Ultra-Light Gamma-Camera for Security and Emergency Situation – 14066

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ABSTRACT

Gamma-ray imaging is the most important way to identify unknown gamma-ray emitting objects in decommissioning, security, overcoming accidents. Over the past two decades a system for producing of gamma images in these conditions became more or less portable devices. But in recent years these systems have become the hand-held devices [1]. This is very important, especially in emergency situations, and measurements for safety reasons. We describe the first integrated handheld instrument for emergency and security applications. The device is based on the coded aperture image formation, position sensitive gamma-ray (X-ray) detector Medipix2 (detectors produces by X-ray Imaging Europe) and tablet computer. The development was aimed at creating a very low weight system with high angular resolution. We present some sample gamma-ray images by camera. Main estimated parameters of the system are the following. The field of view video channel ~ 49^0 . The field of view gamma channel ~ 30^0. The sensitivity of the system with a hexagonal mask for the source of Cs-137 (Eg = 662keV), is in units of dose D ~ 100 mR. This option is less then order of magnitude worse than for the heavy, non-handheld systems (e.g., gamma-camera Cartogam, by Canberra.) The angular resolution of the gamma channel for the sources of Cs-137 (Eg = 662 keV) is about 1.2^0. Total weight 2600 grams. First application of system for very active objects imaging are presented.

INTRODUCTION

Registration of images of gamma-ray sources and sources of hard X-ray emission is recognized in recent years as the experimental method for mapping the distribution of radioactive elements in studies of plasma physics, in high-energy astrophysics etc [1]. Creating a portable gamma cameras allows their application in emergency situations [2, 5]. For the formation of gamma-image on the detector of portable gamma-camera the principle of the camera obscure, or a method of coded apertures is used. Coded aperture (mask) is a set of transparent and opaque to gamma radiation elements arranged in a particular pattern[3]. It comprises a base structure and an extra portion of the mask pattern which defines the basic design of the structure. Family -based mask patterns URA type often used in practical applications due to the advantages set inherent to said coding apertures family.

Scheme of measurements with using a coded mask is shown in Fig 1. Emitting object X gives the detector image M, which displays modulated (coded) aperture A flux of radiation from the source M = A * X. To determine the source image must hold its restoration using the inverse matrix C of the matrix apertures C = A- 1. Then X ~ C * M.

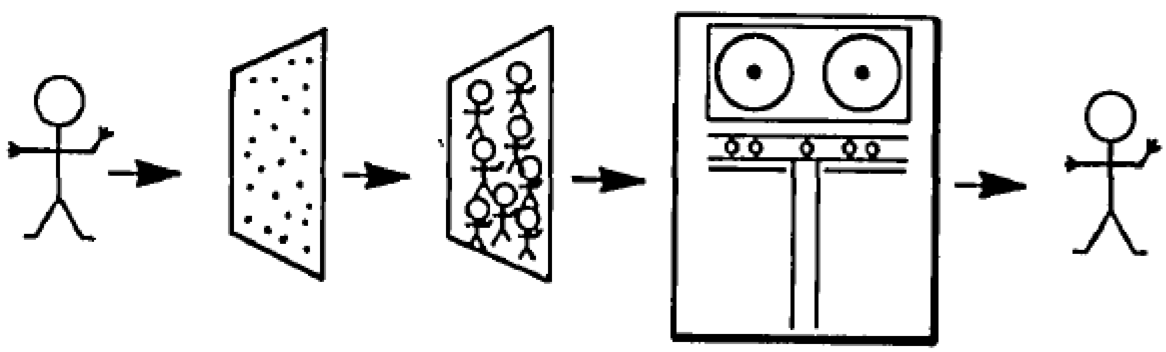
If the measurement is required field of view (in angular coordinates) θ x θ sterradian , with an angular resolution - - $\delta\theta$, then the number of elements of the mask (rank masks) will be N = $(\theta/\delta\theta)^2$. If the number of open cells (holes) in the mask n, the transparency mask is ρ = n / N.

What are the possible detectors for use in portable systems? There are two types of position-sensitive detectors which are small enough for use in portable systems: Scintillating with different photo registration (PMT or image intensifier + CCD) and semiconductor based detectors of modern semiconductors operating at room temperature - pixel and stripped detectors based on CdTe. First detectors have a large size and complex management and the second in until recently were not very accessible . Recently, the international research consortium develops detector Medipix2 [4] made for him power and control through the USB interface, and this detector has become attractive for portable gamma camera. For CdTe detector with a thickness of 2 mm evaluated the sensitivity using a simple model of image acquisition [6].

