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Letter to the Editor

A novel gamma-ray imaging concept using "edge-on" microchannel plate detector

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Abstract

The "edge-on" illuminated microchannel plate (MCP) position-sensitive detector (PSD) is used for gamma-ray imaging for the first time. The superior position resolution of the MCP is combined with high detection efficiency due to the "edge-on" illumination mode. The results of imaging a 15 μCi ^{137}Cs source (662 keV quantum energy) are presented.

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Position-sensitive hard X-ray (20–2000 keV quantum energy) detectors are currently used for the imaging and monitoring of the radioactive materials. In most systems, 2D scintillator screens [1–5] and arrays [6–9], as well as semiconductor arrays [10–12] are applied. Pin-hole [3,6–8] and multiple-hole [1] collimators and coded apertures [4,5,9] are installed at the input face of the detector to provide an image of the radioactive sources. Position-sensitive photomultipliers [1,4,6–9] and charge-coupled devices (CCD) [3,5] are used as readout systems for the scintillators. Plate-like detectors are also used for the scanning and locating (but not imaging) of the radioactive sources [13].

The applications of hard X-ray position-sensetive detectors (PSDs) in medicine are described in detail in review [14]. Although the parameters of hard radiation PSDs are continuously optimized, there is a fundamental limitation: increasing the position resolution leads to decrease of detection efficiency. At the same time, it is well known that microchannel plate (MCP) detectors provide a superior position resolution but the detection efficiency of conventional MCP detectors is low for the hard radiation [15,16].

Recently, we have suggested a novel hard X-ray detector based on MCPs that provides a higher hard X-ray detection efficiency in comparison with conventional MCP detectors [17,18]. The "edge-on" illumination of the MCP has been used to combine the superior position resolution of MCP with high detection efficiency. It has also been predicted that the positon-sensitive performance of the "edge-on" MCP detector may be used for the hard X-ray imaging systems. Note that this "edge-on" illumination concept has also been applied for silicon strip detector [19] and CCDs [20].

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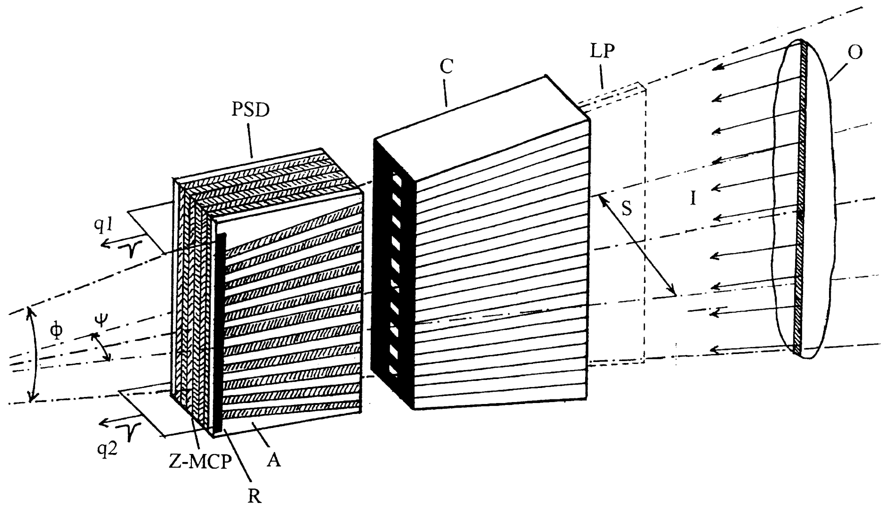

Fig. 1. The diagram of the gamma-ray imager: PSD – position-sensitive dectector; C – lead collimator; LP – lead plate; I – ionizing radiation; O – radioactive object; S – scanning; Z-MCP – double Z-assembly of the MCP; A – multistrip anode; R – resistive charge divider, $q1$, $q2$ – detector signals; ϕ, Ψ – angle of view at the vertical and horizontal planes.

