A SCINTILLATION-SOLID STATE DETECTOR AS THE PERSPECTIVE TOOL FOR REGISTRATION OF BEAMS OF HIGH ENERGY PARTICLES IN VISIBLE AND INFRARED REGION

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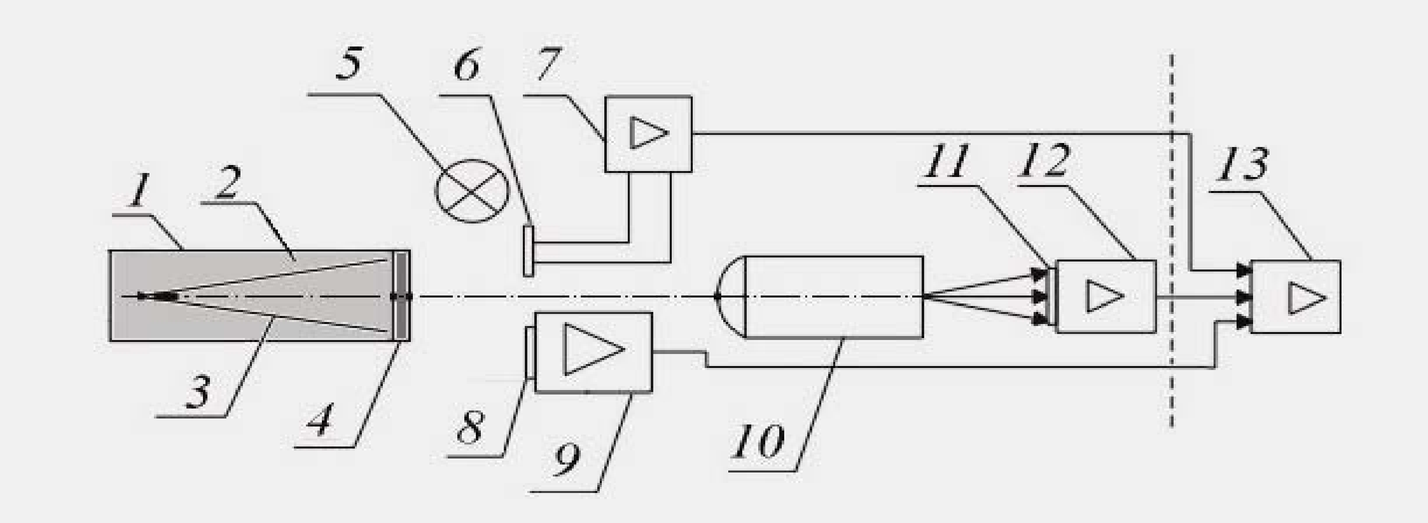
INTRODUCTION

Synchrotron radiation (SR) is generated by relativistic protons at their passage through area of sharp change of intensity of a magnetic field at edges dipole magnets of the accelerator. In proton ring accelerators of SR it was experimentally observed and used for diagnostics of a beam with energy above 250 GeV.

In experiments for registration of radiation were used photo-electronic multiplier and semi-conductor gauges.

Typical diagram of the SR-diagnostics [1]



