germanium enables a thick depletion layer which translates into a large sensitive area.
The energy resolution presently obtained for 5.3 MeV α particles is limited by the electronic noise of the experimental set-up. This, together with the fact that the photodiodes saw only a small fraction of the scintillation photons, suggests that a substantial improvement in resolution can be expected by covering a larger solid angle with photodiodes to gain a larger signal, and by further optimization of the electronics. Coverage of a large solid angle is also required to obtain a uniform response for events occurring at different parts of the counter. On the other hand, spatial information of events may be obtained by weighing signals from each (or groups of) photodiode(s).

Other possible applications of these photodiodes include liquid 3He scintillation counters which can be used as neutron spectrometers, and liquid Ne or Ar scintillation counters which are useful as high energy charged-particle detectors.

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