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STUDY OF PHOTOMULTIPLIERS RADIATION HARDNESS

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Abstract

Belianchenko S.A., Britvich G.I., Datsko V.S. et al. Study of photomultipliers radiation hardness: IHEP Preprint 96–90. – Protvino, 1996. – p. 4, figs. 2, tables 1, refs.: 7.

The radiation hardness of PM FEU-115 with the photocathode windows from glass S096-1, dynode systems of alloyed type and PM windows from MgF_2, radiation hard-glass S096-1, glasses S096-1, S050 is studied. No noticeable changes were registered in the optical transmission of the photocathode S096-1 window for the accumulated dose up to 35 Mrad, the PMP FEU-115 output signals — up to 15 Mrad and the alloyed type dynode system amplification — up to 100 Mrad. At the same time S095-2 and S050 the (borosilicate type) glass windows lose the transparency a few times under doses less than 1 Mrad.

Аннотация

Белянченко С.А., Бритвич Г.И., Глуховский Б.М и др. Изучение радиационной стойкости фотоумножителей: Препринт ИФВЭ 96–90. – Протвино, 1996. – 4 с., 2 рис., 1 табл., библиогр.: 7.

Изучена радиационная стойкость ФЭУ-115 с окнами из стекла С096-1, динодных систем сплавного типа и входных окон ФЭУ из MgF_2, радиационностойкого стекла С096-1, стекол С095-2, С050. Показано, что не наблюдается изменений пропускания фотокатодных окон из стекла С096-1 вплоть до 35 мрад, сигналов ФЭУ-115 — до 15 мрад и усиления динодных систем сплавного типа — до 100 мрад.

Introduction

The study of the radiation hardness of vacuum photosensors becomes necessary as a consequence of their wide use in particle detectors operating under intense radiation conditions typical for physics experimental setups at modern colliders.

Published papers [1,2,3] don't provide the needed information on the real PM radiation hardness.

The investigation of photocathode window materials represents special interest since inorganic transparent materials are used, for example, as Cerenkov radiators, scintillators, exit optical windows of liquid and gas detectors and so on.

The present work is devoted to the radiation hardness study of PM FEU with photocathode windows from S096-1 glass, dynode systems of alloyed type and PM photocathode windows from MgF_2, radiation hard glass S096-1, S095-2 and S050 glasses [4].

1. Radiation hardness measurement of photocathode windows

The two PM FEU-142 windows samples from monocrystal MgF_2, seven S096-1 windows samples, two window samples from S095-2 glass (PM FEU-85) and two samples from S050 glass (PM FEU-84) were used to investigate radiation hardness of photocathode window materials. The samples were irradiated in the gamma radiation field of 661 keV under an absorbed dose rate of 5.2 rad/s. Transmission spectra of the samples were measured with a spectrophotometer SF-26 before and after each cycle of irradiation.

The typical transmission spectra (normalized to air) of MgF_2 and S096-1 glass samples are shown in Figs.1, 2. The scattering of the obtained transmittances within a few percent is apparently due to measurement errors and not to the effect of irradiation. This is confirmed by the similar scattering of the transmission spectra among different window samples of the same type.

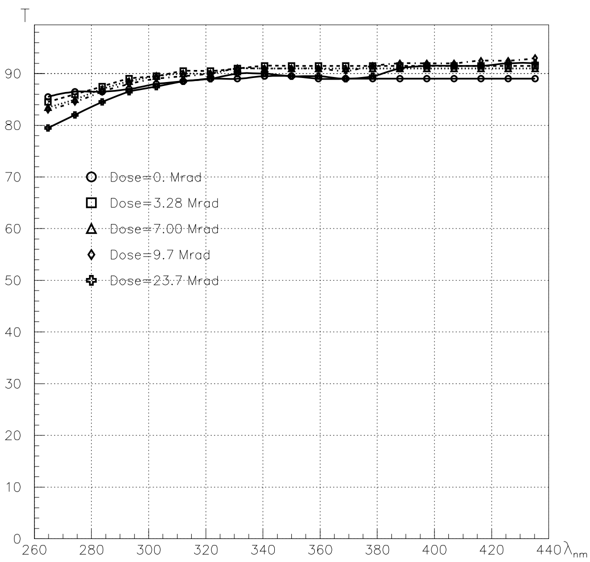

Fig. 1. Transmission spectra of the MgF_2 window under different irradiation doses.