In such masks MURA for use in the system may be considered a hexagonal mask hexagonal URA with rank R = 17 or rectangular URA mask 29 x 31 and 41 x 43 elements.

Practical realization of the ideal characteristics of the mask is limited precision, it was made, matching the relative geometrical arrangement of the mask and the detector elements are displayed on the detector mask. These issues are studied using models developed on the basis of studies selected patterns for making masks.

Selection onboard computer - Acer Iconia Tab W500P dock AMD C60 It has two USB ports required, has enough light weight and it is running Windows7, which greatly facilitates the development of software to control the system.



[shadow-gram] [image restored]

[object] [aperture (mask)] [decoding procedure]

Figure 1. The scheme of gamma-imaging using coded aperture

METHODS

Choosing the layout of the system

The results of experimental studies and modeling show the possibility to obtain the gamma image sources with an energy of 1 MeV using systems with a rather thin and light so the masks. Consider a system with a mask of tungsten alloy thickness of 1.5 mm and a detector Medipix2/CdTe semiconductor detector with dimensions ~ 14x14x2mm [6]

The mask has the following characteristics : type – different URA/MURA based patterns; material - tungsten, thickness 1.8 mm, the pattern pitch of 0.4 mm diameter of holes approximately 0.3 mm.

System parameters :

field of view FoV 20 -30^o, the angular resolution $\delta\theta$~ 1^o:

the sensitivity of detection of the source of Co-60 creates a dose of the camera about 10mR / h - 1R / h in a 100- 1s , which will use the camera in a portable version. For smaller dose rates from the source will require a longer exposure using a wireless or wired link

Medipix2 fee associated with a laptop computer via the USB. The time , it is necessary to put the camera still during the exposure and manage from a remote computer

system includes a USB video camera and a laser pointer. Schematic layout of the device shown in Fig. 2 .

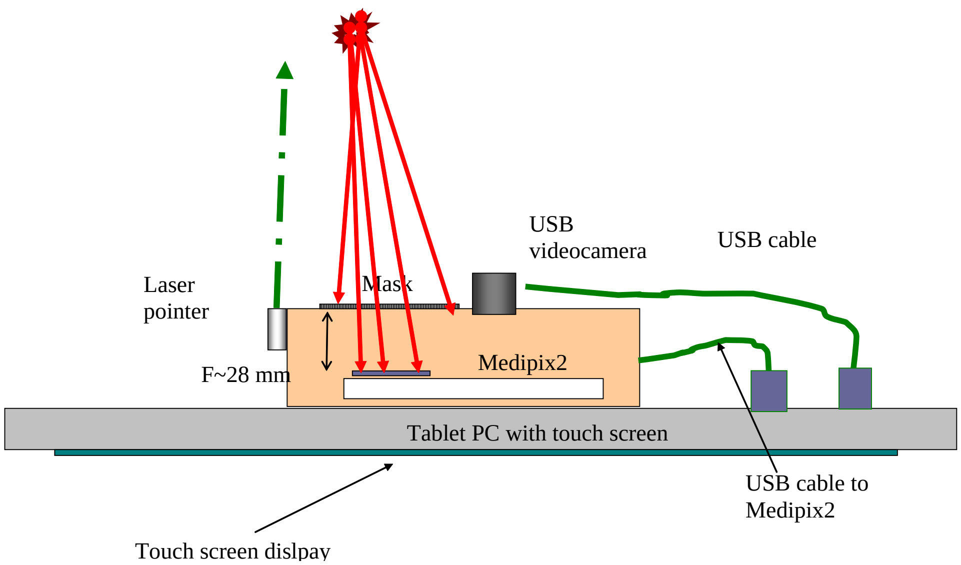


Figure 2. The selected configuration of a lightweight camera to search for the strong gamma-ray sources in emergency situations

The algorithms produce and recovery of gamma imaging

Masks are of high dimensionality. Therefore, improvement is necessary algorithms to coded pictures. The camera also has a fairly large pixels, comparable to the size of the mask elements, so special procedures are necessary to prepare the data for processing recovery procedures. Work on the establishment of appropriate algorithms for shadow pictures and images.

Algorithms for obtaining and recovery of gamma imaging

Work on the production and recovery algorithms scale - images included consideration of the mode of operation of the scheme mask-antimask [3]. Square MURA mask type and hexagonal type URA mask when turning (at 90 and 60 degrees, respectively) are transformed into its opposite. Getting shadow patterns in two positions masks can significantly improve the resulting images.

Masks have a small hole dimension. It is therefore necessary to improve algorithms coded pictures - to develop a new algorithm for the projection mask structure on the detector.

