DEVELOPMENT OF PORTABLE OMNIDIRECTIONAL COMPTON GAMMA CAMERA WITH MINIMAL NUMBER OF HIGH PERFORMANCE CDZNTE DETECTORS

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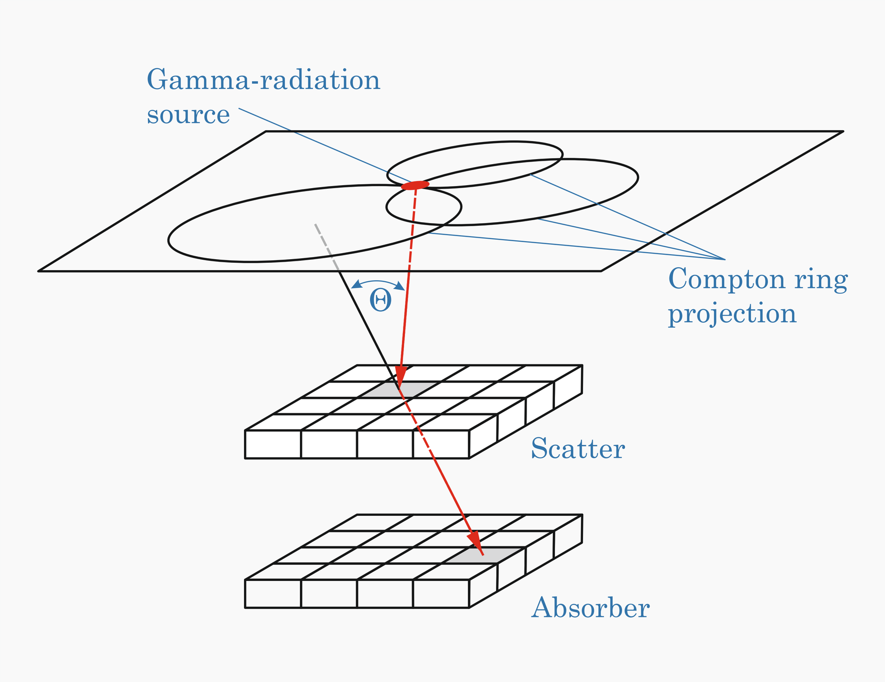
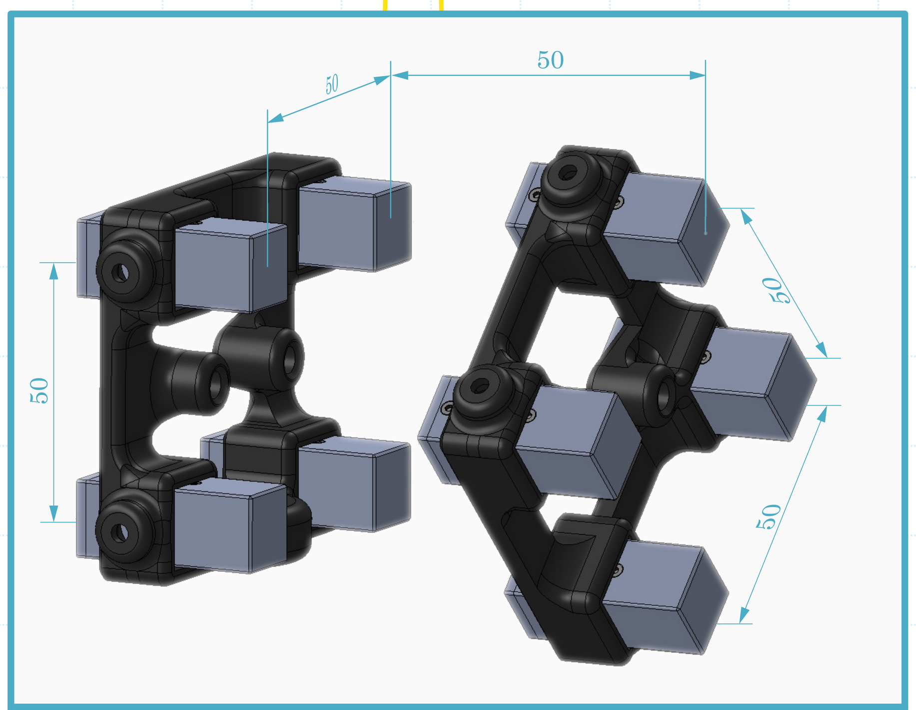
Victor Ivanov[1], Valerijs Ivanovs[1], Maksims Piskunovs[1], Anatoli Loutchanski[1], Jens Keubler[2], Jörg Brutscher[2]

[1]ZRF RITEC SIA, Latvia [2]GBS Elektronik GmbH, Germany

Compton gamma cameras are imaging devices designed to visualize and characterize gamma radiation sources. These devices are based on the analysis of Compton scattering mechanism which allows to determine the direction and energy of recorded gamma-rays without the use of any collimators. Existing Compton gamma cameras usually are multi-channel systems, have a relatively complex design that includes several detecting elements and are relatively expensive. We present results of a development of new imaging gamma-spectrometer – Compton gamma camera based on application of a set of 500 mm^3 quasi-hemispherical CdZnTe detectors [1] and MCA527nano [2] multi-channel analyzers operating in the List Mode.



