TEMPERATURE STABILIZATION OF SIPM-BASED GAMMA-RADIATION SCINTILLATION DETECTORS

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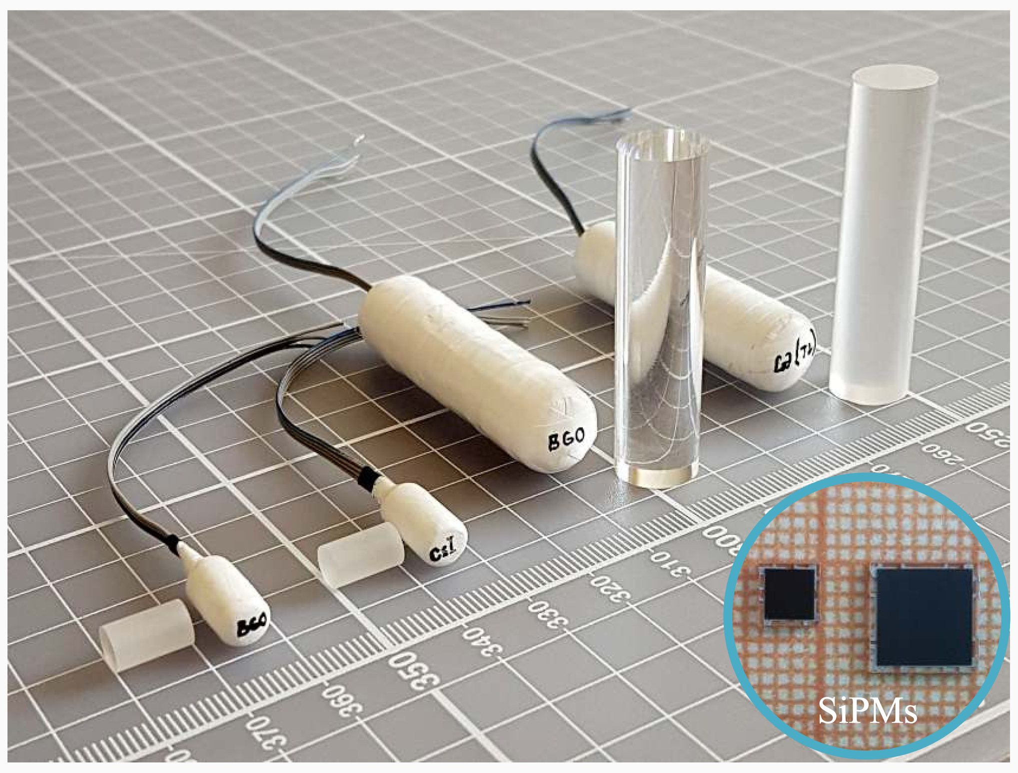
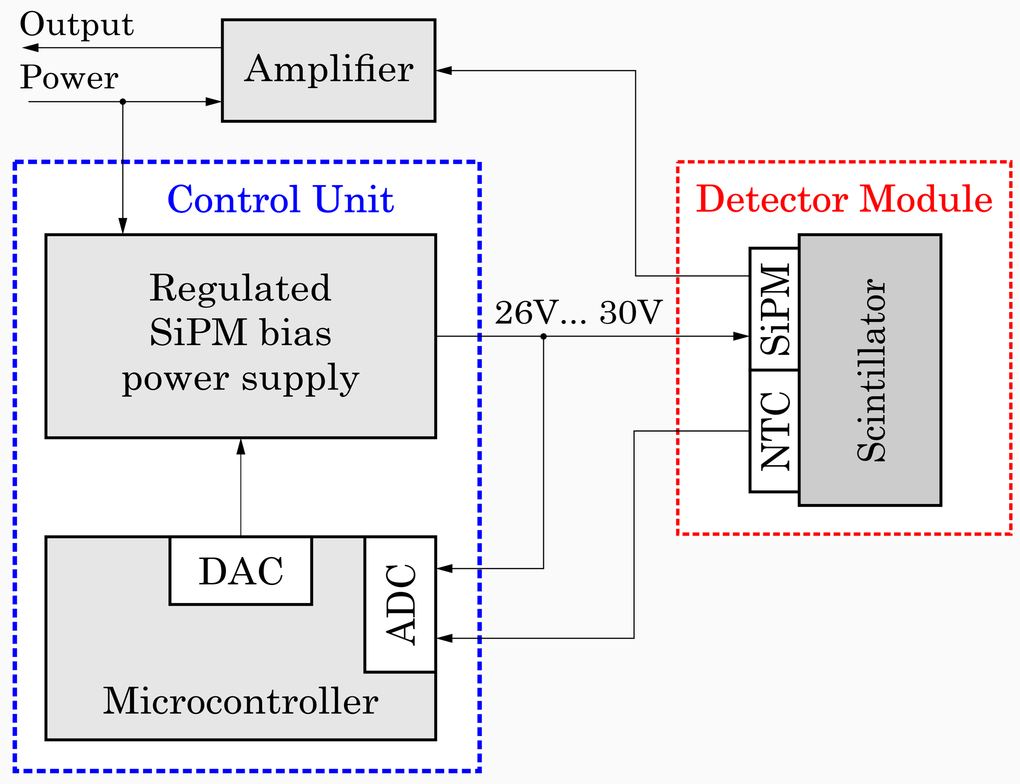
Currently, silicon photomultipliers (SiPMs) coupled with various scintillators are used as gamma-radiation detectors for different applications. Many tasks require the ability to use detectors in environments with varying operating temperatures. However, the profound dependences of the characteristics of both SiPMs and scintillators on temperature make it difficult to use these detectors in changing environmental conditions. The presence of such temperature dependence makes it necessary to use special techniques for the stabilization of the detector parameters. We proposed, developed and tested a method and an electronic module based on microprocessor control of the SiPM bias voltage for compensating for the temperature instabilities of the gain of an SiPM and the light output of BGO and CsI(Tl) scintillators.



