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A study of the operation of especially designed photosensitive gaseous detectors at cryogenic temperatures

L. Periale[a], V. Peskov[a,b,*], C. Iacobaeus[c], B. Lund-Jensen[d], P. Pavlopoulos[b], P. Picchi[a], F. Pietropaolo[a]

[a]*CERN, Geneva CH 1211, Switzerland*
[b]*Pole University Leonard de Vinci, Paris, La Defense Cedex 92916, France*
[c]*Karolinska Institute, Stockholm S 17176, Sweden*
[d]*Royal Institute of Technology, Stockholm S 10691, Sweden*

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Abstract

In some experiments and applications there is need for large-area photosensitive detectors to operate at cryogenic temperatures. Nowadays, vacuum PMs are usually used for this purpose. We have developed special designs of planar photosensitive gaseous detectors able to operate at cryogenic temperatures. Such detectors are much cheaper than PMs and are almost insensitive to magnetic fields. Results of systematic measurements of their quantum efficiencies, the maximum achievable gains and long-term stabilities will be presented.

The successful operation of these detectors open realistic possibilities in replacing PMs by photosensitive gaseous detectors in some applications dealing with cryogenic liquids; for example in experiments using noble liquid TPCs or noble liquid scintillating calorimeters.

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1. Introduction

Noble liquids such as LAr, LKr and LXe are unique detecting medias: (1) their stopping power is high enough for many applications, (2) they are excellent scintillators, emitting in the VUV region of spectra, (3) primary electrons created inside the liquid could easily be drifted and collected on an electrode structure providing one with a charge signal, (4) if necessary, primary electrons could even be extracted from the liquids to the gas phase (vapours above the liquid layer) and collected on electrodes placed there. These properties make them attractive for several applications, for example noble liquids scintillating calorimeters [1], cryogenic TPCs [2], cryogenic PETs [3]. Nowadays, expensive PMs are used for the detection of the scintillation light in these devices [4]. There have also been some attempts to use solid-state detectors [5].

We have recently demonstrated that costly PMs and solid-state devices could be replaced by gaseous photosensitive detectors: detectors with a window (which could be immersed inside the noble liquids) or windowless, able to operate in pure noble gases or vapors above the noble liquids [6]. The advantages of these detectors are: a large sensitive area, the possibility to choosing construction materials with low radioactivity levels and the practical insensitivity to the magnetic fields. Due to these properties gaseous detectors are now considered as an option for XENON [7] and ZEPLIN [8] WIMPs detectors and cryogenic PETs [9].

The aim of this paper is to develop prototypes of photosensitive gaseous detectors oriented on real experiments and perform the systematic studies of these devices.

*Corresponding author. Tel.: +41 227674643; fax: +41 227679480.
E-mail address: Vladimir.Peskov@cern.ch (V. Peskov).

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2. Detector's designs and experimental set up

Two types of planar photosensitive detectors were constructed and tested in the frame of this work: the wire-type and the hole-type detectors. The schematic drawing of one of our wire detector (WD) mostly used in this work is shows in Fig. 1 (the description of other wire-type detectors can found in Ref. [6]). Its cathode was made from two parts: a stainless steal (ss) semi cylinder having a diameter of 2, 5 cm and a length of 5 cm was combined with a metalized MgF_2 window. Inside this structure a golden-coated tungsten anode wire was installed. The diameters of the anode wires tested were of 50 and 25 μm. The inner part of the ss semi cylinder was coated by a CsI layer 0.4 mm thick. The distance between the semi cylinder and the MgF_2 window was 1 mm. The cathode parts were grounded; the high voltage was applied to the anode wire. This entire structure was placed inside a compact planar gas chamber (with a diameter of 10 cm) and filled either with $Ar+10\%CH_4$ or $He+10\%H_2$ at a total pressure $p = 1$ atm.

The hole-types detectors used in most these studies were either capillary plates (CPs) obtained from Hamamatsu or "home made CPs" (HMCPs) manufactured by us [10]. The Hamamatsu CPs had a thickness of 0.8 mm and a diameter of 20 mm, whilst the diameter of the capillaries was 100 μm. Most of the measurements in this work were done with double CPs operating in cascade mode (see Fig. 2). The distance between the CPs (we named them "top" and bottom") was 2 mm. The cathode of the top CP was coated with a CsI layer 0.25 μm in thickness. The anode of the bottom CP was in direct contact with the readout plate.