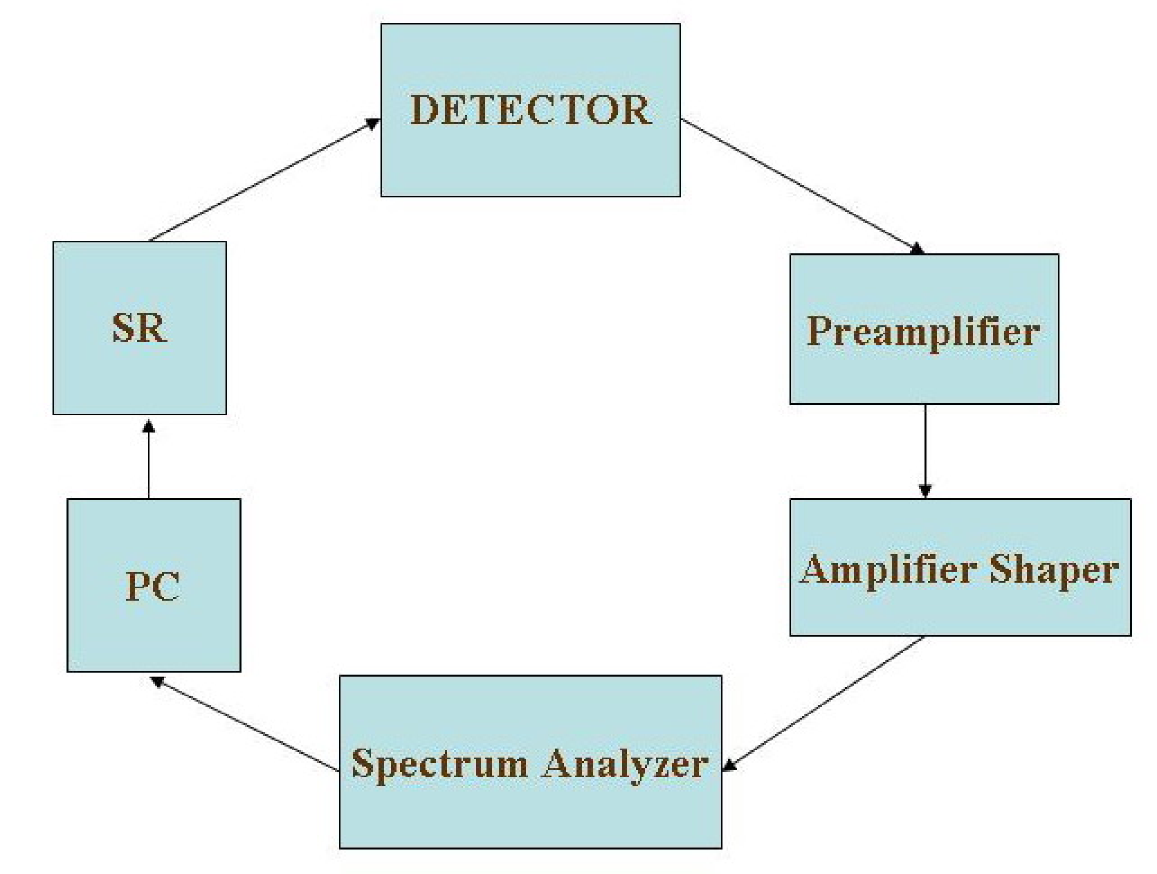
- 1 – channel of SR;
- 2 – vacuum;
- 3 – SR-beam;
- 4 – window for extracting SR;
- 5 – reference source;
- 6 – precision integral detector;
- 7, 9, 12 – amplifier;
- 8 – one-coordinate detector of SR-beam;
- 10 – long-focal-length optical channel;
- 11 – one-coordinate detector of the profile of the proton-beam;
- 13 – electronic equipment for accumulating and processing information using a computer.

WHAT WE HAVE NOW

However for the decision of similar tasks application of photo-electronic multiplier is limited for the following reasons:

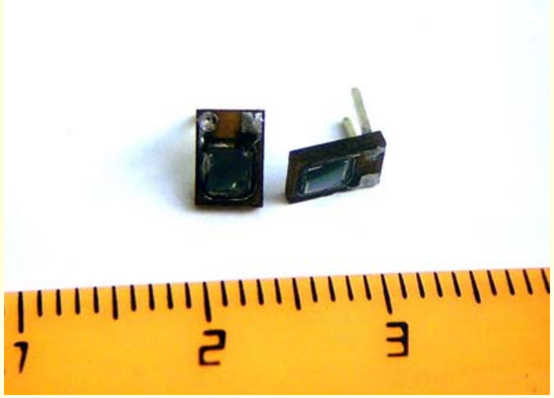
- **big size of photo-electronic multiplier,**
- **a high working voltage,**
- **low noise immunity from electromagnetic fields.**

