GENERAL EXPERIMENTAL

TECHNIQUE

ON THE POSSIBILITY OF IMPROVING THE SPATIAL RESOLUTION OF PHOTOLUMINESCENT PLATES IN REGISTRATION OF IMAGES IN X-RAYS

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Abstract. A system for reading photoluminescent screens with memory is presented, which allows obtaining images with a higher spatial resolution compared to industrial scanners. It was experimentally determined that in the range of 6–25 keV, the spatial resolution of the created reading system does not depend on the quantum energy and is δ = 13±2 microns.

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1. INTRODUCTION

Currently, photoluminescent screens with memory (PSM) based on $BaF(Br,I):Eu^{2+}$ have become widely used as position-sensitive detectors (PSD) of ionizing radiation. In English-language literature, these detectors are called image plates or IP. The operating principle and advantages of PSM are described in detail in many works, see, for example, [1, 2]. One of the main characteristics of PSD is spatial resolution. In photoluminescent screens, it depends on the readout device and is 50-100 μm when using commercially available scanners, while the characteristic size of the sensitive layer crystals, which affects spatial resolution, is approximately 6 μm. The relatively low resolution limits the use of PSM in some experiments, for example, when studying fast processes using contact radiography on high-power laser facilities. On the other hand, the combination of high sensitivity, wide dynamic range, small size, and insensitivity to electromagnetic interference distinguishes PSM among other position-sensitive detectors used in these studies.

This paper describes a method that improves the spatial resolution of PSM when recording images in X-rays.

2. DESCRIPTION OF THE IMAGE READOUT METHOD FROM PHOTOLUMINESCENT SCREENS

In industrial scanners, the image formed by ionizing radiation is read by scanning the PSM surface with a He-Ne laser. The photoluminescent radiation emitted with a wavelength of 390 nm is detected by a photomultiplier tube. In this case, the spatial resolution is limited by the scattering of the laser beam in the sensitive layer and the size of a single element of the scanner's reading array [3].

To obtain data from photoluminescent screens, a system has been created in which, unlike the traditional sequential scanning method, simultaneous reading of the entire image is implemented. Figure 1 shows the scheme of the reading system.

Fig. 1. Scheme of the reading system.

The area of interest of the photostimulated luminescence screen is placed in the center of the microscope's field of view of the Levenhuk MED, which is irradiated with an LED laser ($\lambda = 650$ nm, $P \approx 10$ mW), focused into a spot of 2×4 mm ^{2}). The angle between the laser beam axis and the screen plane is 30°. The resulting photoluminescent radiation enters the optical system of the microscope and is recorded by a Dhyana 400 BSI camera, mounted in place of the standard camera. To suppress scattered laser radiation, a CC-4 filter with a thickness of 3 mm is installed in front of the microscope lens, the transmission coefficient of which is shown in Fig. 2.

Fig. 2. Transmission coefficient of the CC-4 filter with a thickness of 3 mm.

To test the proposed system, a Fuji BAS-TR2025 photoluminescent screen (sensitive layer $BaFBr_{0.85}I_{0.15}$ with a thickness of 60 μm, $\rho = 2.61$ g/cm ^{3} , without a protective lavsan layer [2]) was covered with a test object and irradiated with X-ray photons with an average energy of approximately 8 keV. A metal foil with oval cells of 50×200 μm ^{2} was used as a test object, as shown in Fig. 3.

Fig. 3. Image of the test object under a microscope.

The recorded image was read by a Typhoon FLA 7000 scanner with the minimum possible resolution of 20 line pairs/mm (pixel size 25 μm) and by the proposed system. The obtained results are shown in Fig. 4.

Fig. 4. Obtained results: **a** – Typhoon FLA 7000 scanner...; **b** – proposed readout system.

As shown in the figure, the proposed readout system allows obtaining images with better spatial resolution compared to the industrial scanner. This result is achieved due to the small size of the photosensitive matrix elements and the high magnification factor of the microscope. An inevitable consequence of using a microscope is the relatively small field of view, not exceeding 4×4 mm ^{2}. Despite this, such a field of view is acceptable for experiments on high-power laser facilities

3. DETERMINATION OF THE SPATIAL RESOLUTION OF THE CREATED SYSTEM

The spatial resolution of the created system was determined using the edge function. The measurement scheme is shown in Fig. 5.

Fig. 5. Scheme for measuring spatial resolution.

The Fuji BAS-TR2025 photoluminescent screen was placed close behind a 200 μm thick tungsten foil and irradiated with X-rays from the DRON-7 facility. Selective filters were used to isolate a narrow portion of the bremsstrahlung spectrum. Filter parameters, the accelerating voltage of the X-ray tube U_{tube} and the average photon energy E_{avg} are given in Table 1.