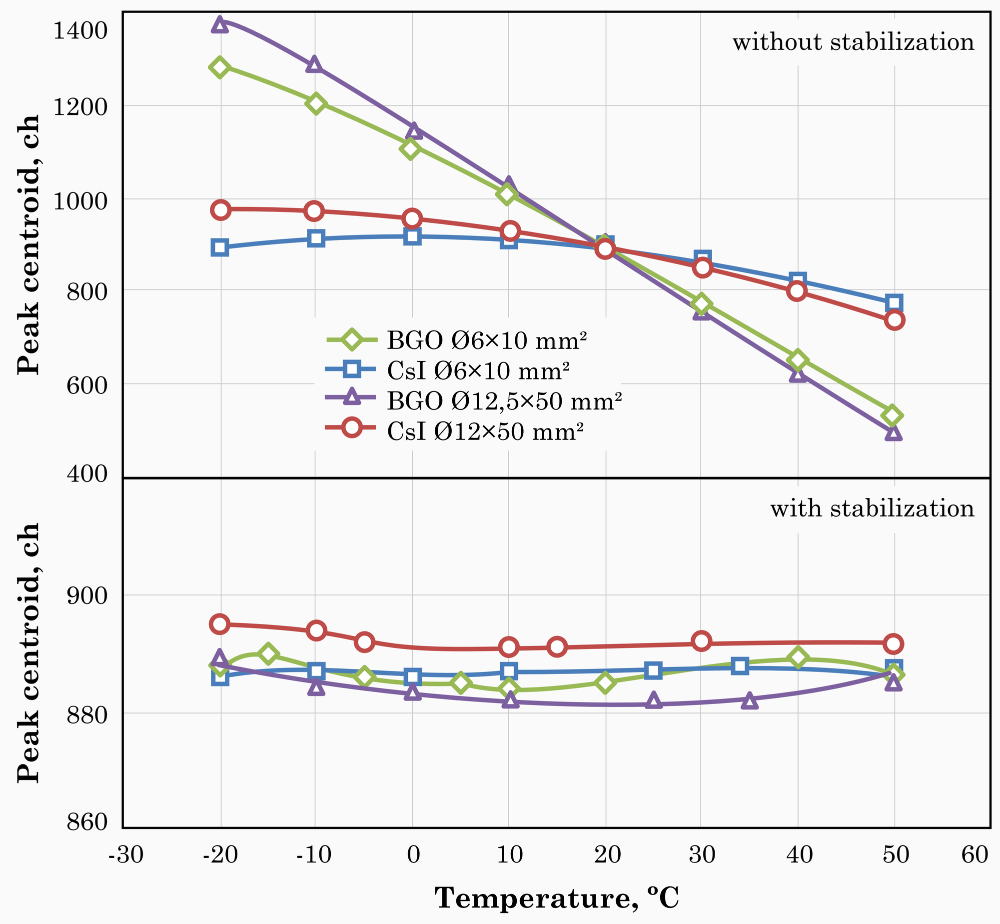
Appearance of the assembled detector modules and SiPM

The detector modules consisting of a scintillator (BGO or CsI(Tl)) from company EPIC Crystals Co., LTD., an SiPM C-type form SensL, and an NTC type thermistor were fabricated. The following 4 detector modules were assembled for the tests: Scintillator BGO Ø12.5 mm × 50 mm, SiPM MicroFC 60035, Scintillator CsI (Tl) Ø12.0 mm × 50 mm, SiPM MicroFC 60035, Scintillator BGO Ø6 mm × 10 mm, SiPM MicroFC 30035, Scintillator CsI (Tl) Ø6 mm × 10 mm, SiPM MicroFC 30035.