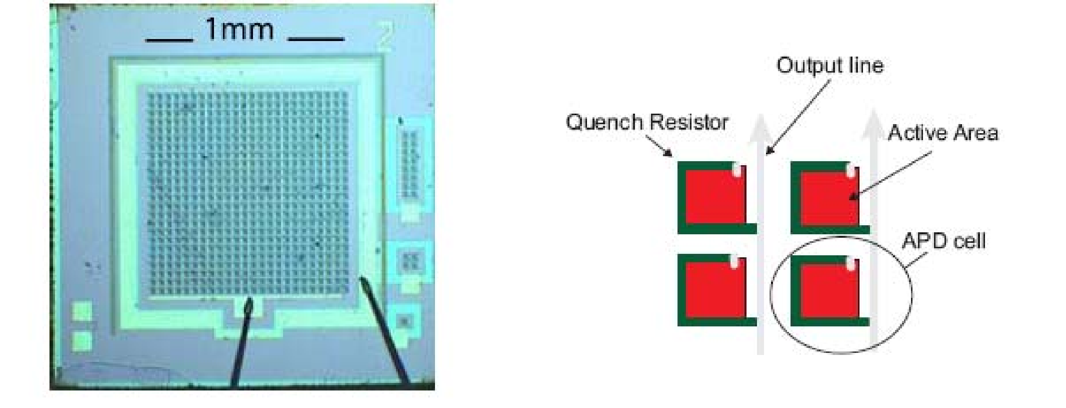
EXPERIMENTAL UNIT (scheme)



SOLID STATE PHOTOMULTIPLIER

Solid-state photomultiplier has not above listed lacks.
This technology develops actively last years in Russia and abroad [2].