In the present work,we report the first results of the application of an "edge-on" MCP detector to the imaging of a radioactive source.

The gamma-ray imager consists of the "edge-on" MCP-PSD, multiple-hole lead collimator with diverging channels, detector electronics and stepper motor. The "edge-on" MCP-PSD consists of two Z-assemblies of MCP detectors installed face-to-face (Fig. 1). Each Z-assembly consists of a 3 mm thick, $43 \times 63\,\text{mm}^2$ MCP converter, two 0.7 mm thick, $43 \times 63\,\text{mm}^2$ MCP amplifiers and a 1D position-sensitive anode with diverging metallic anode strips connecting to a resistive charge divider. The angle of divergence of the anode strips and collimator channels is the same to provide the best position resolution. The multiple-hole collimator has 50 mm length and $1.5 \times 1.5\,\text{mm}^2$ cross-section channels with 6 mm separation and provides hard angle of view $\psi = 28^\circ$ at the vertical plane. Scanning is performed by the stepper motor around a fixed point in the range of $-30^\circ < \phi < 30^\circ$ at the horizontal plane. The minimal angular step of the scanning is $0.1'$, providing 0.5 mm minimal step at a distance of 10 m. The electron avalanche from MCP is accepted by the anode strips and is divided in parts $q1$ and $q2$ by the resistive line. The vertical position of the incident photon is determined from the relation $q1/(q1 + q2)$ while the horizontal position is derived from the number of steps. Standard detector electronics and treatment algorithms are used for the digitizing of the detector signals and visualization of the data. The process of the scanning is controlled by an IBM PC in which the L-card (L-154) is installed. This card is used for digitizing two detector signals by its 12 bit ADC and for controlling the stepper motor. The exposure time may be changed in the range of 0.5–1000 s/step.

Two identical scans are perfomed to image the radioactive source. The first one is performed with a 3 mm thick lead plate installed at the face of the collimator, closing its channels. In this case most of quanta directed from the source to the detector bulk are absorbed in the lead plate while the scattered and background radiation are detected. The second scan is performed with the lead plate absent. The image of the source is derived by subtracting the first scan data from the second Fig. 2a shows the background-substracted image of a 15 μCi cylindrical 2×6 mm ^{137}Cs source (662 keV quantum energy) scanned for 15 min at a distance of 0.3 m. Fig. 2b shows the same image after mathematical treatment (filtration).

Although the first results of the testing are non-optimized and the investigations of the system are