This algorithm will be used to create the file projection of a special format that will be used for the treatment of shadow pattern recovery procedures.

Masks should have a precise location of very small holes. Available sizes are determined, so maybe cutting technology.

It has been determined that laser cutting is possible to manufacture masks with holes ~ 0.35 mm arranged at ~0.4 mm pitch.

After determining the mode of laser cutting developed working drawings for manufacture of masks with holes of diameter ~ 0.35 mm. Diameter of masks is 46 mm.

After correction processing program masks were made first mask layer. Each mask consists of 4 layers, the total thickness of 1.8 mm mask. Pictures of made masks are shown in Figure 3

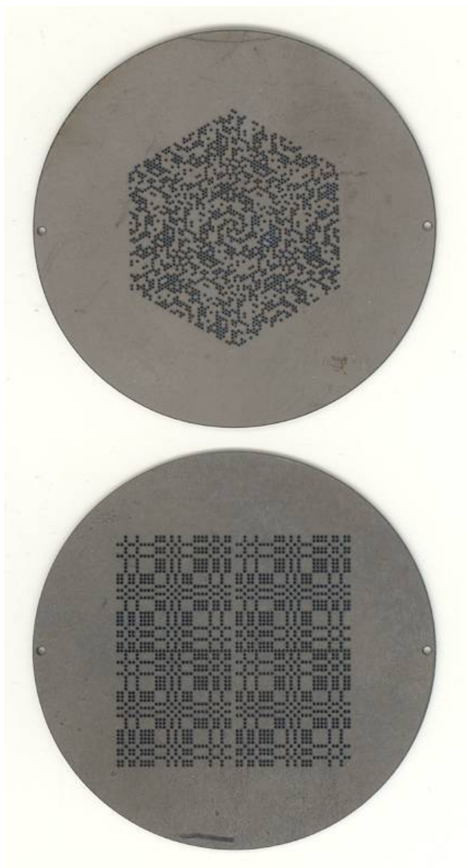


Figure 3. Photos of made masks of two types - mask 17 rank at the top, a square mask MURA31 below.

Development of algorithm for estimation EDR using system's detector.

According to the obtained from the manufacturer's specifications studied the feasibility of developing an algorithm to estimate the dose of radiation of different energies. Estimates for the determination of MED integrated over the field of view and for the DER selected solid angle according to a signal from the detector.

Development of software modules to account for the parallax between the optical and gamma channels of the system.

Optical systems and code channels are offset relative to each other along the vertical axis. Following the development of the plant unit masks could estimate the distance between the axes (linear parallax - see Figure 2.) And to develop an algorithm taking into account the parallax images when applied to any object distances.

Produced system has the following weighting parameters as in Table 1

Table 1. Weight of the components of the system to work "by hands"

		gramms
	Tablet PC	960
	Detector Medipix2 assembly	110
	Cables	80
	The detector enclosure and the mask	740
	Overall system frame	720
	Total	2610

Figure 4 presents detector Medipix2 with communication module FITPix before installing into the detector housing with block of coded mask

Figure 4. Detector Medipix2 with communication module FITPix before installing into the detector housing with block of coded mask

Selecting a program to link PCs and development of management programs Pad on-board computer with a remote control laptop.

The developed system suggests two ways to obtain the gamma images. Online mode - work "with hands" when the operator is holding the spy system in hand, while in the area where the source provides a sufficiently high flux of radiation in a short time is the gamma images from different directions and identifies the main sources. Detection of images by the accumulation during considerable time for complex sources. Hand- system module is mounted on a tripod or stand (see Fig 5). The operator goes out of the room and controls the system with the controlling computer (laptop) , which is associated with the on-board radio LAN. For remote control program for producing gamma - imaging system is selected Radmin software version 3.4.