Table 1. Experiment parameters

Filter	Filter thickness, mg/cm ^{2}	U_{tube}, kV	E_{avg}, keV
Fe	32.5	9	6.4
Zn	48.6	13	8.4
C_8H_7Br	206	18	11.9
Zr	158	24	16.1
Sn	295	37	25.6

The recorded images on all photoluminescent screens were sequentially read using the created system and the Typhoon FLA 7000 scanner. Fig. 6 shows the image profiles at $E_{avg} = 11.9$ keV. The full width at half maximum of the derivative of the image profile was used as an estimate of spatial resolution.

Fig. 6. Image profiles and their derivatives at quantum energy around 11.9 keV

Based on the experimental results, it was determined that in the range of 6-25 keV, the spatial resolution of the proposed readout system does not depend on the quantum energy and is $\delta = 13 \pm$

2 μm; when reading the image with a Typhoon scanner, δ ~ 90 μm. Previously in work [4], when scanning images using a Typhoon FLA 8000 scanner (pixel size 25 μm), it was determined that the spatial resolution for Fuji BAS-TR2025 is 94 ± 2 μm.

4. CONCLUSION

To obtain data from photoluminescent screens, a readout system was created based on a Levenhuk MED 25 microscope, a Dhyana 400 BSI camera, and an LED laser
(λ = 650 nm). Unlike the traditional method of sequential scanning, the proposed system implements simultaneous reading of the entire image from a 4 × 4 mm ^{2} area. Such a field of view is acceptable for experiments on high-power laser facilities.

The spatial resolution of the created system was determined using the edge function. For this purpose, a Fuji BAS-TR2025 photoluminescent screen partially covered with a 200 μm thick tungsten foil was irradiated with X-rays generated by the DRON-7 unit. The quantum energy was varied in the range of 6-25 keV using selective filters and the accelerating voltage applied to the X-ray tube.

Based on the experimental results, it was determined that in the range of 6-25 keV, the spatial resolution of the proposed readout system does not depend on the quantum energy and is δ = 13 ± 2 μm. Such high spatial resolution is achieved due to the small size of the camera's photosensitive matrix elements and the high magnification factor of the microscope.

REFERENCES

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FIGURE CAPTIONS

Fig. 1. Diagram of the readout system.

Fig. 2. Transmission coefficient of the CC-4 filter with a thickness of 3 mm.

Fig. 3. Image of the test object under a microscope.

Fig. 4. Obtained results: **a** – Typhoon FLA 7000 scanner (pixel size 25 μm), **b** – proposed readout system.

Fig. 5. Diagram for measuring spatial resolution.

Fig. 6. Image profiles and their derivatives at quantum energy of about 11.9 keV: **a –** proposed readout system, **b –** Typhoon FLA 7000 scanner (pixel size 25 μm).

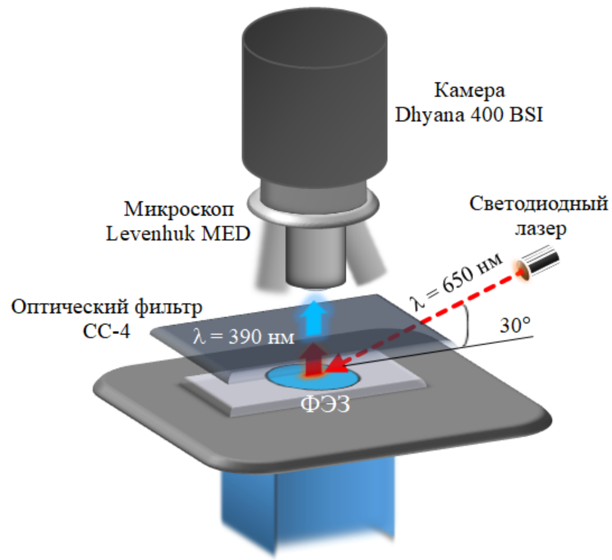
Камера
Dhyana 400 BSI
Микроскоп
Levenhuk MED
Светодиодный
лазер
Оптический фильтр
СС-4
λ = 650 нм
λ = 390 нм
30°
ФЭЗ

Fig. 1.