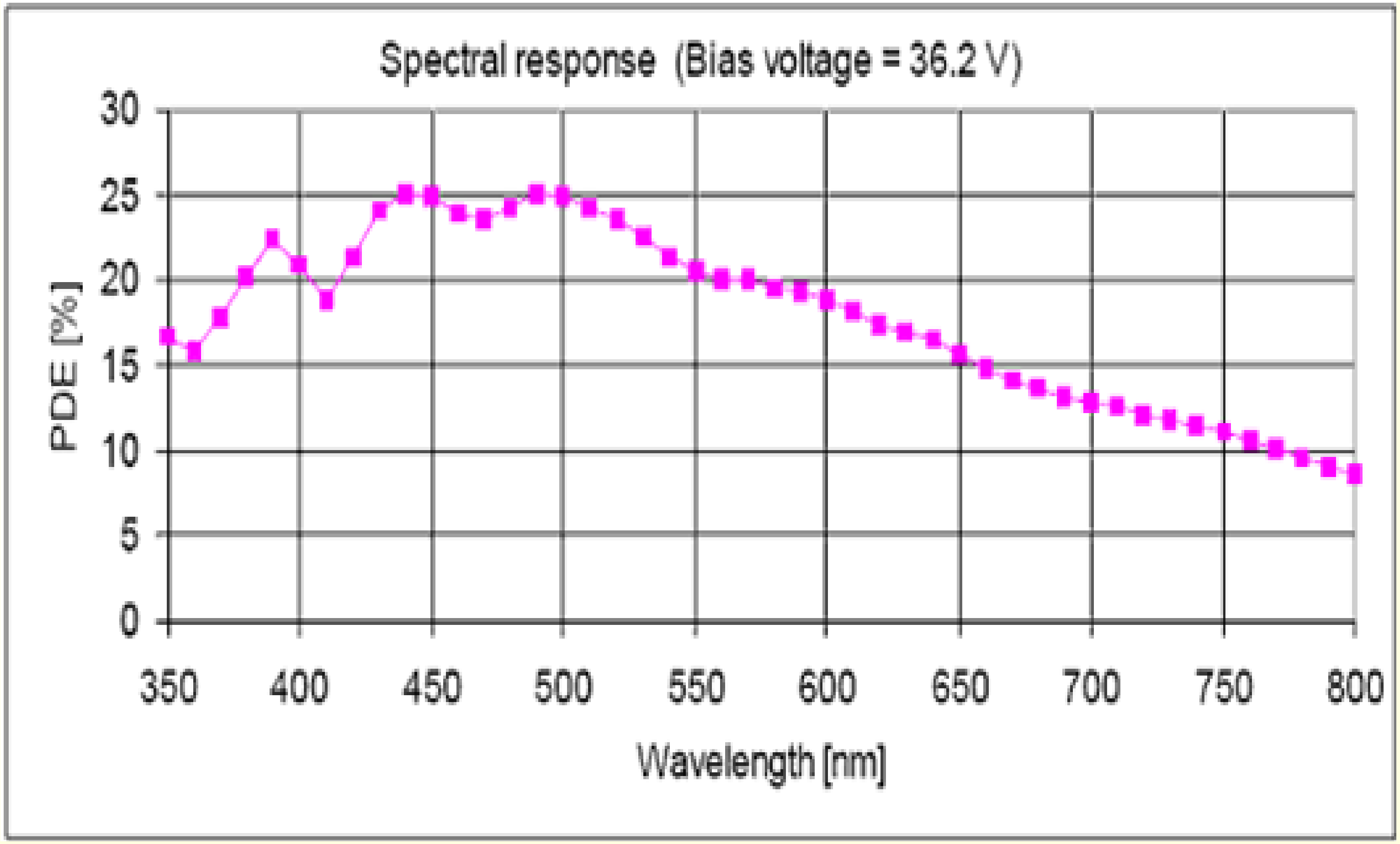


DISCRIPTION

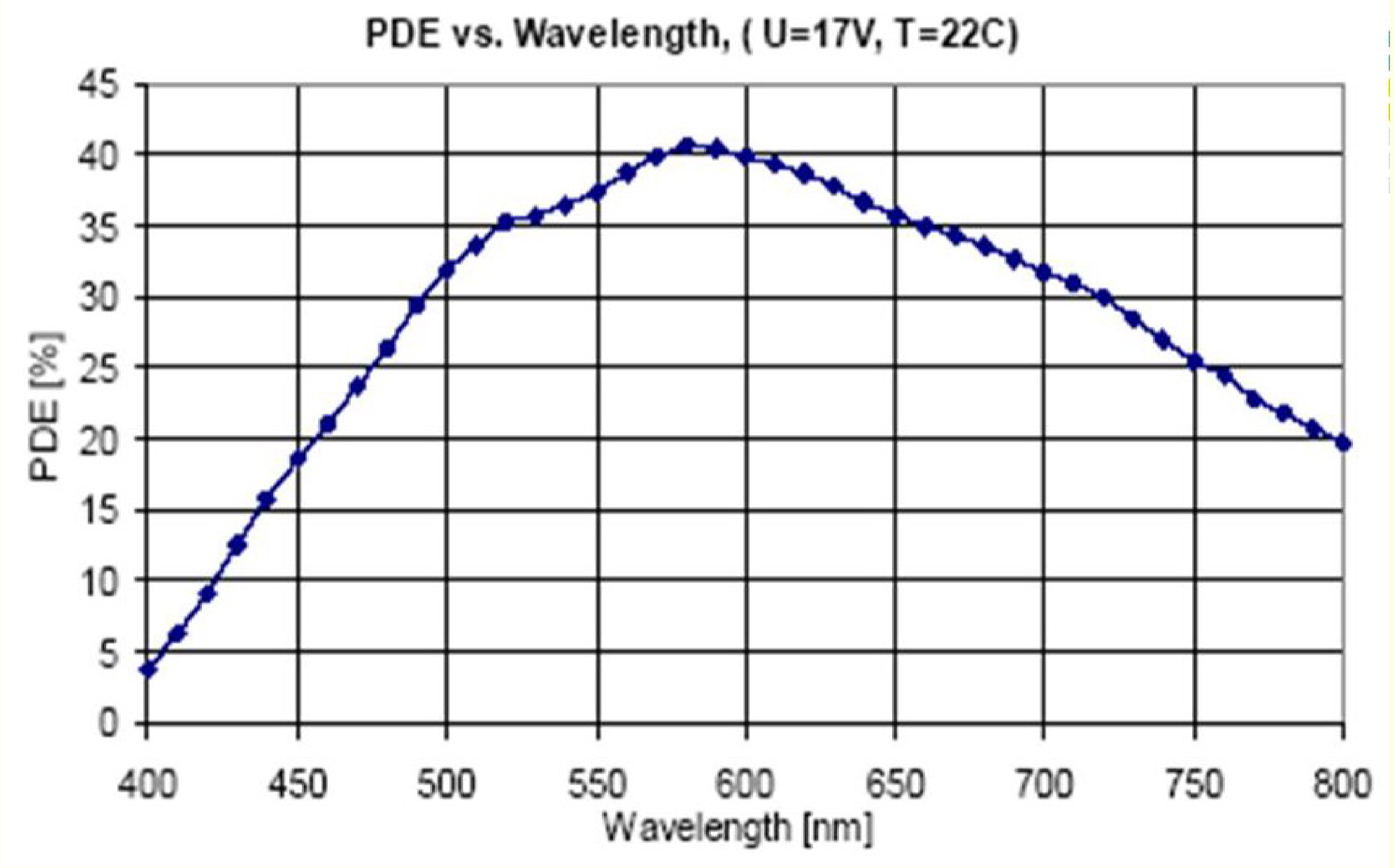
- **A typical solid-state photomultiplier receiver contains a matrix (an ordered array) of *pn*-junctions (pixels) with dimensions of the order of $(30 \times 30)\cdot 10^{-3}$ mm, mounted on a common substrate.**
- **All the pixels are joined by aluminum buses, and the same bias voltage is applied to them. This bias voltage exceeds the breakdown voltage (20–60 V), which means that the device operates in the Geiger mode.**
- **The outputs of the all the pixels are connected to the common output of the device through load resistors.**
- **Each *pn*-junction operates in the Geiger mode with a multiplication factor of 106, but the whole matrix acts as an analog detector, since the output signal is equal to the sum of the signals of the *pn*-junctions, generated by the photons absorbed by them.**