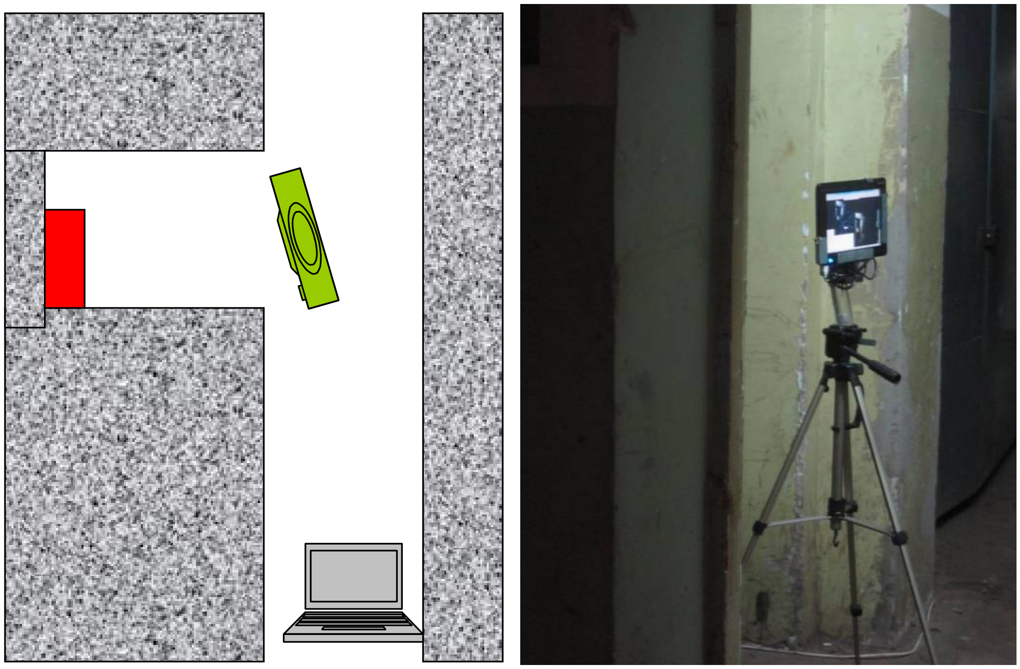


Figure 5. Scheme of remote measurements and photo the gamma camera which is autonomously set

MEASUREMENTS

One of obtained gamma- image of canisters with radwaste made by portable camera is presented in Fig. 6.

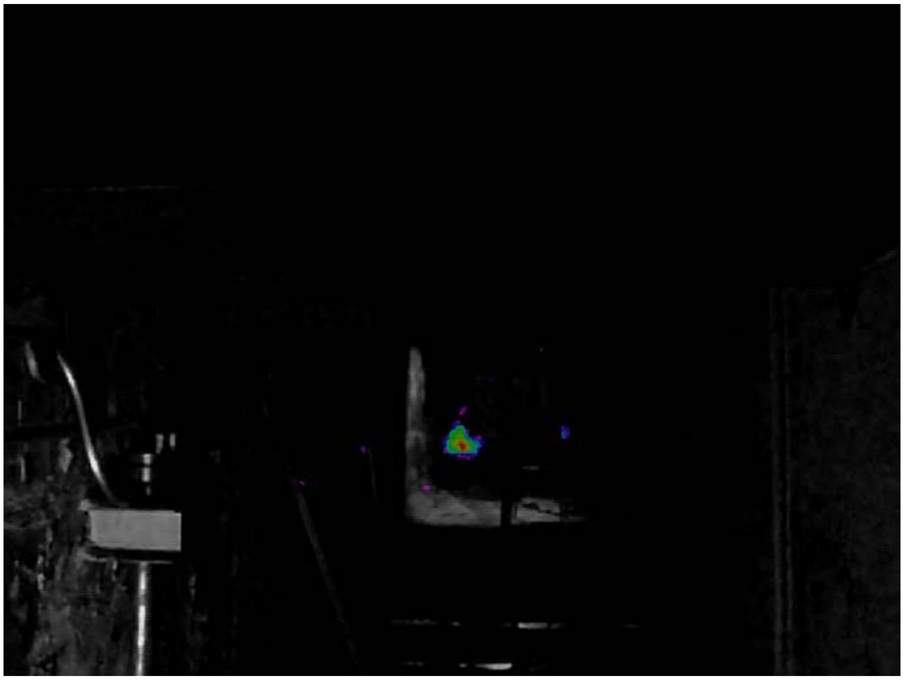


Figure 6. Gamma- image of canisters with radwaste made by portable camera

The resulting images allow us to estimate the actual angular resolution and compare it with the theoretical resolution of the gamma channel 0.9^o. In real images obtained angular resolution is approximately $1.15^o = 4/175 * 49^o$

A comparison with the images obtained by standard gamma camera.

Additional measurements were performed to compare the test capabilities of gamma- camera with a standard gamma camera to perform work on the mapping of radioactive contamination of the system Cartogam made by Canberra [7]. Images strong source was imaged using a system Cartogam during 1 - 2 min.

Strong source of canister from a distance of 3 meters is clearly visible during the 1 - 2 minutes.

The angular resolution of the image $18/136 * 50 == 6.6^o$ a (measurements in the laboratory with a point source for the camera Kartogam obtained angular resolution 5.15^o) i.e two objects are at an angular distance of 1.5^o merge into a single object.