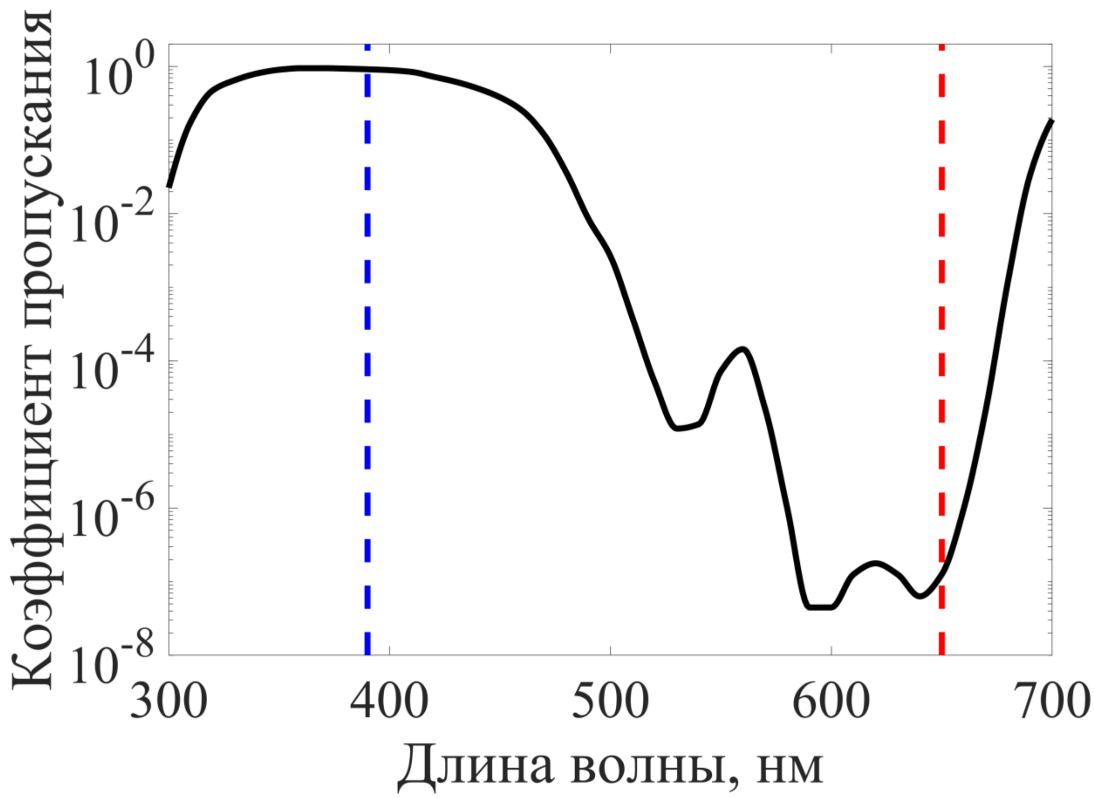
Коэффициент пропускания
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
300
400
500
600
700
Длина волны, нм

Fig. 2.

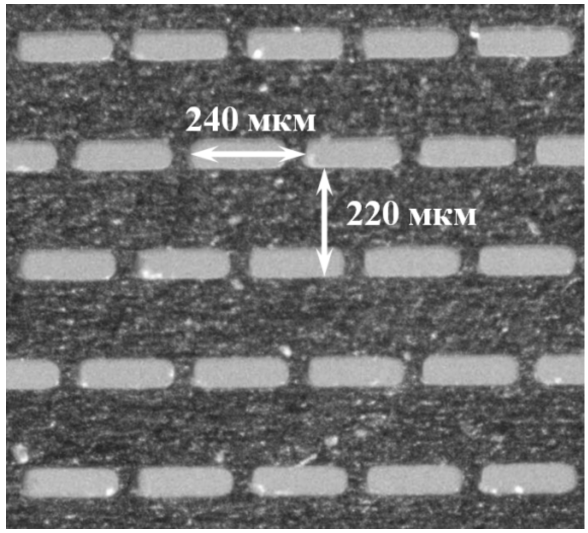

Fig. 3.