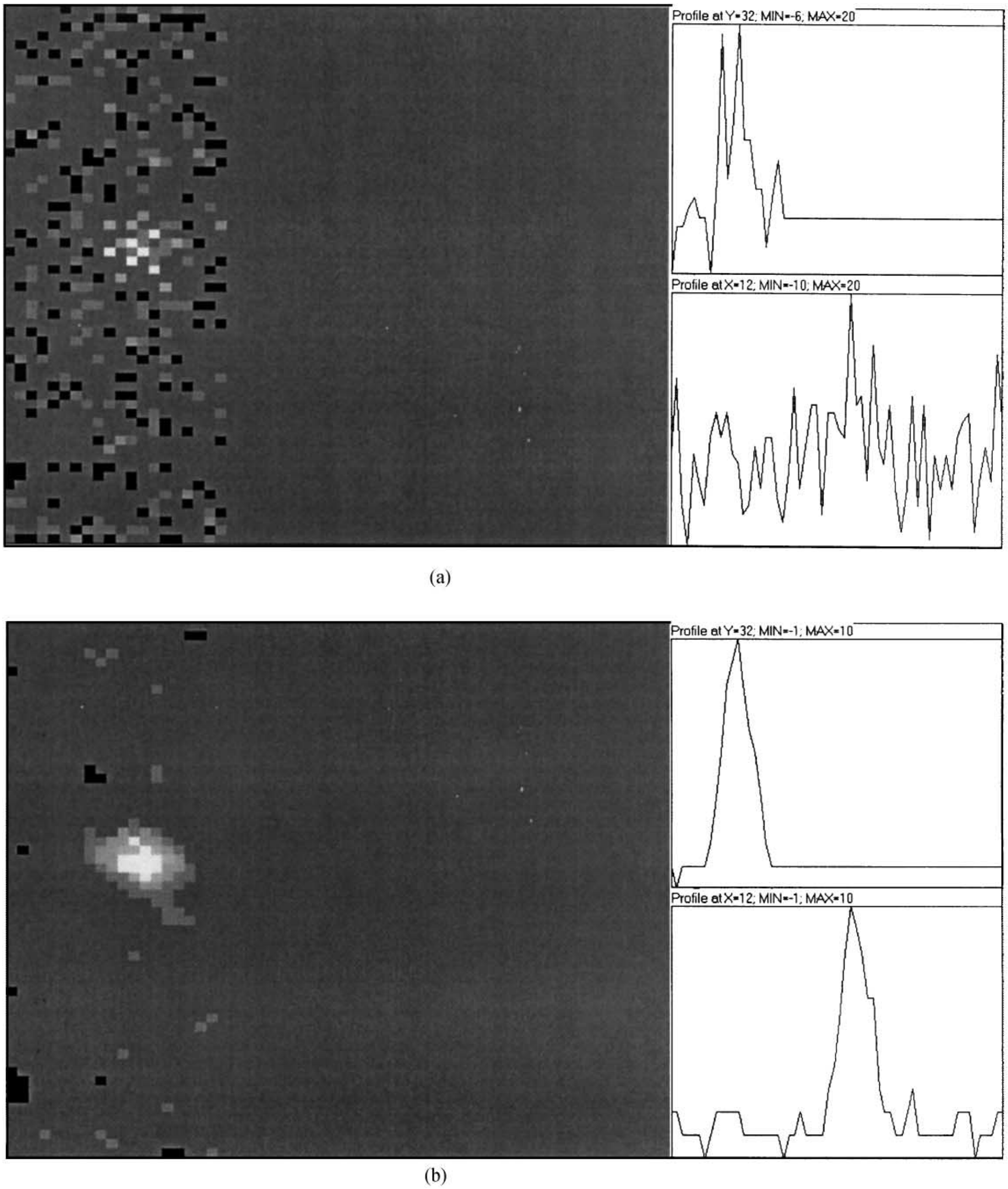

Fig. 2. (a) Background-subtracted image of the 15 μCi radioactive ^{137}Cs source scanned for 15 min at a 0.3 m distance; (b) the same image after mathematical treatment (filtration).

continuing, the use of the "edge-on" MCP-PSD for radiation imaging in the nuclear industry, as well as in medicine and other fields appears possible.

Following are the potential advantages of the "edge-on" MCP-PSD that are essential for diagnostic systems:

1. The minimum pixel size may be decreased down to the channel diameter (10–30 μm).
2. Direct energy-to-charge conversion and high-charge amplification up to 10^9 is provided in the pixel.
3. High content of lead (up to 80% in weight) in the MCP material (lead glass) provides a high sensitivity of the MCP to hard X-ray and increases the photoabsorption and decreases the Compton scattering.
4. The shape of the pixel is determined by the shape of the anode strips that may easily be optimized.
5. Pinhole and multi-hole collimators may be used simultaneously for the same PSD assembly.
6. High temporal resolution (up to 100 ps) of the MCP is possible.

The structural and compositional parameters of the "edge-on" MCP converters may be optimized using hard X-ray detection model for MCP detectors [21] to provide the maximum detection efficiency of the MCP-PSD. Note that the "edge-on" Micro-Sphere Plate (MSP) and "edge-on" Porous Dielectric Plate (PDP) may also used as a sensitive element of the hard X-ray PSDs [22].

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