SELECTION OF OPTIMAL STABLE HIGH-VOLTAGE POWER SUPPLY FOR PHOTOMULTIPLIER TUBE OF SCINTILLATION DETECTOR

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ВЫБОР ОПТИМАЛЬНОГО СТАБИЛЬНОГО ВЫСОКОВОЛЬТНОГО БЛОКА ПИТАНИЯ ФЭУ СЦИНТИЛЛЯЦИОННОГО ДЕТЕКТОРА

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Аннотация. *В настоящей работе мы привели результаты исследования основных влияющих факторов на работу оптического прибора на примере фотоэлектронного умножителя работающего в сцинтилляционной сборке с кристаллом NaI(Tl), который в свою очередь является одним из основных инструментов в подводных радиологических исследованиях с применением метода in-situ Западных и Азиатских стран.*

Introduction. Currently, due to the expansion of industrial activity and the increase in the number of nuclear power plants near coastal areas, there is a growing demand for rapid radiological measurements in the marine environment. An in-situ approach is an economical and easy-to-use method. This method has reached a high level of analytical performance, mainly using underwater gamma spectrometry [1]. In addition radioactive monitoring, marine gamma-ray spectrometry has been used for a range of other applications. They are geological mapping, mineral exploration, obtaining a general picture of the distribution of radionuclide in bottom sediments and examination of cable routes to assess the radiation dose to optic fibre telephone cables [2]. Unfortunately, today the development and application of underwater gamma spectrometry in the study of shelf areas are not in the best condition in Russian science, unlike in Western and Asian countries science. This is confirmed by the almost complete absence of publications by Russian experts in this field. It should also be noted that most of the above studies were conducted in the waters of the seas of moderate, subtropical and tropical climates. Thus, this indicates the priority of shelf areas studies in the Arctic region. The aim of the project is to carry out a complex of radio-geochemical studies within the eastern-Arctic shelf of Russia, which are able to significantly complement classical geophysical and geological studies.

We are planning to conduct a continuous radiometric survey of the Arctic shelf's bottom sediments by the help of complex developed by our team. The radiometric survey is based on the registration of the natural radioactivity of bottom sediments using a scintillation counter. The systems most commonly used for γ-radiation spectroscopy in seawater, are based on NaI(Tl) detectors, which are characterized by high-detection efficiency and low cost [3]. Detector will be enclosed in a special sealed and vibration-resistant underwater container, with a cargo system and a connecting cable. The complex will consist of three detection units to increase the efficiency of registration of rare events arising from the interaction of photons from radioactive substances dissolved in water. The word "efficiency" means a physical increase in the size of the detector – in the first approximation, the per-channel summation of the number of counts.

The advantages of a scintillator combined with a photomultiplier tube (PTM) are high recording efficiency, high time resolution (10^{-9} – 10^{-10}), the ability to measure the energy of radiation particles and create counters of various geometric shapes and volumes. The main disadvantages are the voltage instability effects of the high-voltage power supply to PMT and large noise in the output signal [4]. We should pay attention to some characteristics of the PMT to find out why these disadvantages occur. Characteristics of the PMT are determined by the external conditions of its operation, the quantum yield of the photocathode, the secondary emission coefficient of dynodes (σ) and their number, the spectral composition of the light and the voltage of the photomultiplier. The number of secondary electrons per primary electrons is indicated by the secondary emission coefficient σ. This coefficient strongly depends on the energy of the incident electron, i.e. on the potential difference between the dynodes. The gain K generated by a system of n dynodes with the same σequals. $K = \sigma^n$. The dependence of σ on voltage leads to a very strong dependence of K on the voltage of the PMT power supply. This implies high demands on the stability of the supply voltage (usually not worse than 0.05%). The dark current gives noise pulse of different amplitude at the output of the PMT. It makes difficult to use the photomultiplier in measuring low-energy γ-radiation. The dark current is caused by the following reasons: thermoelectronic emission from the photocathode of the photomultiplier and its dynodes, leakage current, ionic and optical feedbacks, radioactivity and luminescence of constructive materials of the photomultiplier. When cascades work at 100 V, most of the dark current is caused by the thermionic emission from the photocathode and the first dynode, and this effect strongly depends on the temperature and voltage at the photomultiplier [5]. It follows from all above that the high voltage stabilization on the PMT is necessary. The objective of this work is to select the optimal power supply of the detector based on the need for an inexpensive power supply with high stabilization.

Main part. In this work we compared three power supplies assembled according to different schemes, hereinafter referred to as Scheme 1, Scheme 2 and Scheme 3.

Scheme 1.The voltage converter provides the output voltage of –1.5 kV. When the load current varies from 0 to 200 μA, output voltage change is not detectable by a four-digit digital voltmeter. Thus, the stability of the output voltage does not exceed 0.1%. The device is designed according to the traditional scheme using self-induction reverse voltage surge. This power supply is designed to work from unstable 12 V power source. The power supply has a negative lead connected to the common wire. The main advantage is its low cost. The cost of this power supply is 1240 rubles, and it includes costs of all components of the scheme and its housing. And if we consider the planned number of detection units, the saving becomes substantial.

Scheme 2. The power supply provides the maximum output voltage ~ 1 kV. The voltage can be adjusted by the trimming potentiometer. The device is assembled on a microcircuit MC64053. Non-standard transformer was used to increase the voltage. A series of diode bridges is used to rectify the alternating voltage. In the primary and secondary winding, teflon wires are used for heat resistance, as well as to avoid inter-turn circuit. The power supply is designed to work from an unstable 12 V power source. The cost of the components of the scheme was less than a thousand rubles.

Scheme 3. THV 12-2000N. The power supply provides the output voltage of – 2 kV. The THV series are regulated miniature high voltage power modules. The power supply has a minimum temperature drift and a very stable output voltage due to the use of highly stable components. Typical applications for these high voltage power supplies are photomultiplier tubes, gas chromatography, analytical instruments and wherever where small size and high output voltage stability is requested. 8h after warm-up time the power supply stability is 0.05 %. Temperature coefficient is ±0.01 %/K [6]. His main advantages are excellent output stability, low temperature coefficient, ultra low ripple and compact metal case. The power supply cost about 22000 rubles.

Results. As a result of testing Scheme 1, we discovered the instability of the output parameters. The instability is appearing when the ambient temperature changes. Scheme 2 was harder to assemble, but its output parameters are quite high stability. Scheme 3 has excellent stability and his output parameters don't change in the wide range of temperature, but its cost is extremely high.

Conclusion. The results of work: assembled power supplies according to Scheme 1 and Scheme 2; were compared three power supplies; selected the best option. Several commercial high voltage modules were also acquired. Unfortunately, at a cost of half the cost of the products assembled according to Schemes 1 and 2, the electrical characteristics of these high-voltage modules do not always correspond to the declared values. In the future, we plan to adjust the schemes in order to improve the output parameters and try to reduce its size.

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