Typical Compton gamma-camera device.



The location of the detectors in the proposed detectors layout.

Typically, the Compton gamma cameras include two layers of detectors - a scatterer and an absorber. The task of the camera's detector system is to determine the cone of probable events, the direction of the cone's axis, and the scattering angle. The scattering detector is used to determine the coordinates of the Compton scattering and the energy of the Compton electron. The absorbing detector is used to determine the absorption coordinate and the energy of the absorbed secondary Compton quantum.

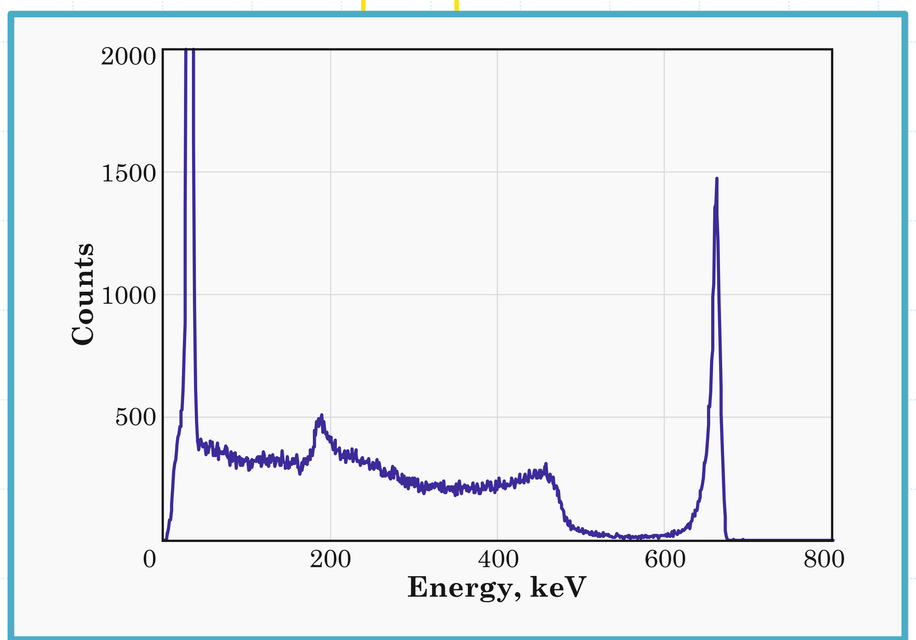
In this work, we study scheme for recording Compton events based on recording the released energy in separate spectrometric detectors, such a scheme was considered in [3] for scintillation detectors. To find the minimum number of detectors and the corresponding measurement conditions, the operation of a system composed of the described detectors was simulated as a Compton camera in various geometries of the detectors layout. Configurations with 2 + 2, 3 + 3, 4 + 4 detectors were considered. The acquisition of a signal for a stationary system and with its rotations during measurements around the axis was simulated. The images were reconstructed using standard methods of back projections and MLEM [3, 4]. For systems 2 + 2, 3+3 detectors images without artifacts are obtained only when the system of detectors is rotated. Experimentally, this was tested on a stand for the 2 + 2 system. The rotation was carried out manually. The image of the scene obtained in this experiment with two sources of ^{137}Cs with different activity 10^7 Bq and 10^6 Bq is shown in the figure. For the 4 + 4 detector layout, it is possible to obtain an artifacts free image without rotating the detectors. For such a scheme, a prototype was made. The optimal distances between detectors for the selected configuration were determined by simulation. An example of the obtained image of the source superimposed on the video image from the wide-angle camera installed on the prototype is shown in the figure.

The used MCA527nano is an ultra-small multi-channel-analyzer, suitable for applications with limited space and very low power consumption requirements. List Mode measurement method was used for the data acquisition. Measurements in the List Mode generate a list with spectroscopic and time-based information. During measurements in the List Mode, the values of the signal amplitudes and the time of their arrival are saved for each measuring channel. After exposition, coincident events are selected and image reconstruction using this data is being carried out. Such an approach, in our opinion, makes it possible to simplify the design of the measuring circuits of the Compton gamma camera. Structurally, 8-channels were combined into two 4-channel modules. Energy resolution of the used CdZnTe detectors in each of 8 channels is about 2% at 662 keV.