- **A light quantum incident on the active part of the pixel generates a primary electron, which produces a discharge in the pixel, which is extinguished when the voltage on the pixel falls below the breakdown voltage.**
- **Quenching, i.e., cessation of the discharge, occurs when the voltage on the *pn*-junction falls below the breakdown voltage due to the presence in each pixel of a current-limiting load resistor.**
- **The current signals from the operating pixels are added in the common load.**
- **The particular features of operation in the Geiger mode is the linear dependence of the pixel gain on the bias voltage and the low requirements imposed on the temperature and supply-voltage stability compared, for example, with avalanche light-emitting diodes.**

SPECTRAL RESPOSE



PDE vs. WAVELENGHT



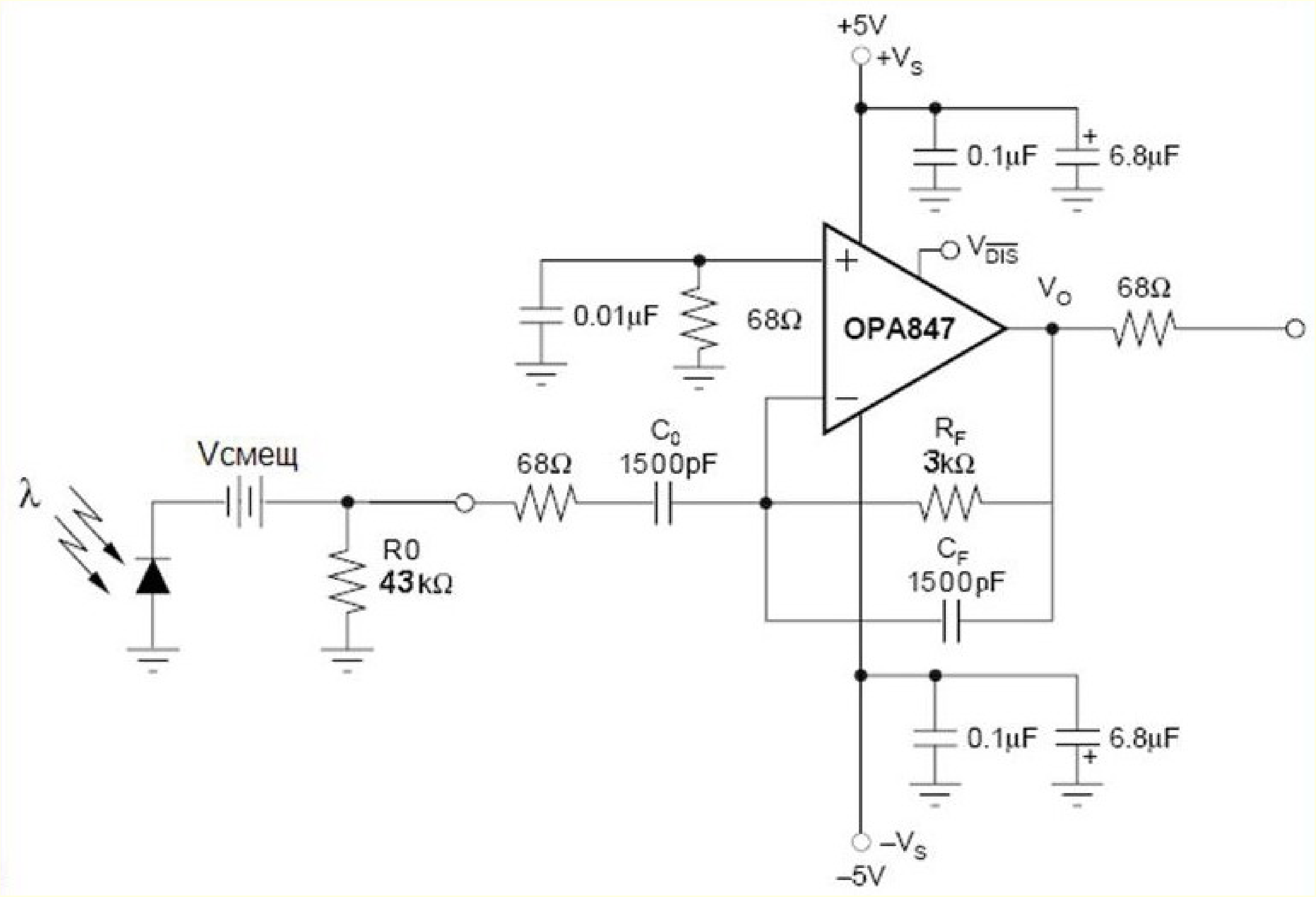
HOW CAN WE USE SSSD

- **Because of its advantages, solid-state photomultipliers can successfully replace vacuum photomultipliers in the measuring system.**
- **For this purpose, using solid-state photomultipliers, we developed a combined ionizing radiation detector for detecting SR, x-rays, gamma rays and neutrons, together with a solid-state scintillation detection (SSSD) unit.**
- **It consists of a scintillator, a solid-state photomultiplier, a preamplifier, a casing and an electrical connector [3].**

FILING OF THE IONIZING RADIATION

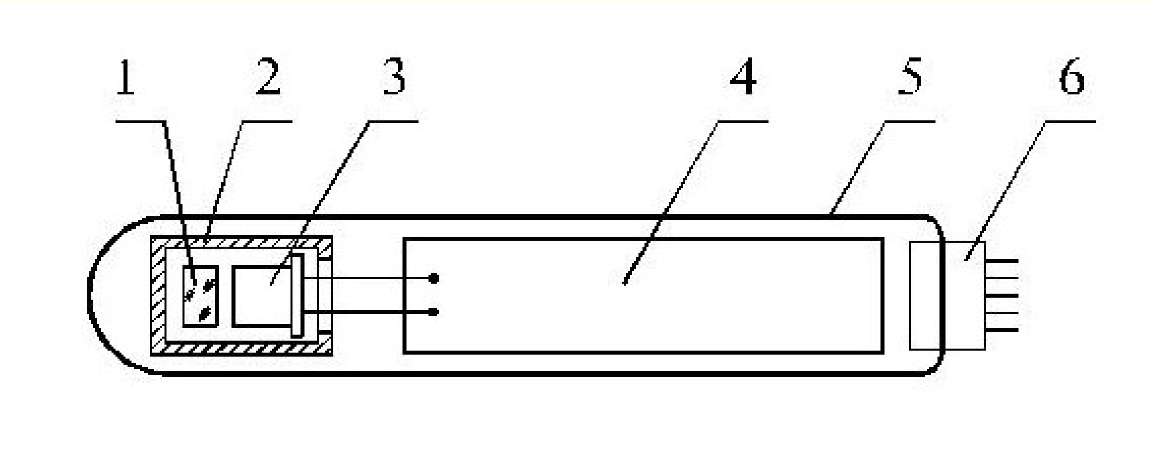
- When filing the ionizing radiation double transformation is carried out:
  - At first the ionizing radiation cooperates with a scintillator, photons in a light spectral range are thus formed.
  - Then light quantums are registered SSSD.
- This device consisting of a scintillator, SSSD, a preamplifier, a housing and an electric connector is designated as BDST – the detecting scintillation ion block with SSSD [4].