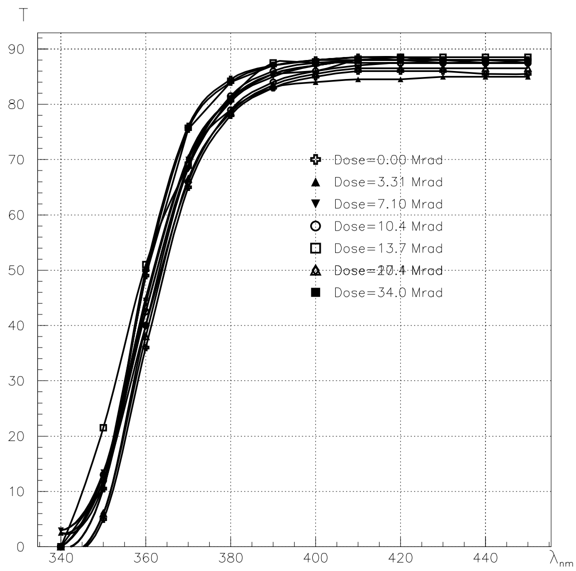

Fig. 2. Transmission spectra of S096-1 glass window under different irradiation doses.

Photocathode windows from S095-2 and S050 glasses lose the transparency essentially already under doses less than 1 Mrad. For example, the S095-2 glass windows lose the transparency for the scintillation NaJ:Tl (the wavelength of maximum emission, $\lambda_{max} =$ 413 nm) five times under an irradiation dose of about 700 krad.

Borosilicate glass used as the photocathode windows material of PMs at Hamamatsu and other related companies is an analog of S050 glass (Russian make). Therefore the radiation hardness of the S050 and borosilicate grasses is to a great extent insufficient for a number of applications of PMs, for example, in the case of the CMS electromagnetic calorimeter [5], the LHC-B inner electromagnetic calorimeter and hadron calorimeter [6] and so on.

2. Radiation hardness measurement of dynode system

A priory dynode systems should have the unique radiation hardness. Indeed under 10^4 hours operation for conventional PMs and the nominal mean anode current of several mkA for alloyed dynode, the equivalent dose corresponding to the electrons ionization losses in the surface layers of the last dynode and anode amounts to a few thousand Grad.

We have carried out the radiation hardness measurements of PM FEU-84 and FEU-110 dynode systems under ^{60}Co gamma irradiation (E $\simeq$ 1.25 MeV). Both photocathode current and amplitude of PMT output pulses were measured with the photocathode being illuminated by the constant and pulse light from the LED (the wavelength of maximum emission, $\lambda_{max}- \simeq$ 560 nm).

The measurement of the photocathode current have permitted to exclude the influence of variation of the photocathode windows transparency and photocathode sensitivity on the obtained results of dynode systems amplification under the irradiation.

The PM FEU-84 radiation hardness was checked up to 10 Mrad and the PM FEU-110 – up to 100 Mrad. No changes in the dynode systems amplification were found within the limit of 5% measurements accuracy.

This fact was taken as a starting point for designing the secondary emission calorimeter of flight type [7] with the radiation hardness of tens of Grad.

3. Measurement of the radiation hardness of the PM FEU-115 with a photocathode window from S096-1 glass

The radiation hardness determination procedure consisted in measuring both the photocurrents and output signal amplitudes of two PM samples (1 and 2) before and after irradiation. Simultaneously the same parameters of the reference PM sample were measured to check the stability of the measuring apparatus.

Output signal amplitudes were measured in three different wavelength regions with the help of $YAlO_3 : Ce$, the wavelength of maximum emission, $\lambda_{max} = 350$ nm, $CaF_2 : Eu$, $\lambda_{max} = 430$ nm and $B_4Ge_3O_{12}$, $\lambda_{max} = 480$ nm scintillating crystal excited by a α-radiaoctive source ^{238}Pu. The photocurrent was measured under the photocathode illumination by the LED light of $\lambda_{max} = 560$ nm.

The ratios of the measured mean values of PM output signals to photocurrents after and before irradiation are given in Table.

The adduced data show that the values of PM output signal amplitudes and photocurrents do not change within a few percent accuracy under the irradiation up to 15 Mrad. Taking into account the data on the radiation hardness of the photocathode windows from S096-1 glass it follows that the photoemission and the dynode system amplification of PM FEU-115 don't change up to 15 Mrad either.

Table 1.

Dose	0.7 Mrad				5.5 Mrad				15.5 Mrad			
λ_{max}nm	350	430	480	560	350	430	480	560	350	430	480	560
Sample 1	1,04	1,05	0,985	1,05	1,04	1,05	1,09	1,08	0,97	0,98	1,03	1,00
Sample 2	1,05	1,02	1,00	1,05	1,07	1,04	1,00	1,01	0,86	0,93	0,92	0,97

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