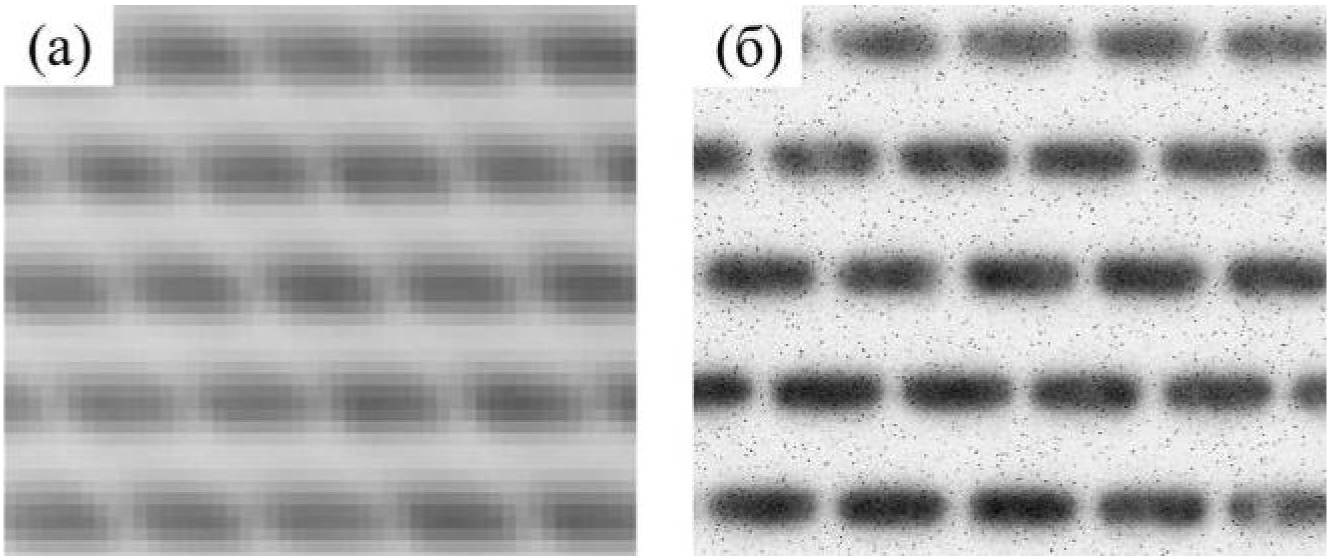

Fig. 4.

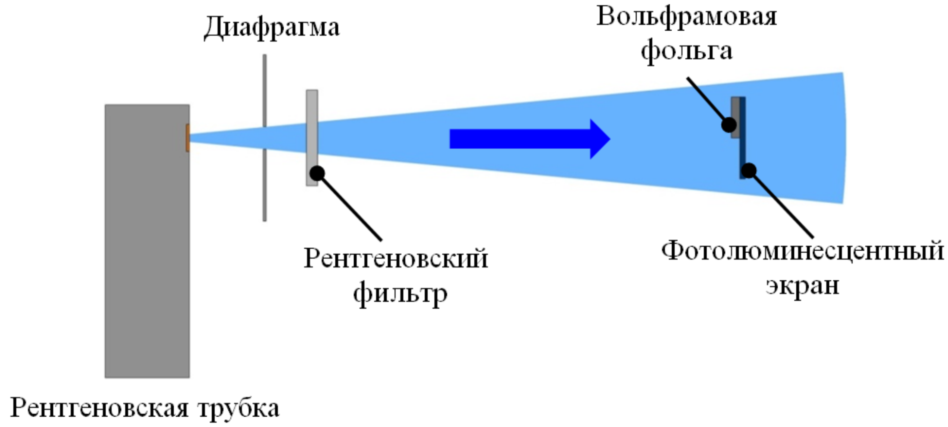
Диафрагма
Вольфрамовая фольга
Рентгеновский фильтр
Фотолюминесцентный экран
Рентгеновская трубка

Fig. 5.

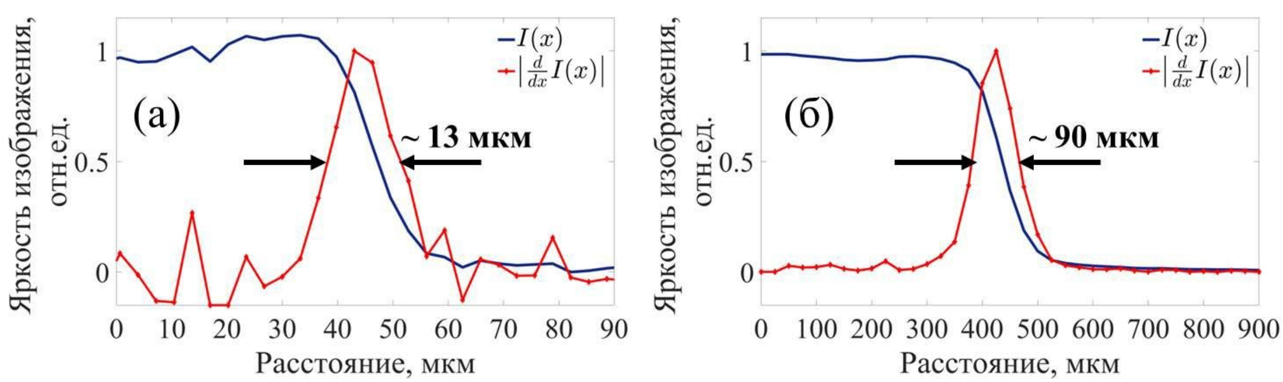
Яркость изображения, отн.ед.
(а)
~ 13 мкм
Расстояние, мкм
(б)
~ 90 мкм

Fig. 6.