PREAMPLIFIER



ONE VERSION OF USING SSSD

We show a diagram of one version of this system – the BDST



Sketch of the BDST

1) scintillator;
2) body;
3) solid-state photomultiplier;
4) electron preamplifier;
5) body of the detection unit;
6) plug.

BASIC CHARACTERISTICS OF BDST

- volume of the CsI(Tl) scintillator 16 mm^3,
- counting efficiency ~10 pulses/μR (^{137}Cs), measured energy range 10–3000 keV,
- temperature range from –60°C to +60°C,
- energy resolution with respect to the 662 keV not more than 10%,
- permissible load not less than 10^5 pulses/sec,
- dosage power measurement range not less than $5 \cdot 10^{-8}$–0.3 Gy/h,
- power supply 5 V, 5 mA and 24 V, 100 μA,
- diameter 13 mm,
- and length 80 mm.

Comparative characteristics of the Solid-State Scintillation Detection Unit and Other Light Detectors with a CsI(Tl) Scintillator

Characteristic	CsI(Tl) scintillator + detector			
	photomultiplier	pin-light-emitting diode	avalanche light emitting diode	SSSD
Recorded γ-quantum range, keV	$10–10^7$	$60–10^7$	$60–10^7$	$10–10^7$
γ-radiation dose operating range, R/h	$10^{-5}–40$	$10^{-5}–4$	$10^{-5}–4$	$10^{-5}–40$
Gain	10^6	1	150	10^6
Supply voltage range, V	500 – 1500	40	200	22 – 50
Operating temperature range, °C	± 60	–40 ... +30	–40 ... +30	± 60
Effect of magnetic fields	considerable	zero	zero	zero
Effect of mechanical loads	considerable	negligible	negligible	negligible
Detector volume, mm^3	10000	100	100	10
Operating life	limited	unlimited	unlimited	unlimited

ADVANTAGES OF BDST

By comparison with similar detectors, the SSSD has the following advantages (see the table):

- **high photon recording sensitivity in the visible-light range**
- **high signal level at the output (10^6 electrons for each recorded light photon),**
- **compactness,**
- **wide operating temperature range,**
- **practically complete absence of a dependence of the parameters on magnetic fields,**
- **long operating life, etc.**

