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R&D of microchannel plate phototubes ☆

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Abstract

The development of photomultiplier tubes with microchannel plates (MCP PMT) in Novosibirsk began 10 years ago. MCP PMTs are compact photodetectors with a record time resolution which can work in a strong magnetic field. The system of aerogel Cherenkov counters ASHIPH based on these PMTs (80 PMTs, 500 liters of aerogel) has been working in the KEDR detector since 2003. The main parameters of these PMTs are listed. It is shown that the photocathode life time cannot be expressed correctly in the units of the collected anode charge. The recent optimization of the MCP PMT design is described.

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Keywords: MCP PMT; Photocathode life time; Aging effect; Cherenkov counters

1. Introduction

The photomultiplier tubes based on microchannel plates (MCP PMT) are a promising type of photon detectors. They are compact, able to work in a strong magnetic field and have a record time resolution. Several groups have published results of MCP PMT investigations [1–5].

Works on MCP PMTs in Novosibirsk began about ten years ago [4]. Budker Institute of Nuclear Physics (BINP) and "Katod" enterprise have developed a phototube with two MCPs and a multialkali photocathode. The PMTs can be produced with either 18 or 25 mm photocathode diameter and an entrance window from borosilicate or UV glass. A multianode option can be manufactured as well [5].

We use the MCP PMTs in ASHIPH counters of the KEDR detector [6] which is working at the e^+e^--collider VEPP-4M at BINP. Counters have size of about $50 \times 20 \times 7\,cm^3$ and work in the magnetic field of 0.65 T. The light collection is performed with the help of wavelength shifters. Such approach allows to use only one small PMT per counter.

In 2003 eighty counters were installed into the KEDR detector [7] and now work in the experiment. As far as we know, it is the first mass application of MCP PMTs in a real experiment.

2. Parameters of MCP PMT

MCP PMTs which are used in the ASHIPH counters have multialkali photocathode of 18 mm diameter, borosilicate window, two MCPs with 8 μm channel diameter (Fig. 1). In the period from 1998 to 2002, several hundreds of MCP PMTs have been manufactured. The main parameters of these PMTs are listed below.

2.1. Quantum efficiency

Spectral response has maximum at a wave length of 500 nm and ranges up to 850 nm [6]. The value of quantum efficiency is between 18% and 26%, the average is 23%.

2.2. Photoelectron collection efficiency

Recently, we have done a measurement of the absolute collection efficiency of photoelectrons in MCP PMT. The average efficiency for a sample of 64 PMTs is 0.58, that is

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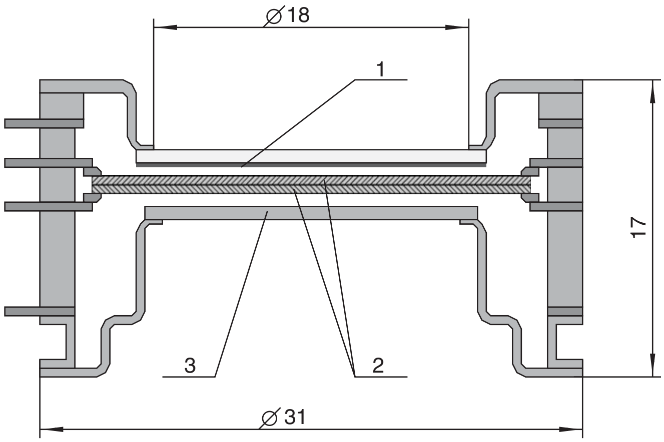

Fig. 1. The MCP PMT scheme. 1—photocathode, 2—MCPs, 3—anode.

close to the open area ratio of MCPs. A measurement method will be published.

2.3. Gain

Two microchannel plates provide a gain of 10^6. Typical voltage over two MCPs which allows to reach gain of 10^6 is 2.1–2.6 kV. The single photoelectron response has a quite narrow peak.