The temperature stabilization of the parameters of the assembled detectors was conducted using the method of active monitoring of the detector bias voltage. The microcontroller, which includes 12-bit ADCs and DACs, achieves the operation control of the entire circuit. Based on the calibration table stored in the processor memory, the required bias voltage of the detector is determined. The microcontroller periodically measures the current temperature of the detector and controls the correctness setting of the bias voltage of the detector. The signal from the detector through the amplification/shaper stage is sent to the subsequent recording equipment.



Block diagram of the temperature compensation scheme of a detector

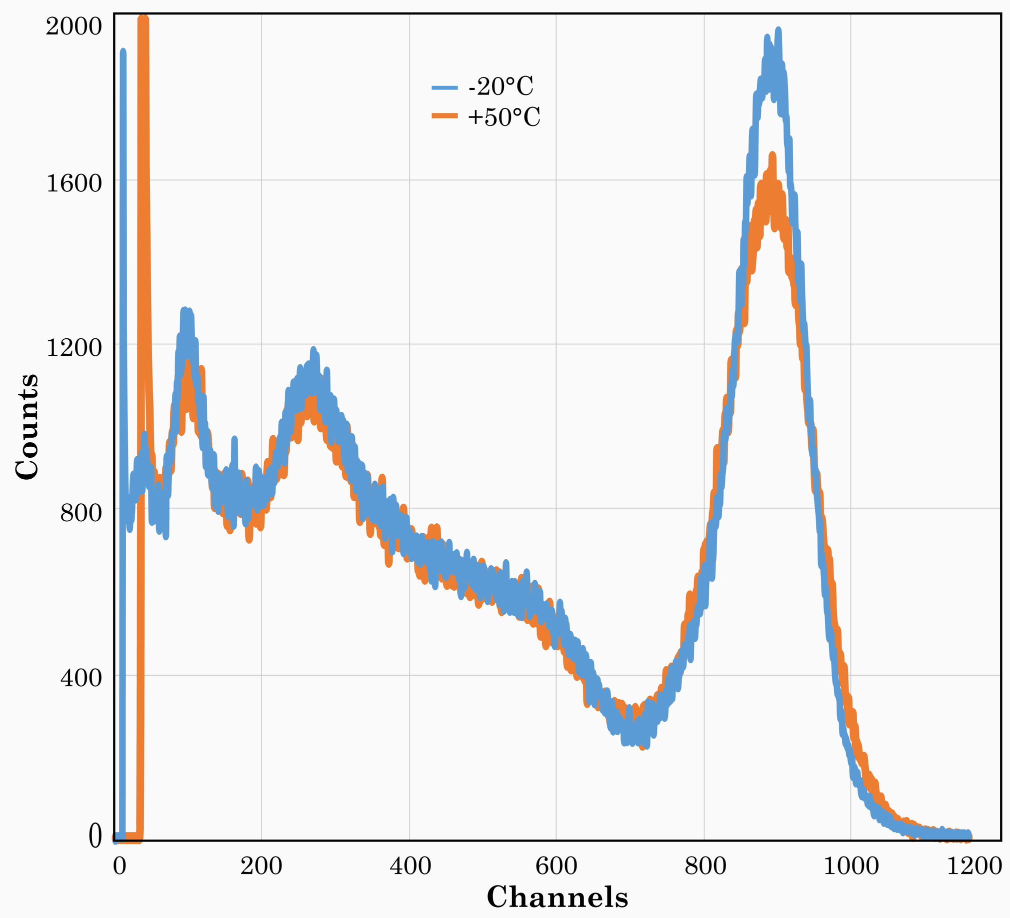


Dependence of the photo peak at 662 keV centroid on temperature with and without using the stabilization scheme measured with different detectors

The developed temperature compensating scheme was tested in the temperature range of –20°C to +50°C using the temperature chamber. The change in the position of the photo peak centroid in the tested temperature range for BGO detectors without the use of stabilization was significant. The amplitude of the signals decreased approximately by a factor of 2 in this temperature range. The same parameter for the CsI(Tl) was not so significant than for BGO detectors, but still very noticeable.

The use of the temperature compensation circuit allowed us to stabilize the peak positions for all types of detectors.

Changes in the photo peak position did not exceed 0.07%/°C. Measurements in a dynamic mode with constantly changing operating temperature (approximately 1.8°C/min) yielded the same results. At the same time, the use of the compensating scheme does not significantly affect the dependences of the energy resolution on temperature.