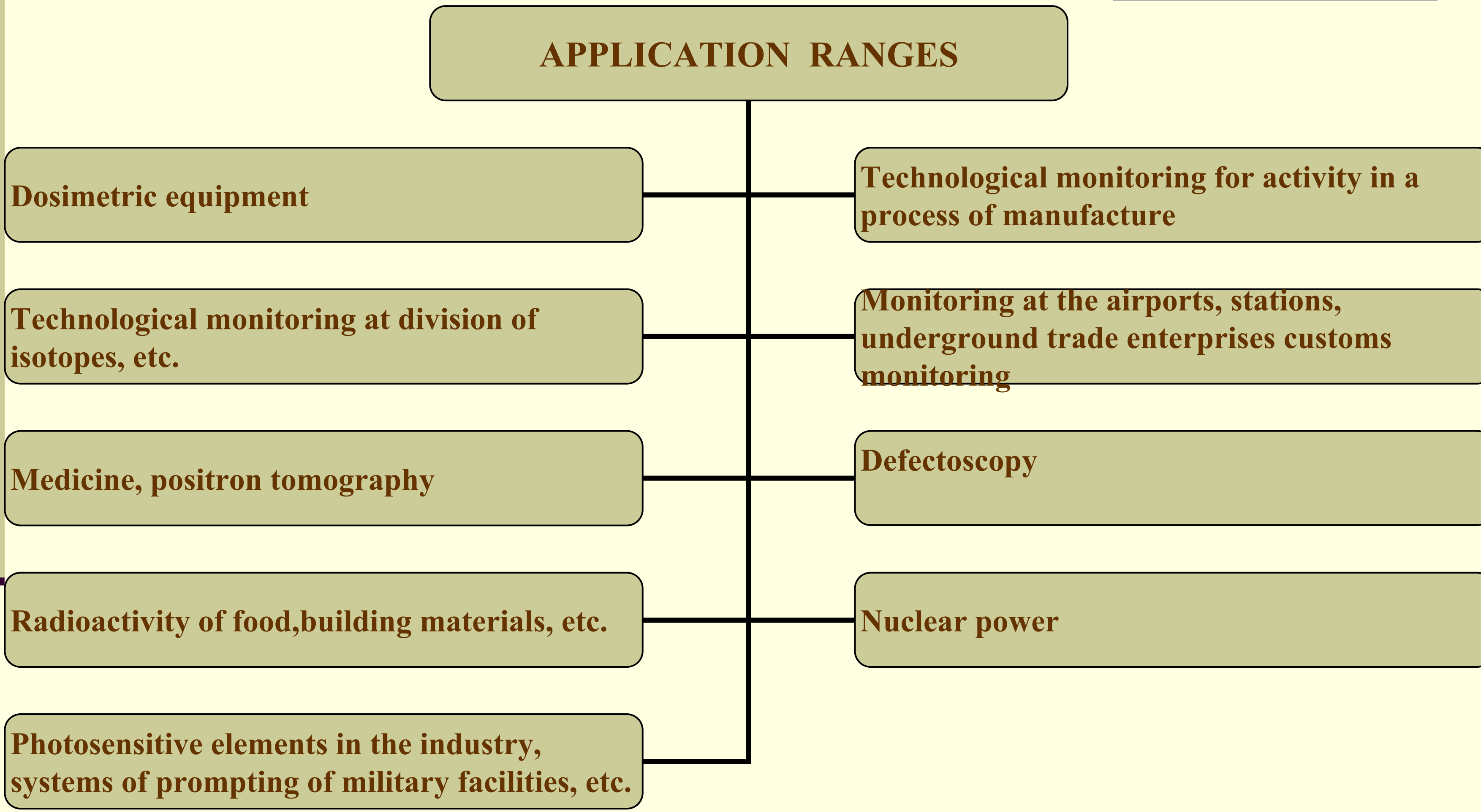
Definitions of spectral characteristics x-ray and radiation scale

The generalpurpose spectrometer with the detection block of BDST
1 – BDST, 2 – the generalpurpose spectrometer

BDST POSSIBILITIES

- Simultaneous power rating of a dose and spectral characteristics of radiation allows to increase essentially an informativnost of dosimetric and technological equipment.
- For dosimetric equipment becomes possible:
  - To define nuklidny structure of sources of radiation that is especially important at "radiation survey". There is a possibility to define an isotope which defines radiation that is essential at work on the district.
  - To define efficient biological dose/dosage rate, i.e. influence on a human body. Various energy of gamma-quantums has different impact on biological objects at the same capacity of an air dose.
- For technological equipment at control of activity in a process of manufacture to define an isotope responsible for increase in radioactivity of technological objects, for example:
  - Nuklidny structure of radioactive waste of the nuclear industry,
  - Nuklidny structure of the heat-carrier in reactor installation of the nuclear power plant that will allow to supervise the major for safety parameter – leakproofness of an envelope of fuel elements.
  - Technological monitoring at division of isotopes, etc.
- Similar possibilities when monitoring radioactivity:
  - Food,
  - Building materials;
  - Radioactivity detection at the airports, trade enterprises, customs monitoring, stations, the underground.
- Especially it should be noted essential advantages which arise when using SSSD in a positron - an electronic tomography and at a technological defectoscopy.

APPLICATION RANGES



CONCLUSIONS

In conclusion we note that, by appropriate calibration of the apparatus, the diagnostic instrument described should find application as a monitor for measuring the absolute intensity of accelerated proton beams.

The above-mentioned advantages of the SSSD enable it to be used successfully in experimental equipment of proton accelerators.

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