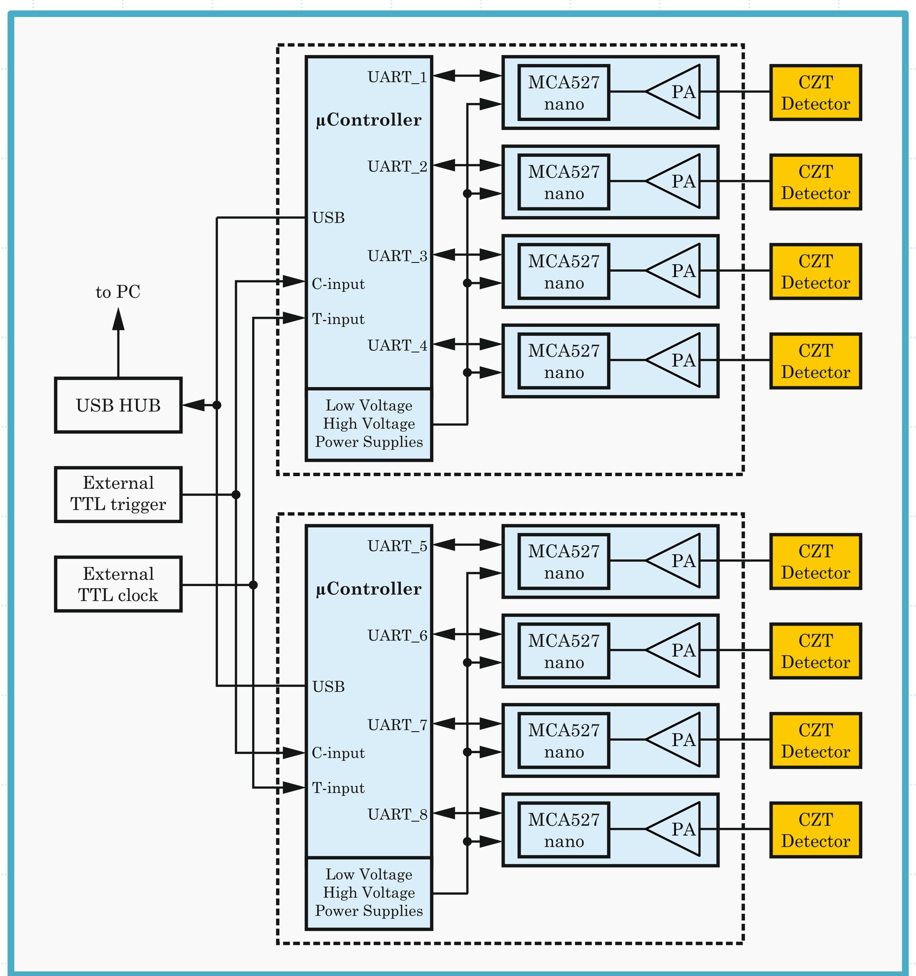
An external TTL trigger starts the measurements in all channels synchronously. The time resolution in the List Mode is 100 ns at 10 MSps and 50 ns at 20 MSps. When measurements are started by an external TTL signal, each MCA starts within 100 ns (50 ns). The time error from one MCA to another MCA is 100 ns (50 ns) max. for each event as long as is used the same external TTL clock source for each MCA. Coinciding events in two different channels within a time lags of 0.4 μsec or 2 μsec were selected.

Measurements with different position of gamma radiation source relative to the Compton camera were performed. The reconstruction of the image of the radiation sources based on the measurement results made it possible to obtain a reliable identification of the position of the radiation sources and the applicability of the proposed approach to the construction of the camera.

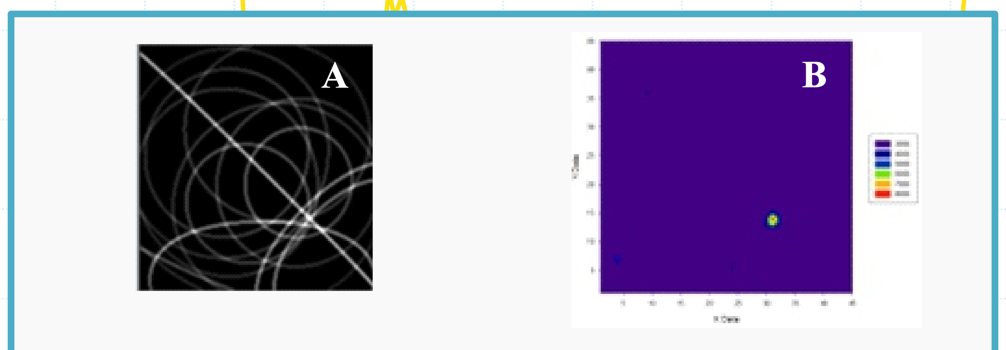
Photograph of the 8-channels prototype Compton camera.