2.4. Intrinsic noise

The multialkali photocathode has a rather high thermo-emission current. The typical noise rate is 10^4–$10^5\ s^{-1}$ from the 2.5 cm^2 photocathode area at room temperature. The noise rate increases by about 3 times per 10 K. The amplitude distribution of the noise pulses has the shape of that for the single photoelectron one.

2.5. Magnetic field influence

One of the most attractive properties of the MCP PMT is its ability to work in a strong magnetic field. Measurements of the gain drop in the axial magnetic field have been performed (Fig. 2). At field of 2 T the gain drops by 3–5 times for different samples of PMTs.

2.6. Time resolution

Unique property of MCP PMT is its high time resolution. Physicists from KEK (Japan) have obtained a 35 ps transit time spread for Novosibirsk MCP PMT as well as for MCP PMT manufactured by Hamamatsu [3].

2.7. Life time of photocathode

The main problem of MCP PMTs is a limited life time of the photocathode because of ion feedback. Therefore, a layer of Al_2O_3 of about 5 nm thickness is placed on the entrance of the first MCP in some devices. This layer

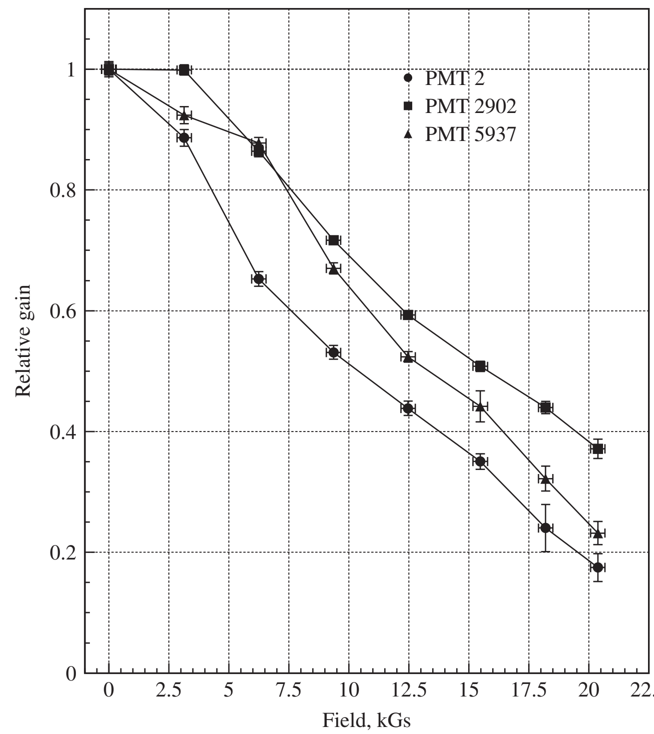

Fig. 2. The MCP PMT gain dependence on the axial magnetic field.

protects a photocathode from the feedback ions, improves the life time essentially but decreases the photoelectron collection.

According to our measurements, the protective layer decreases a collection efficiency by a factor of 2 at voltage of 300–400 V on the photocathode–MCP gap [8]. We cannot increase voltage on this gap because of a fast noise increase.

Under normal conditions of experiment, the level of the beam background for the ASHIPH counters in the KEDR detector is much lower than the intrinsic noise of PMT. We have investigated the photocathode life time of PMTs without the protective layer. Several PMTs worked at the gain of 10^6 without an external illumination. After a few months of the operation, we did not observe the quantum efficiency change within the measurement accuracy of $\pm 3\%$. After that we switched on a light source. The anode current increased by about 10 times. Under such conditions the quantum efficiency dropped greatly in a few weeks. After the light source was switched off, the quantum efficiency was stable during a year of the test. Fig. 3 presents the quantum efficiency at the wave length of 500 nm versus the collected anode charge. The results of the photocathode life time when PMTs operated without an external illumination can be found in Ref. [7].

From the results of these measurements (Fig. 3) we made a conclusion that the commonly used way to give the life time in the units of the collected anode charge is incorrect for MCP PMT. The photocathode aging strongly depends on the anode current. The life time should be given with the notice about the MCP PMT operation mode.