Comparison of the two systems leads to the conclusion that the new gamma camera has a small loss in sensitivity, but has a very high angular resolution, which allows the accurate determination of the position of gamma-ray sources and their structure.

The developed camera has possibility of spectrometric measurements. Figure 7 presents spectra of Cs-137 source obtained through a special signal processing of gamma-ray detector Medipix2 gamma-camera.

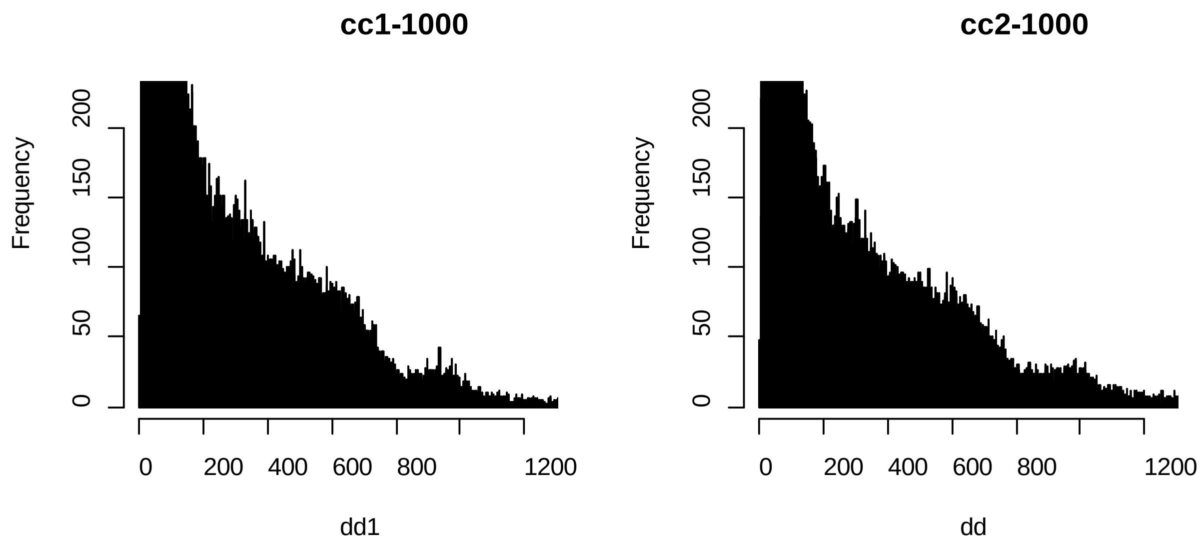


Figure 7 Two spectra of Cs-137 source obtained through a special signal processing of gamma-ray detector Medipix2 of developed gamma-camera

CONCLUSIONS

The portable system for gamma-ray imaging of different gamma-sources was developed and tested in real radioactive environment. Based on the parameters describing the system, it is possible to draw the following conclusions about its practical use.

The most important application of the system - an interactive search of bright gamma-ray sources, i.e. determining the position of the source of Cs- 137, for EDR ~ 0.01R / h in time around 10 seconds.

As part of the research is designed and implemented as a software algorithm using a square mask for gamma-imaging. The optimum parameters for the system adjustment were find for different environmental conditions and different energies of detected nuclides.

According to the results of tests in real conditions for the angular resolution of sources of Cs-137 and Co -60 is 1.2 degrees. Sensitivity to small source of 10 mR for Cs- 137 (100mkR for Co -60) for the background , the dose of which is comparable to the dose from the source and is distributed throughout the solid angle sensitivity deteriorates to 200 400mkR for Cs- 137. Investigated different modes of the detector Medipix2. Conducted studies to determine the optimum conditions of the detector for different energies of gamma radiation. It is possible to increase the sensitivity of the system .

To improve the usability of the device, increasing the automation of certain operations and the possibility of its using by untrained personnel it is need still a lot of work to improve and debug software and hardware systems, a large amount of R & D. It is not economically viable. But two or three of these systems are needed in emergency centers of main countries, and the operators of these systems can undergo regular training and coaching the developers of the system.

Research on the production of images in real conditions has shown that the system and the efficiency of its use.

System has possibility to evaluate the partial dose rate of radiation from individual sources and obtain the energy spectra of gamma radiation up to energy of 1 MeV.

On the basis of the results obtained when testing the system, it is possible to draw the following conclusions about its practical use:
The most important application - an interactive search of bright gamma-ray sources, such as determining the position of the source of Cs- 137, creating DER ~ 0.01 R / h in around 10 seconds.

Another important application could be to find spots for exposure to plutonium, americium, which is very effective is recorded by the system.

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