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Field enhanced response of a CsI photocathode to BaF_2 and KMgF_3 scintillation

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Abstract

We present the electric field enhanced response of a CsI photocathode to gamma-ray induced UV-scintillation of BaF_2 and KMgF_3 crystals. The photocurrent enhancement, at a field of 400 kV/cm, is of a factor of 1.5 for KMgF_3 and 3 for BaF_2 .

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CsI photocathodes to UV-scintillators has been observed. It is in accordance with our previous data on the CsI quantum efficiency dependence on the electric field.

This important result may be exploited in various fields of research, with other scintillators and most probably with other types of photocathodes. The present photocathode, used here for demonstration purposes, has a very small effective surface. Therefore full advantage of the field enhancement technique could be taken provided more practical devices could be developed. Various methods are being presently under investigation, to exploit the field enhanced photoemission and secondary electron emission, also in a charge multiplication mode.

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of 2 cm in diameter and 1 cm thickness, was coupled to this wire structure. The crystals were irradiated by γ -rays from a collimated ^{137}Cs source, with an activity of about 450 Ci. Such a high source intensity was required in order to provide a reasonable photocurrent, of the order of few picoamperes, with the present wire photocathode geometry. At each anode voltage the photocurrent and the dark current were measured successively, the latter by placing an opaque screen between the crystal and the photocathode. The measurements were made in vacuum of $3 \cdot 10^{-5}$ Torr.

The wire-photocathode was prepared by an evaporation of a CsI layer on one side of the wire grid, at room temperature. The CsI layer on the wire has a crescent moon shape with a maximum thickness at the center of about 500 nm. The cathode grid had an active area of 80 mm in diameter and was made from Au-plated tungsten wires of 10 μm in diameter with a 1 mm spacing. After evaporation, the photocathode was rapidly mounted into the vacuum test chamber. In this chamber it was transferred to the measurement area under 1 atm of nitrogen. The transfer time was of the order of 2 hours.

Fig.2a shows a normalized photocurrent from the CsI wire-photocathode as a function of the electric field strength on the wire surface, measured for BaF_2 and KMgF_3 scintillators. Data points of each set are normalized to the point at the lowest field value.

For comparison, Figs.2b and 2c show the dependence of the QE of CsI on the field, at wavelengths 160 nm, 185 nm and above 200 nm; the data being taken from ref. [11]. The first two wavelengths correspond to spectral regions obtained by convoluting the emission of KMgF_3 and BaF_2 respectively with a typical QE curve of CsI.

One can see from Fig. 2a that the field enhancement effect for BaF_2 is much stronger than for KMgF_3 : for BaF_2 it reaches a factor of 3, while for KMgF_3 it amounts only to about 1.5, at 400 kV/cm. This is in a qualitative coherence with the data from Fig.2b.

The detailed behaviour of the photocurrent as a function of the field for BaF_2 is not the same as for the 185 nm wavelength and can be explained as follows. As it was observed in [11], the QE enhancement for each wavelength region has a specific dependence on the field. At short wavelengths, below 190 nm, it is a linear function of the square root of the electric field strength with a slope increasing from shorter to longer wavelengths. At wavelengths close to the red boundary (200 nm) the QE increases much faster, even faster than linearly with the field (Fig.2c). Since the effective wavelength for BaF_2 is shifted with field to longer wavelengths, the resulting dependence of the photocurrent on the field is an integral of these functions and differs from that measured at a fixed wavelength.

Data presented in Fig.2a,b,c, are obtained with a cold CsI photocathode, i.e. being not subjected to a thermal treatment. It is known however that the photoresponse could be further enhanced by heating the photocathode following its preparation [12, 13]. From our experience, the heating will increase the quantum efficiency of CsI at the longer wavelengths, where a further field enhancement is expected to be very considerable (see Fig.2c).

We may conclude that a strong field enhancement of the photoelectric response of

Figure captions

Fig.1 A schematic view of the experimental set-up. The photocurrent from the CsI multiwire photocathode, induced by gamma-ray scintillation in BaF_2 or KMgF_3 crystals, is measured in vacuum.

Fig.2 a) Normalized photocurrent from CsI as a function of the electric field strength. Two data sets are presented: for BaF_2 and KMgF_3 scintillators. Each data set is normalized to the point at the lowest field value.

b),c) Normalized quantum efficiency of CsI as a function of the electric field strength, at 160 nm, 185 nm and above 200 nm. Errors are smaller than the point size. Data taken from ref. [11].

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Fig. 2