In some particular measurements, for example under conditions with a high risk of sparking, (HMCPs) were used. They were made of G-10, had thickness of 1 mm, a diameter of 20 mm whilst the diameters of the holes were of 0.3 mm. The advantages of these detectors are the very low price and the possibility of achieving gains higher than with CPs. We also used these detectors in a cascaded mode. The cathode of the top HMCP was coated by a CsI layer 0.4 μm in thickness.

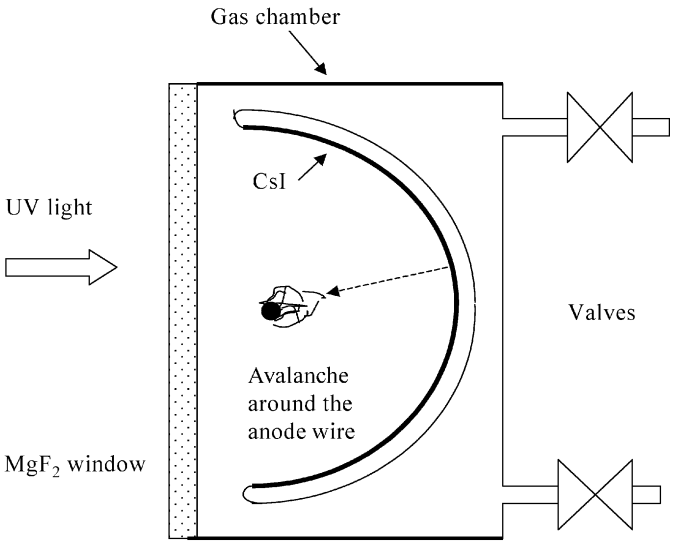

Fig. 1. Schematic drawing of the wire detector installed inside the gas chamber.

The cascaded hole-type detectors were installed inside a small gas chamber filled either with $He+10\%H_2$ (in the case of CPs) or with pure noble gases: Xe or Ar (as in the case of HMCPs) at a $p = 1$ atm.

In all experiments the gas chambers were attached to other chambers which we named a "scintillation chamber" (see Fig. 1 in [6]). This chamber was filled with on of the noble gases: Xe, Kr or Ar and contained a radioactive source (^{241}Am, ^{106}Ru, ^{109}Cd or ^{55}Fe). These sources produced scintillation lights recorded by the photosensitive gaseous detectors. In some experiments the window separating the gas and the scintillation chamber was removed, so that the detector in the gas chamber was filled by the same noble gas as the scintillation chamber.

These two chambers coupled to each other were installed inside the cryostat allowing controllable cooling to be made from room temperature until LN_2 temperature (see [6] for more details). While being located in the cryostat, the detectors could be run in two modes: flushed by a gas so that the pressure was kept at 1 atm, ("flushed detector") or filled by a gas to a $p = 1$ atm at room temperature, sealed and then cooled so that the density remained constant during cooling and all measurements taken ("sealed detector"). In some measurements our gas chambers were directly immersed inside the LN_2, LAr or cooled alcohol.

Besides the scintillation light produced by the radioactive sources, in some measurements we also used external UV sources: a pulsed H_2 lamp (a few ns pulse durations) and continuous Hg lamp. The pulse lamp was very convenient in measuring the detector's gain and feedbacks [11]. The Hg lamp was used for measurements with single photo-electrons.

The absolute quantum efficiencies (QE) of our detectors were measured at room temperatures using a monochromator combined with a continuous Hamamatsu H_2 lamp. The intensity of the spectral resolved light beam from the H_2 lamp was measured by an ionization chamber filled with TMAE vapors in which the QE is well known. After these measurements, the relative changes in the QE were continuously monitored (this time without the monochromator) during all measurements (cooling, warm up) by measuring a photocurrent or a counting rate produce by the Hg lamp.

3. Results

The gain versus voltage for the WD filled with $Ar+CH_4$ is presented in figure Fig. 3. One can see that within this mixture the maximum achievable gain was very high: ${}^{WD}A_m > 10^6$. In spite of the fact that this detector could operate close to the limited Geiger mode, at gains of