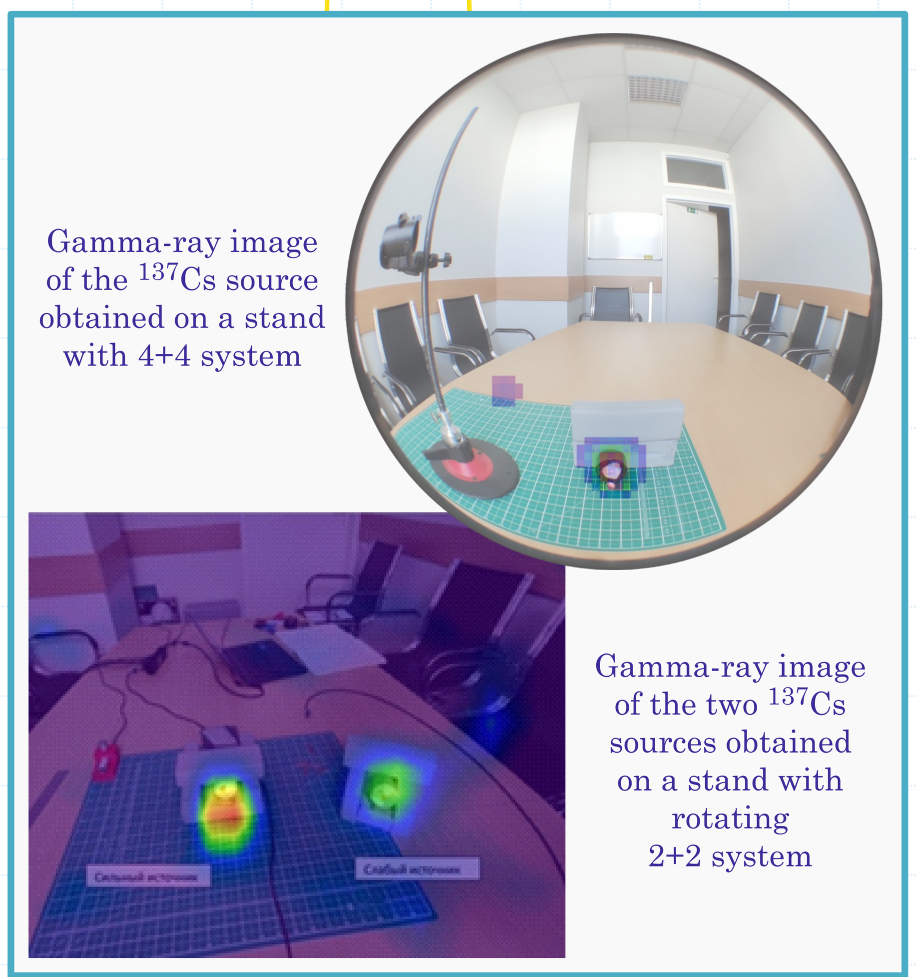
Typical ^{137}Cs spectrum obtained with the CdZnTe detector.



Structural block diagram of the developed Compton camera.



The initial image of the source (A) and source image after restoration (B).



Gamma-ray images superimposed on the video images from the camera installed on the developed Compton cameras.

MAIN RESULTS AND CONCLUSIONS

- Measurement results with proposed Compton gamma camera showed the possibility of reliable identification of the position of the radiation sources.
- Back propagation reconstruction give angular resolution of about 12 deg.
- After maximum-likelihood expectation maximization reconstruction, it is possible to improve angular resolution up to 4 deg.
- The results and simulation of the camera operation show that it is possible to detect gamma radiation, identify isotope and determine the direction to the source in a 4-π solid angle, i.e. the camera is an omni-directional system.

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ZRF RITEC SIA
Gustava Zemgala gatve 71A, Riga, LV-1039, Latvia
Tel./Fax: +371-67543304, E-mail: ritec@ritec.lv

GBS Elektronik GmbH
Bautzner Landstraße 22, 01454 Radeberg, Germany
Tel.: +49(0)351-2170070, E-mail: kontakt@gbs-elektronik.de