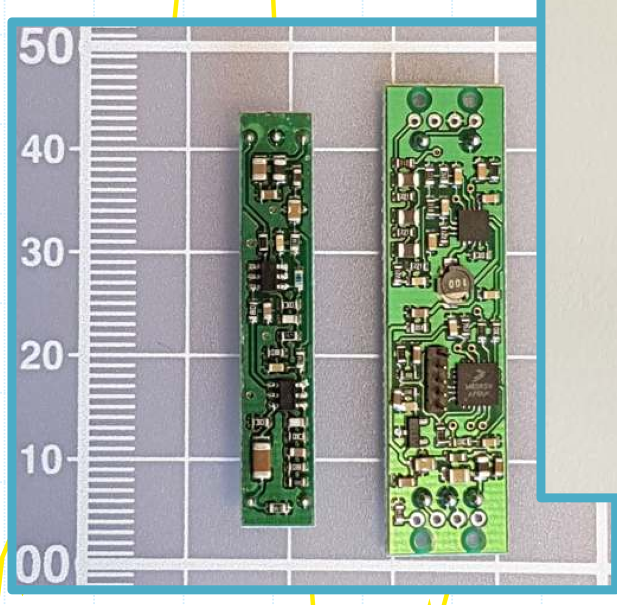
Spectra of ^{137}Cs recorded by the SiPM-based detector with a BGO scintillator of size of Ø6 mm × 10 mm at two operation temperatures

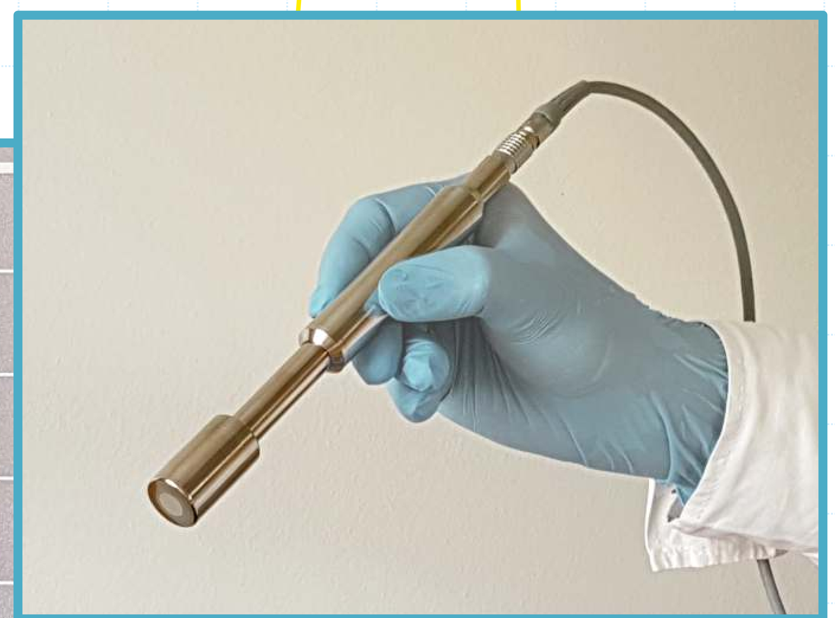
MAIN RESULTS:

- A temperature compensation module using the method of active monitoring of the bias voltage of a detector was developed and tested with SiPM-based BGO and CsI(Tl) scintillator detectors of different sizes.
- A method of accurate calibration of the stabilization unit allows for compensating the temperature instabilities of scintillation detectors, SiPMs and electronic components.
- The proposed method and the developed temperature stabilization module demonstrate a significant improvement in the temperature stability of the tested detectors. The temperature coefficient of the photo peak of 662 keV in the temperature range from -20°C to +50°C is approximately 0.07%/°C for all types of the tested detectors.
- The developed temperature-compensating module was used in the small-scale production of the surgical gamma-radiation probes.

All the elements of proposed electronic scheme are located on two small PCBs with dimensions of 45 mm × 12 mm and 39 mm × 7 mm, that are coupled to each other by a connector.

PCBs of the temperature compensation module





Appearance of the surgical gamma-radiation probe

The developed correction scheme was used to stabilize the characteristics of a surgical probe intended for the measurement of gamma-radiation from isotopes injected into the human body for cancer diagnostics. The surgical probe consisting of an SiPM-based BGO scintillator detector of size Ø6×10 mm², a tungsten collimator, a thermal compensation scheme and a shaping amplifier is designed for application in the temperature range of +10°C to +40°C. The gain stability for the temperature range is <0.6%.

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