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ScienceDirect

Nuclear Energy and Technology 2 (2016) 14–19

www.elsevier.com/locate/nucet

Photometry of ionizing radiations

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Available online 6 May 2016

Abstract

Possibility to develop telemetry system for remote control of radiation environment in the preset points in space was examined and practically implemented. The system is based on the capability of certain media to emit visible-light photons under ionizing radiation. Dedicated high-aperture low-noise detector of photons operated within visual wavelength range allowing selective registration of light from the preset point is space was developed. Photon detector was developed on the basis of large-size paraboloid mirror and photomultiplier tube with cooled photocathode. Studies of luminosity of air, quartz glass, plexiglass and water under irradiation with alpha particles, beta particles and gamma quanta were performed using the developed equipment. It was demonstrated that the developed installation is capable to ensure remote detection of ionizing radiation with comparatively low dose rates. The best sensitivity of the installation during operation using air as the passive radiator was achieved under irradiation with alpha and beta particles. It is recommended to use radiators made of quartz glass and plexiglass for registration of gamma radiation. The main advantages of the system are the absence of cable communication lines between sensors and the light detection device, simplicity and reliability of the sensor, its high radiation resistance, expediency of the implemented control and possibility to simultaneously control several points inside the controlled premises. The developed installation can be useful for evaluation of radiation situation at facilities utilizing nuclear technologies both in normal operation conditions and during emergency situations accompanied with leakages of radioactive substances.

Keywords: Radiation dosimetry; Detector of photons; Sources of ionizing radiation; Luminosity effects under different ionizing radiation.

Introduction

Optical telemetry radiation monitoring systems refer along with radio systems to the most efficient and reliable types of equipment [1–3]. Range of light radiation in atmosphere significantly exceeds ranges of ionizing radiation which allows detecting light signal at significant distances from the source. Registered light signal contains information both about the parameters of the ionizing radiation per se (time, energy and spatial distribution) and about the external conditions of its generation and penetration (radiation source depth or height, distance between the source and the point of detection of the light signal, optical characteristics of the propagation medium). Development of telemetry methods of detection of areas in space inside the controlled premises with elevated values of dose rates is a promising direction in the advancement of such systems [4].

Energetic secondary charged particles are produced in the medium under ionizing radiation resulting in the ionization and excitation of atoms of the medium. Optical radiation is generated in translucent medium as the result of luminescence and fluorescence. Generation of Cherenkov radiation is possible for secondary electrons with energies in excess of the threshold determined by the optical properties of the specific medium.

In practice there are cases when serious accidents emerge accompanied with release of large amounts of radioactive substances. In such cases it is necessary to localize in space the source of radiation and to undertake preliminary assessment of the level of contamination. Application of telemetry

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Peer-review under responsibility of National Research Nuclear University MEPhI (Moscow Engineering Physics Institute).

Russian text published: Izvestia Visshikh Uchebnikh Zavedeniy. Yadernaya Energetika (ISSN 0204-3327), 2015, n.3, pp. 40-48.

http://dx.doi.org/10.1016/j.nucet.2016.03.003

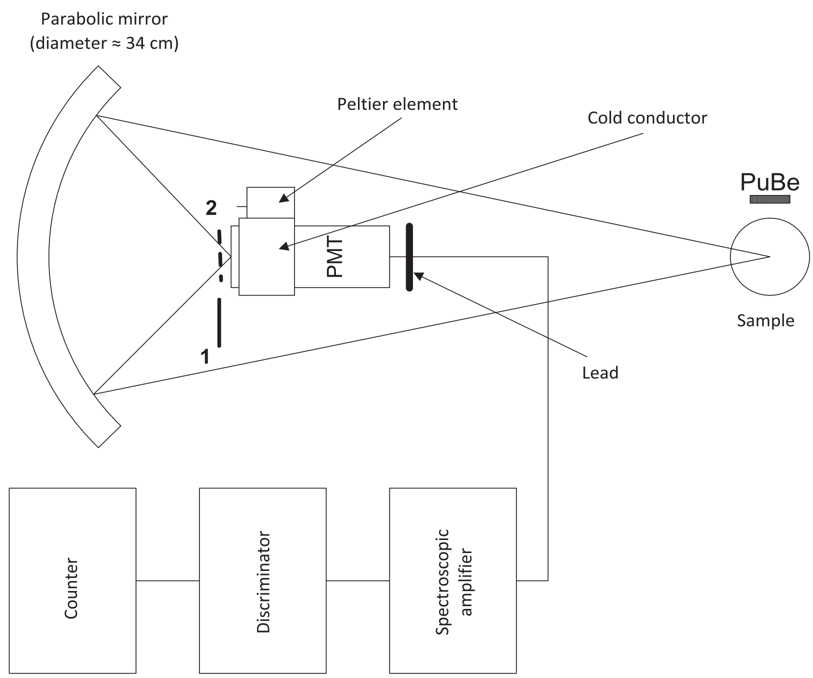

Fig. 1. Block diagram of the experimental installation operated in the counting mode: 1 – ligthproof diaphragm installed in position 2 during background measurements.

monitoring in the assessment of contamination level in case of surface contamination with α-emitting isotopes is problematic. The prospect of implementation of such remote monitoring technique may significantly reduce risks of irradiation of personnel conducting mitigation operations on the emergency site. Such measurements could be performed in a stand-alone mode if it were possible to equip all potentially dangerous premises with large number of detectors which is not always practical because of high associated costs.

Possibility is examined in the present study to develop the system in which ionizing radiation in contact with air or with other media produces photons of visible light while dedicated detector ensures registration of emitted photons penetrating from the preset area in space, is capable to determine the luminous power emitted by these photons at remote distances and makes on this basis estimation of local dose rate of ionizing radiation.

Block diagram of the experimental installation

Layout of the experimental installation is shown in Fig. 1. The mainstay of the installation in the parabolic mirror with 34-cm diameter serving as the concentrator of light penetrating from one point in space (location where the sample under investigation is placed) to other point where light detecting device is positioned. Use of this property of the mirror allowed spacing the source of radiation and the photoelectric detector at some distance from each other and, thus, reducing the radiation background. The cause of this background is the fact that ionizing radiation interacting directly with materials of the photoelectric detector (for instance, with glass) is capable to generate in it light radiation which is not associated with radiation emitted from the spatial area under measurement and, therefore, this light acts as a background. The most reliable method for reducing this background is to create the conditions when the source of radiation and the photoelectric detector are positioned at large distances from each other. Protection of the photoelectric detector made of materials efficiently absorbing ionizing radiation and installed between the photoelectric detector and the source of ionizing radiation can serve as additional protection from background.

Furthermore, the system under discussion can be reconfigured in such a way as to sequentially study light power emitted from different spatial areas and spatial distribution of luminous intensity. In fact, by changing the direction of optical axis of the mirror and the distance between the mirror and the photoelectric detector one can achieve projection on the photoelectric detector of virtual image of any point in space inside the controlled premises or equipment. Such approach is interesting because correlation exists between the intensity of ionizing radiation and the intensity of light within the given area in space. Such design of the photoelectric detector allows effectively suppressing background from parasite light sources (light penetrating from directions other than the direction towards the sample will be collected beyond the limits of sensitive area of the photoelectric detector).

Detector of photons is positioned at the point where the mirror shapes the image of the light source (sample). In this configuration light reflected from any point of the mirror surface has equal chances to reach the photoelectric detector and to be detected. With such geometry the photoelectric detector is located at significantly larger distances from the source of radiation than the sample under measurement which allows reducing the background. Small fraction of gamma quanta capable to reach the photoelectric detector is